"This is a timely update of Rich's classic book on Oracle Database performance tuning to cover hot new topics like Oracle Database 12*c* Release 2, Oracle Exadata, and Oracle Cloud Database as a Service. This is a must-have for both traditional DBAs and DBAs in Cloud DevOps teams moving to these new products."

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Oracle Executive Vice President

ORACLE

Oracle Database 12*c* Release 2 Performance Tuning Tips and Techniques

ORACLE DATABASE 12c

Up-to-Date Strategies for Optimizing Oracle Database Performance

Richard Niemiec
Oracle Certified Master, Oracle ACE Director

Oracle Press

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"Rich makes most complex concepts in Oracle simple and interesting. His deep passion to educate everybody is unique in all his books. I remember 12 years back when I started learning Oracle reading Rich Niemiec books, and even today I consider his books the most reliable source in decision making. No DBA library in this world is complete without Rich Niemiec books."

—Shiv Iyer, Founder & CEO, Ask DB Experts, Bangalore, India

"When I was a junior DBA in Chicago sixteen years ago, Rich Niemiec's brilliant and unique DBA/developer topics exposed me to the wonderful world of performance tuning. In today's era of Oracle Exadata when hardware and software are engineered to work together, I find Rich still at the forefront of this technology."

—Steven Xueyong Lu, iTech Consultant Lead, Oracle China

"Tuning Oracle Databases is a science. When I need to have an answer to any tuning issue, I always turn to Rich's Oracle Tuning Books. Whether it is 9i, 10g, 11g, or 12c, I know I can find the correct solution to the problem."

—Stan Novinsky, Senior Oracle DBA/VMware Engineer, The Johns Hopkins University Applied Physics Laboratory

"To every difficult problem exists a simple solution; this is what I've learned from Rich's books"

—Ghazi Ben Youssef, MBA, Senior Oracle DBA, Sogique, Canada

"If you could buy only one book this is the one to have in your DBA arsenal. If it's not on your shelf, consider yourself unarmed. Rich does an excellent job of piecing the puzzle of performance tuning in an easy to follow outline."

—Jerry D. Robinson Jr., Senior DBA, Northrop Grumman

"I admire Rich for his knowledge on Oracle Technology. This book from him is another masterpiece useful for anyone who would like to excel in Oracle Performance Tuning. The book encompasses Rich's rich Oracle expertise and experience and is a must read for all Oraclelites."

—Hardik Bhatt, Chief Information Officer, State of Illinois

"If you need the best tuning DBA: call Rich Niemiec! Or get his Oracle tuning book"

—Julian Dontcheff, Global Database Lead, Accenture, Finland

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—Joseph Flores, Director Upward Bound, Purdue University Calumet

"Rich Niemiec is a phenomenal entrepreneur with incredible depth of knowledge regarding Oracle applications."

—Prof. Gerald Hills, Coleman Chair of Entrepreneurship, University of Illinois at Chicago

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—Bobbi Jo Johnson, Upward Bound Advisor, UW-Sheboygan

"The best Oracle Tuning book that I ever read is from Rich Niemiec and I would recommend his book to anyone who needs a better understanding about performance tuning and to enhance their skills in Oracle."

—Shaharidan Karim, Senior DBA, Commerce Dot Com Sdn Bhd, Malaysia

"Rich's boundless passion for technology combined with his zeal to share provides him the unique advantage to create a profound product that is rich in every way—he provides an insider's view that you cannot afford to miss."

—Anil Khilani, Global Technical Lead, Oracle Corporation

"Back in the time before MetaLink when Oracle Support was measured in hold time and pounds of manuals, I was lost in the darkness between unrealistic expectations and unreasonable demands. And then there was Rich. Years later, Rich is still a beacon whose insights light the path to my own discovery."

—Fran Koerner, LAOUG Treasurer, DIRECTV, Oracle DBA

"Developers take note: Tuning is not just for DBAs. The proven techniques Rich explains in this book will help you create the most efficient application possible. Every developer who works with the Oracle database should own and read this book."

—Peter Koletzke, Quovera

“Michelangelo tells us that our problem is not aiming too high and missing but in aiming too low and hitting every time. With a master like Rich on your bookshelf, you can aim high with confidence.”

—Ronan Miles, British Telecommunications, London

“Rich Niemiec’s record as an expert speaks for itself. His diverse and extensive skills in Oracle technology with infinite possibilities impacts various aspects of life’s application.”

—Albert Nashon Odhoji, Project Coordinator, THE SLUMCODE GROUP, Nairobi, Kenya

“Rich doesn’t just know Oracle—he is THE Oracle!”

—Dennis Remmer, MD, E2 Australia, National President, Australian Oracle User Group (AUSOUG)

“Rich is not only a subject matter expert with Oracle technologies, he is also an outstanding author and friend. He consistently contributes his time, knowledge, and professional experience with the Oracle user community by introducing new features or helping others in need of support. It’s individuals like Rich who truly make an impact for the greater good in the Oracle community.”

—Richard Stroupe, President, TRS Consulting Inc., Co-author Oracle Database 10g Insider Solutions

“The knowledge and skills from Mr. Niemiec are a unique experience within tuning issues.”

—Filipe Texeira de Souza, Systems Manager, Rio de Janeiro City Hall’s Secretary of Education, Brazil

“Rich is a true expert in Oracle tuning. He not only masters the theory and tools, but is also able to perform insightful analyses of real-world problems and present the results in a way that makes sense even to people not so experienced with database technologies. This is important since business people are getting more and more interested in IT performance in general—as they really should.”

—Jussi Vira, Manager, SAP Technologies and Infrastructure, Nokia Corporation

“Rich Niemiec is the Oracle expert on tuning and we can all learn from Rich.”

—Dr. Oleg Zhooravlev, CEO, Adit Information Technologies, Israel

“Someone said that smart people learn from their mistakes while wise people learn from others’ mistakes. When involved in performance and tuning issues I think that both smart and wise ones can learn from the vast and valuable experience Rich has documented within these pages.”

—Maurizio Bonomi, Italy

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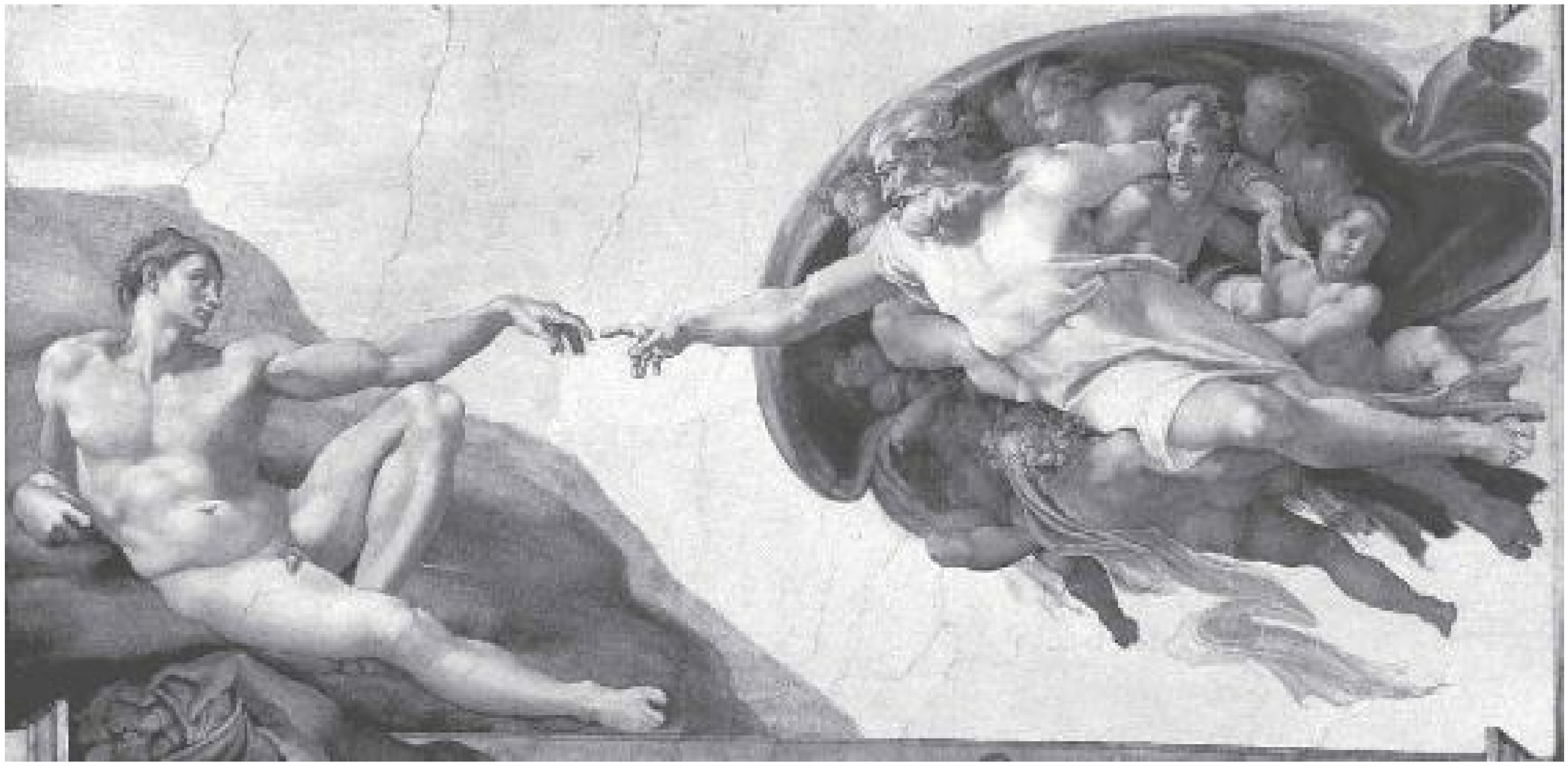
About the Author

Rich Niemiec is a world-renowned IT Expert. Rich is an Oracle Ace Director, Oracle Certified Master, and was a cofounder and the CEO of TUSC: a Chicago-based, Inc. 500, systems integrator with ten U.S. offices focused on Oracle-based business solutions. TUSC was started in 1988. Rich also has served as an Executive Advisor to Rolta International Board of Directors, President of Rolta TUSC, and President of Rolta EICT International. TUSC was the Oracle Partner of the Year in 2002, 2004, 2007, 2008, 2010, 2011, and 2012 (Rolta TUSC for the last two). Rolta is an international market leader in IT-based geospatial solutions and caters to industries as diverse as infrastructure, telecom, electric, airports, defense, homeland security, urban development, town planning, and environmental protection. Rich is the past president of the International Oracle Users Group (IOUG) and the current president of the Midwest Oracle Users Group (MOUG). Rich has spoken in virtually every major U.S. city and many major international cities over the past three decades and has been named by attendees as the Top Speaker at Collaborate/IOUG (six times), MOUG (ten times), as well as at Oracle OpenWorld. Rich has architected and tuned many Fortune 500 systems over the past 25 years. Some Fortune 500 accounts he has managed and tuned include ACT, M&M Mars, McDonald’s Corp., Nokia, Navteq (MapQuest), University of Michigan, AT&T, and PepsiCo. His experience in data processing ranges from innovation and architecture to teaching and consulting, with an emphasis on executive direction, database administration and architecture, performance tuning, project management, and technical education. Rich was one of six Oracle Certified Masters originally honored worldwide and works cooperatively with Oracle development from time to time, especially during the beta process. In 2011, he authored the Oracle best seller *Oracle 11*g *Performance Tuning Tips & Techniques* (McGraw-Hill), an update of his previous three Oracle best sellers on Oracle8*i*, Oracle9*i*, and Oracle 10*g* performance tuning. He was awarded the National Trio Achiever Award in 2006 and the Purdue Outstanding Electrical & Computer Engineer award in 2007. He has also won IOUG’s prestigious Chris Wooldridge award twice. Rich was inducted into the Entrepreneurship Hall of Fame in 1998.

About the Technical Reviewer

Michelle Malcher is a data and security professional with several years of experience in database development, design, and administration. She has expertise in security, performance tuning, data modeling, and database architecture of very large database environments. As an Oracle ACE Director, she enjoys sharing knowledge about best practices involving database environments. Her experience is focused on designing, implementing, and maintaining stable, reliable, and secure database environments to support business and important business processes. She has held several positions on the IOUG Board of Directors. She has authored articles for the IOUG *Select Journal* and a book, *Oracle Database Administration for the Microsoft SQL Server DBA* (McGraw-Hill/Oracle Press, 2010) and is a co-author of *Oracle Database 12*c*: Install, Configure & Maintain Like a Professional* and *Securing Oracle Database 12*c (McGraw-Hill/Oracle Press).



"We've all been touched by the hand of God and Greatness is within us."

To Regina, the love of my life…

I was sitting in the Sweet Shop at Purdue University, where I was a student, when I noticed Regina; one look stopped me in my tracks. I was instantly attracted to her. She was dressed for the working world, unlike most college students, and she had a laser focus and concentration while she studied that appealed to me as well. She was stunning in every way that mattered to me. What are all those things you see in a single moment that leads you to your eventual spouse, the person you'll spend your entire adult life with? I don't know. I know it's different for everyone, but for me, the world stood still for that moment. What is it that the mind sees that you don't notice until much later? Maybe I was just getting older, looking for something deeper; maybe it was the Marine in me that was looking for that super, well-put-together, sharp looking, fine young lady. I don't know, but *I sure didn't pass her up*. I boldly sat down at her booth; she was not amused, perhaps even slightly irritated by this. Regina had worked hard at a job during the day and gone to college at night to get her two-year degree focused on management. Now, she had transferred to Purdue and was working on her four-year degree; she had no plans to be distracted from her goals. I asked her about her class. She was in Speech Pathology. She said the homework was pretty hard (it was the physics of sound waves and frequencies—I was in Electrical Engineering—child's play, I thought). I told her that I could teach her this in about 10 to 15 minutes and then we could go catch a movie. No, she wasn't looking to go to a movie with me or anyone else. I quickly read the examples in her book and started teaching her how to do these problems (scanning the examples and figuring it out like the true DBA I would become). If she was impressed, she sure didn't show it. She hesitantly let me help her through her homework, kindly thanked me, and she said she had to go now. *Wouldn't see a movie, wouldn't let me walk her home, and wouldn't give me her number—that was three strikes if ever I saw it*. It was back to the game room for me and pinball, Asteroids, or Space Invaders.

She was across the room when I walked in a week later, same booth, same look, focused as ever, but a hint of concern. I walked over and could see graphs on the page. It was physics class homework again…I was in luck. I actually asked to sit down this time (figuring that was the right thing to do, and figuring she'd say yes this time). "No," she said, explaining she was really too busy with physics homework and then French class homework (I figured that I was in luck again—three years of high school French class just might come in handy for the very first time in my life). I took a look at her physics book and said that I could help her with this in no time and then I could help her with French as well. Reluctantly she agreed, and I sat down. When we were done, I asked if she wanted to go do something. "Not right now," she said, indicating she really needed to get home and prepare a bit more for French class. ("How much does she study?" I thought. It was early in the semester and I wasn't even considering picking up a book until the first test.) I tried again, "How about a movie sometime?" "Maybe, sometime, if I see you here." "Can I get your number?" "No, my mother told me never to give out my number. Maybe, if I see you here, sometime." I persisted, "How about Tuesday?" (Tuesday was dollar movie night and that's really about all I could afford anyway.) "Okay," she relented, "I'll meet you here next Tuesday."

So I met her there the next Tuesday, driving up in my beat-up Pinto wagon with the clutch going out. Halfway there, startled, Regina noticed the road going by under her feet (I had a reasonably sized hole in the floor)—I instructed her to slide the cardboard a little to the right to cover the hole. "Ohhhhh…okay," she said slowly. So I took her to see *Platoon*, being the Marine I am (yes, I should have taken her to a romantic comedy, seeing it was a first date, but I wasn't quite that smart—I was still just a kid who really didn't know a lot about anything). After the movie, I told her I would spring for another movie since it was dollar night. She agreed. It was a magical night; as I drove her home, she was a bit warmer to me, but still not willing to get too close—but, she did give me her number to study again some time together. A week or two later after seeing her in the Sweet Shop another couple of times and studying with her, I told Regina that I'd like to cook dinner for her. I couldn't do it at my place since my room consisted of a bed and a desk (it had a community bathroom), but I told her I would cook at her place if her roommate allowed that (and since she had a stove). I actually couldn't remember having cooked anything to that point in life. (I had sisters, and my brothers and I would wash dishes or do other odd jobs for them and they would cook things for us in return.) So I went to the store, bought a couple of steaks, potatoes, and a vegetable. In the checkout line I asked the older ladies in front of me: "How long do I cook this stuff, about an hour or so each?" They give me this concerned look and instantly started instructing me, but the line was too fast and I didn't fully comprehend everything they were saying. I arrived at Regina's apartment and nervously started to prepare things, and when I was about to put the steaks on, she asked: "You want me to help? We might want to put those potatoes on first." She'd keenly figured out that unless she helped, we would probably have to eat out, and given my financial situation, she may even have to buy. She pretty much cooked the whole dinner and then thanked me multiple times for cooking such a wonderful dinner. We were hitting it off, and after that night we started to study together a whole lot more.

I grew up in poverty at times, so I can handle anything that comes my way. I didn't really date too many people in high school, and it was a tough place (we called it "Teenage Wasteland," after the song by The Who). Before meeting Regina, I had never really found that special person who I liked well enough to live with forever and who would live with me through better or worse—plenty who would live with me through better, but not worse. I used to study with Regina all night for tests (my professors started wondering why my grades were so good this early in the semester). One day I told her to keep in mind that I may not turn out to be much…not many from my neighborhood ever did. I might even just end up as a homeless person. She said if I did, she would be the homeless person by my side. Wow, now that's the woman I wanted to marry—someone who would stick by me! I was 100 percent sure now! It was probably there from the first time I looked at her. What is it that your mind sees that you just can't walk by? Something deeper, maybe just God taking you right to the person at just the right time, the person who fits you perfectly in life. For me, Regina is the best person I've ever met, and she makes me a better person every day of life! She quietly helps people from the shadows of life; with no praise, she tenaciously continues on. My prayers were answered the day of our wedding, and I can honestly say that marriage has continued to get even better the longer we've been married (it will be 30 years for us in 2018). How lucky I was to have met Regina on that first day!

Regina is wonderful, because she focuses on what's really important in life. Neither one of us had too much materially while growing up, but we learned important lessons in life. Most things that really matter in life don't cost too much. Regina always values the things that matter most in life: God, family, close friends, a cool night, a day in the country, a fall day with a cup of hot pumpkin spice coffee, a gentle breeze, a field of wildflowers (God's natural beauty); it's the simple things that matter a lot, not the artificial things in the world that are shiny on the outside and hollow on the inside. It's not that we don't need some things, and we can buy some cool things here and there as well (God gave us all this, too, to enjoy), but we have to be careful that things don't weigh us down and take away from life either. Regina always knows that balance and keeps me balanced. I had just gotten out of being with the regular Marines (and into the Reserves) and starting a new semester when I met her. Regina showed me that college was a rare privilege and she was going to study hard until she graduated. Regina was never perfect, but she was always a perfect fit for me. She is indeed one of those Uncommon Leaders the Marines taught me that I'd meet in life. The things that the Marines taught me to work on to better myself were the things I saw in Regina, and still do:

- *Integrity* She has a deep love and commitment to her family and to her faith.
- *Physical courage* She endures all things and motivates others to do the same.
- *Initiative* She helped create something from nothing in our period of history (TUSC and Cornerstone Young Women's Learning Center), and was always there when I needed her.
- *Mental courage* Her courage to look past criticism and still work to make a difference.
- *Unselfishness* She shares all she has—both the first and last of what she has at times.
- *Tact* She always tries to find a way through and never loses her desire to help.
- *Tenacity* She attacks issues head-on. Her parents passed to her an incredibly rare tenacity.
- *Respect* She shows respect for everyone, *but still pushes them hard to better themselves*.
- *Humility* She humbly makes a difference from the shadows of life.
- *Fortitude* Fortitude is strength of mind to endure pain and adversity with courage and character. Regina has had fortitude above and beyond the call of duty over the years!

Regina is a rare find and truly the diamond in the rough (that's hard to spot unless you look for *exactly* this). Success doesn't happen overnight; it includes many painfully long nights, tender patience, rigid tenacity, deep learning, and most of all adapting and overcoming…for me, I had a woman by my side who helped me with all of these attributes. She allows me to see the future while not missing the present. The Purdue Sweet Shop led me to the sweetest sweet—Regina!

Contents at a Glance

Contents

Acknowledgments

"Perhaps, in order to really become free, we have to move from struggling to hear God's Voice to letting God's Voice speak through us."
—Rabbi Jonathan Kraus

The goal of this book is primarily focused on helping beginner and intermediate Oracle professionals understand and better tune Oracle systems. Many expert topics are also covered, but the objective is primarily to assist professionals who are frustrated and looking for simple tips to help improve database performance. This book has one simple aim: to provide an arsenal of tips you can use in various situations to make your system faster.

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In Memory:

"Only a life lived for others is worth living."

—Albert Einstein

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God takes us home one day when our work is done; we'll be with them soon enough to *"run with angels on streets made of gold."* I look forward to that day, but until that day, let's continue to make a difference and ensure that God speaks through us by our wonderful actions toward one another! By always looking to improve our integrity, knowledge, physical courage, loyalty, self-control, enthusiasm, unselfishness, tact, moral courage, respect, humility, and initiative, we will ensure that we have the fortitude to face any tough challenge ahead. And, of course, never forget, faith, hope, and love... "and the greatest of these is Love." To make a difference in the world with character and with a heart that always brings out the best in others—this is my goal in life!

Introduction

"The enterprise that does not innovate inevitably ages and declines. And in a period of rapid change such as the present, an entrepreneurial period, the decline will be fast."
—Peter F. Drucker (1909–2005)

Disruptive innovation occurred as postal mail moved to e-mail, as telegraph moved to telephone, as telephone moved to cell phones, computers moved to smartphones, encyclopedias moved to Wikipedia, and floppy drives moved to USBs. You don't stop innovation! So what's next? Most everything in *Star Trek* either has been invented or is in the process of being invented. *Star Trek* technology that once looked so futuristic now looks very old. Even *Twilight Zone* predictions pale in comparison to the reality we see unfold daily. E-mail has given way to texting and then to Snapchat, cell phones are now moving to smart watches, and the promise of Google Glass is now moving to virtual reality (VR) devices. Small plastic pieces that you picked up at Wal-Mart in the past can now be printed in the home. You no longer need Microsoft Office installed on every device as Google Docs will do it for free in the cloud from any device (Microsoft now has a cloud version—kids use Google). All of these technologies are already here; they are not what's next. *Innovation* is the introduction of something new or different. Some companies embrace innovation and thrive, while others don't, and fall behind or disappear. Some innovation is helpful or only mildly unsettling while other innovation radically disrupts people, countries, or businesses. When innovation occurs in a product category, no amount of new investment in the older product will yield a normal rate of return. Building a nicer, faster, better telegraph machine could not stop the telephone. Microsoft stayed flat as a stock for ten years until it came out with its Azure cloud computing platform. Oracle is embracing the cloud, not only because of Amazon's amazing profits in the cloud services market, but because cloud computing is an innovation that is here to stay. Oracle has realized that it must embrace it to survive. In Peter Drucker's *Innovation and Entrepreneurship* book, he talks about the "deadly temptation to feed yesterday and starve tomorrow." As clearly represented by Oracle Database 12*c* (the *c* standing for *cloud*), Oracle has resisted the temptation to feed its on-premises business at the expense of starving the cloud, knowing that it would be a losing proposition in the long run.

Many people think the cloud is the path to eliminating their job. If you are one of them, I have news for you: where there is more innovation, there is more business and more profit to be had than anywhere else. There will be greater demand as companies move at least part of their operations to the cloud, while keeping some of them in-house (a hybrid cloud model that will be used by many companies for a time). Companies requiring great control or security might allow little movement to the cloud, but the majority of IT innovation today is happening in the cloud. To be more precise, with mobile applications, cloud computing is where most mobile-enabling technologies live. When the operations department at a company resists the cloud, the development department moves their Agile development directly to the cloud with DevOps (a new person with Development combined with Operations experience) personnel. Big data and consumer applications are already in the cloud, as is the next-generation IT person. Is your job as a DBA or sysadmin going away? No, it's just shifting, at least partly, to the cloud, to include managing the consolidation of applications, enabling faster development, working with throw-away architecture, and developing the future robotic helper (if you're willing to educate yourself and embrace the bend in the road). Those who are educated and prepared for the cloud will be able to make more money in this demand area of the economy. Those who resist will find themselves with flat expectations, but still with more than enough work to manage operations that can't be moved to the cloud. I see the industry bifurcating, or splitting into two: those who move to the cloud and have bots (computer robots) working for them to make them more productive, and those who stagnate and become workers of the future robot bosses (perhaps only a computer—not necessarily a robot walking around) that manage their operations, constantly looking for ways to eliminate them and save the company yet more money.

The first cloud warning shot from Oracle came with 12*c* Release 1 (as the *c* was for cloud), but the bigger shot came with Oracle Database 12*c* Release 2. Oracle 12.2 has been released first in the cloud (without a timetable for the on-premise release). Oracle 12*c*R2 was announced by Larry Ellison on September 18, 2016 to be released on the Oracle Exadata Express Cloud Service at $175/month (even Oracle salespeople selling Exadata complained about the low price). This announcement is Oracle telling you that the cloud is the most important focus that they will ever have. Larry Ellison calls it a once in a generation move to the cloud. Whether it's Larry Ellison, Mark Hurd, Safra Catz, Thomas Kurian, Andy Mendelsohn, or Judith Sim, these Oracle leaders all talk about the cloud first or the cloud only. They'll only accelerate this innovative arena and eventually starve their on-premises business.

As with many new technologies, the cloud is painful to adopt, with so many moving parts including your own personnel. But consider companies like Google, Amazon, Apple, and Oracle; what do they have in common? They are mature companies that innovate constantly and embrace or create the future, and they have all invested heavily in the future of the cloud. Even Facebook and Twitter succeed because they innovate; they grow despite their naive corporate youth. Facebook would have had LinkedIn's market share as well were they more mature in their business growth. *Is your company as innovative and mature as Google*, which went from its origins as an Internet search service to offer mapping, images and video, translation, and Google Docs, and then expanded to encompass everything from the Android OS, smart watches, virtual reality, and Chromecast to a dashboard in your car, to driving your car, to Nest in your house, to robotics? Amazon comes closest to Google. Oracle and Apple are mature leaders and innovators, but primarily limited to the tech world. Oracle went from 8-bit RDBMS, to 32-bit, to client-server, to 64-bit (way back in 1995), to web database, to Linux support, to RAC, to Grid, to BEA middle tier, to every major application including Financials, JDE, EBS, HCM, EPM (Hyperion), SCM, Retail, Data Warehousing, to hardware and Sun, to three to four new hardware appliances every year, to 128-bit with ZFS, to an all-flash server (1 petabyte available now), to In-Memory Database, to multitenant, to web-based and mobile applications, to Oracle Cloud. Don't forget Oracle owns the largest offering of NoSQL databases with the Sleepycat software (Berkeley DB) acquisition (over 100M deployments) and MySQL databases with the Sun acquisition. Their Solaris machine has both security and queries running *in* the silicon with the new M7 chip, and their recent Ravello Systems acquisition hurts Amazon while helping Oracle. Oracle doesn't have the breadth of Google or Amazon in the consumer market, but it has much greater depth and maturity. My calculations based on the number of servers and other data (unofficially) show Amazon, Microsoft, Google, and Oracle as the largest (by far) cloud providers, with HP, Facebook, Yahoo, Digital Ocean, OVH, China Telecom, SoftLayer, Rackspace, Akamai Tech, Intel, and Comcast on the distant second tier (tens to hundreds of thousands of servers). While Google, Amazon, and Microsoft are all in the 1M+ server range, Oracle with compression is the largest public cloud with over 10 exabytes of storage as of October 2016. Oracle is number one due to their own technology! I only see Oracle accelerating by further leveraging the technology they have. Oracle hasn't moved their customers to the cloud yet, but the Oracle Public Cloud (OPC) will get a lot bigger when they do. In the past, most Oracle databases would not fit on an Oracle server in DRAM or even flash, but now they do. I remember seeing a 4000-node Hadoop big data warehouse with 16P (16,000T) of raw disk and people saying that you can't fit big data on Oracle. That same 4000-node cluster would fit on this year's X6-2 with 1.3P and 15× compression to give you 19.5P of raw disk equivalent. A *single machine* replacing an entire room of servers (a *very large* computer room)! Whether on premises or in the cloud, most databases would fit on *one* Oracle server. Think of the power savings and space savings alone, not to mention the maintenance. Think of the cloud you could build starting with this size Lego!

Because of the explosion of data through social media, sensor data, biological, traffic, RFID data, environmental, aerial, wireless, security, video, medical, and archived data, we now have data that will help businesses and individuals make better decisions. However, this widespread availability of data also puts our privacy at risk and requires greater security and products that will protect us. While big data helps us compete better, understand our customers better, grow business streams, and lower costs, we often resist it in IT because the security and maturity of the products in the big data world are lacking. Big Data is supposedly too big to fit in a normal database (which is true if you need a 4000-node Hadoop cluster—replace this with a couple of Exadata Servers instead). Oracle now provides a way to go from Oracle SQL directly to Hadoop, Hive, and other NoSQL databases by writing SQL. The enhanced security of Oracle now makes it possible to manage all of these data sources that are already in the cloud. *Welcome to the future*; it's the best of both worlds! Many NoSQL database are *eventually* consistent; Oracle is just consistent (the correct data all the time). Many NoSQL databases have some security; Oracle has encryption at the chip level, auditing, virtual private databases, global roles, secure application roles, fine-grained auditing, transparent data encryption, audit vault, database vault, multitenant security, and many security evaluations. It will take decades for other vendors to catch up at a time when security is paramount to nations across the world. You want to use Spark? Oracle has a connector to that. You want to use Node.js or Angular JavaScript? Oracle now welcomes that code base.

Archived data used to tell you what happened and maybe even why it happened. Now we head into predictive and prescriptive analytics, where archived data tells you what will happen and what's the best thing that could happen if you act correctly (it's a lot like the movie *Minority Report*—perhaps even more advanced). Oracle has some of the most advanced data warehouse tools with Oracle Business Intelligence Enterprise Edition (OBIEE) in addition to Oracle R Enterprise (a component of Oracle Advanced Analytics) to leverage big data to write these programs. Those tools have been developed over the past two decades. My company once combined several of a customer's systems to show what was going to break in a plant before it broke (reliability system), then checked when their supplier would have the part (supply chain system), ordered the part ahead of time (order entry), trained the correct person to fix it before it broke (training system), ensured that person wouldn't be on vacation when it was probably going to break (HR system), etc. It saved the customer millions of dollars every year in lost downtime. BI tools like Oracle or Entrigna (the next-generation BI tool) will take every database source and allow you to build that future. Perhaps the big data world will be connected via pluggable databases (PDBs), with everyone using multitenant (as suggested by Oracle's decision to deprecate non-CDB [container database] or non-multitenant as of 12.1.0.2). *But be quick*, because the Internet of Things (IOT) is also already here. We've used it at Rolta to build Smart Cities, Rockwell uses it to build smart manufacturing, GE uses it to put better devices in your home, grocery stores use it to market the right products to you, Google has it in your Nest thermostat, and Gartner recommends that companies don't cross the "creepy line" when storing all that information. IOT is already here!

So if the cloud, big data, and IOT are the present, what's the future? The future is robotics in every facet of life. There are robots that already look exactly like a real person, can recognize gestures, fetch a cup of coffee from Starbucks (complete with using the elevator), vacuum your rugs (Roomba—or as I call it, Skynet), water your grass or flowers based on weather data retrieved from the cloud via IOT devices, etc. Robotics is the future, it's here now, it's growing fast, and you should be building things that use these tools as a tech person.

<u>Your goals should be as follows:</u> Get on Oracle 12*c*R2, leverage all of the applicable features (this book will help), learn how to keep an encrypted backup on the cloud, learn how to spin up database cloud services for the development team quickly when they need them (so DevOps isn't needed), learn which systems shouldn't go to the cloud and why (be the knowledgeable and discerning person in the room), and then start fitting robotics into your competitive advantage as a company. *Oracle is the best tool in the world and is unbeatable if you can leverage it fully*. Every great carpenter uses the best tools and learns how to use them well; you need to do the same with Oracle. Read the whole book, implement the tuning techniques in your systems, and get working on what's next for you and your company!

What's coming next? Implants are next with virtual reality and exoskeletons. Those people you see wearing smart watches, Google Glass, or VR headsets will be same ones who also beta test the implants that are on the way. This is the first wave toward a future where you'll no longer recognize the past. It's been 13.7 billion years since the Big Bang to get to this acceleration point in history. What are you doing with this opportunity as you are at the exact right place at exactly the right time in history? What gifts has God given you that you can leverage? Don't worry about losing your job to the cloud like the AT&T operators worried about losing their jobs to computers. Think about how you will react as the road bends ahead, and go where the opportunity lies. God has a place for you out there during this pivotal time in history!

Rod Serling said it well: "There is a fifth dimension beyond that which is known to man. It is a dimension as vast as space and as timeless as infinity. It is the middle ground between light and shadow, between science and superstition, and it lies between the pit of man's fears and the summit of his knowledge. It is an area which we call the Twilight Zone." With Exadata, flash, and the cloud, we have started exploring this area in all corners of the world. It will prove to be an area of implants, augmentations of every kind, and one that will test our definition of what makes up a human being. What amount of human augmentation transforms a human into a robot? What if you could transfer every experience you've ever had and every thought in your mind to a computer and then download that into a 3D printed replica of the brain, printed using your own cells? When incorporated into a 3D print of the rest of your body, is it a person or a robot at that point? (I think it would still be a clone of sorts, perhaps a facsimile, but not the real thing.) Could it go to work for you? When will we be able to 3D print ourselves to help us do chores? What happens when 75 percent of the body is robotic and only 25 percent is human? With human augmentations, the percentage of robotic parts will continue to rise. Will these replicated humans have rights? Consider that a recent U.S. Supreme Court ruling gave *organizations* the right to spend unlimited money on campaigns of candidates running for office; this was perhaps the largest right given to nonhumans in our history. In the future, Wall Street ("the bull" is primarily run by computer trading, *or robots*, today) could use its computer-driven trading profits to install these future robots as leaders of companies in the same way that it does most trading currently —by computer. Why wouldn't they want a robot with the ability of many humans (or every human on earth) running the company instead of a mere mortal? Wall Street and those companies could then use their money to finance the campaigns of their own political candidates, quietly (even the U.S. president, who may potentially nominate Supreme Court justices that they choose). This is no longer science fiction, but challenges we face in the near future. There are now leaders of tech companies funding large projects to ensure our future as a species continues because of this coming shift.

Connecting into the brain has already occurred; what's next will certainly lead us to something well beyond a *Twilight Zone* future. It is a future where arranging atoms to create objects, or transport them or hide them, will become more common. As Rod Serling said, "You unlock this door with the key of imagination." We are no longer limited; what you can imagine, you can create. I think it's an amazing time to live and to work! Perhaps knowledge-building edible technology will be the follow-up to wearable technology. What future will these primarily robotic systems and workers eventually build? It's hard to predict, and hard to predict where we humans will fit in. Wall Street at times can be more beast than bull—it listens to no person or country, and it silently builds more efficiency and productivity into the corporate world based on algorithms of all of those traders throughout its history that made up almost all trading. There is a new world ahead that is part man, part machine, and for this there is a standing-room-only audience watching from the other side. What has God in store for all of us ahead? Is it the final act, or a better future that will bring out the best in each of us and to each of us? Some of us keep looking back for that wisp of what was; try looking forward! What's on the signpost up ahead? Nobody knows for sure, but you'll soon be at this fork in the road. Godspeed humans, and choose wisely!

Why is this brave new world coming so quickly whether we like it or not, and whether we are ready for it or not? We started on the mainframe with 8 bits and the ability to access 256 bytes of addressable memory, and then 16 bits and Windows with 64K of memory and, if you bought extra hardware, 1M of extended memory. Then came the Internet age, as we boldly headed into the gigabyte SGA world that 32 bits brought us and 4G of addressable memory. Now technology has grown to 64 bits and moves from the burdens of 4G max, which the 32-bit Internet world gave us. With 64 bits, the theoretical limit of directly addressable memory (2 to the power of 64) has become 16E (exabytes), or 18,446,744,073,709,551,616 bytes (2^{64} bytes), waiting for us to leverage its incredible power in every aspect of our lives. We will go from gigabyte SGAs to petabyte SGAs (a petabyte is 1000 terabytes) with bigger data. *Make sure you take time to consider where you are in history and what role you want to play!* Consider how much memory computers could directly address (use), and remember that we're using the latest technology to build the latest technology for even greater acceleration:

	Address Direct (Bytes)	**Extended RAM (Result)**
4 bit	16	640 (dawn of computers)
8 bit	256	65,536 (mainframe)
16 bit	65,536	1,048,576 (Windows/PC)
32 bit	4,294,967,296	(Internet/social media)
64 bit	18,446,744,073,709,551,616	(Cloud/robots/implants)

Another way to put this comparison into perspective is to consider what it would mean in terms of miles per hour, with Windows as the starting point:

Shift	**Increase over Windows (Result)**
8 bit to 16 bit	1 mph (Windows)
16 bit to 32 bit	65K mph (Internet)
32 bit to 64 bit	300T mph (robotics/3D/VR/cloud/implants starting)
64 bit to 128 bit	5T*T*B mph (implants/brain augmentation)

Oracle RDBMS History Over the Years

1970 Dr. Edgar Codd publishes his theory of relational data modeling.

1977 Software Development Laboratories (SDL) is formed by Larry Ellison, Bob Miner, Ed Oates, and Bruce Scott with $2,000 of startup cash. Larry and Bob come from Ampex, where they were working on a CIA project code-named "Oracle." Bob and Bruce begin work on the database.

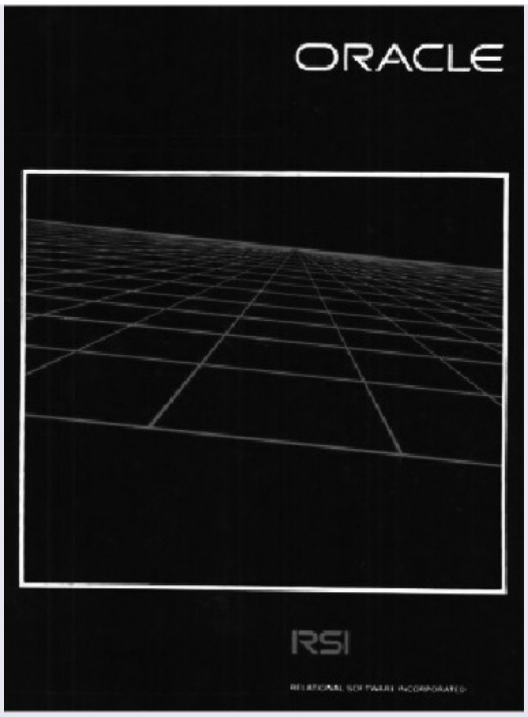
1978 The CIA is SDL's first customer, yet the product is not released commercially. SDL changes its name to Relational Software Inc. (RSI).

1979 RSI ships the first commercial version, Version 2, of the database, written in Assembler Language (no V1 is shipped based on fears that people won't buy a first version of software). The first commercial version of the software is sold to Wright-Patterson Air Force Base. It is the first commercial RDBMS on the market.

1981 The first tool, Interactive Application Facility (IAF), which is a predecessor to Oracle's future SQL*Forms tool, is created.

1982 RSI changes its name to Oracle Systems Corporation (OSC) and then simplifies the name

to Oracle Corporation.
1983 Version 3, written in C (which makes it portable) is shipped. Bob Miner writes half, while also supporting the Assembler-based V2, and Bruce Scott writes the other half. It is the first 32-bit RDBMS.
1984 Version 4 is released, along with some first tools (IAG-genform, IAG-runform, RPT). Version 4 is the first database with read consistency. Oracle is ported to the PC.
1985 Version 5 is released, first Parallel Server database on VMS/VAX.
1986 Oracle goes public March 12 (the day before Microsoft and eight days after Sun). The stock opens at $15 and closes at $20.75. Oracle Client/Server is introduced, which is the first client/server database. Oracle 5.1 is released.
1987 Oracle is the largest DBMS company. Oracle Applications group started. First symmetrical multiprocessing (SMP) database introduced.
1987 Rich Niemiec along with Brad Brown and Joe Trezzo while working at Oracle implements the first production client/server application running Oracle on a souped-up 286 running 16 concurrent client/server users for NEC Corporation.
1988 Oracle V6 released. First row-level locking. First hot database backup. Oracle moves from Belmont to Redwood Shores. PL/SQL introduced.
1992 Oracle V7 is released.
1993 Oracle GUI client/server development tools introduced. Oracle Applications moved from character mode to client/server.
1994 Bob Miner, the genius behind the Oracle database technology, dies of cancer.
1995 First 64-bit database developed.
1996 Oracle 7.3 released.
1997 Oracle8 is introduced. Oracle Application Server is introduced. Applications for the Web are introduced. Oracle is the first Web database. Oracle BI tools like Discoverer are introduced for data warehousing. Tools have native Java support.
1998 First major RDBMS (Oracle8) ported to Linux. Applications 11 shipped. Oracle is the first database with XML support.
1999 Oracle8i released. Integrates Java/XML into development tools. Oracle is the first database with native Java support.
2000 Oracle9i Application Server released. It becomes the first database with middle-tier cache. Launches E-Business Suite, wireless database with OracleMobile, Oracle9i Application Server Wireless, and Internet File System (iFS).
2001 Oracle9i (9.1) released. Oracle is the first database with Real Application Clusters (RAC).
2002 Oracle9i Release 2 (9.2) released.
2003 Oracle at France Telecom is #1 on Winter Group’s Top Ten in DB size at 29T.
2003 Oracle 10g comes out, with grid focus, encrypted backups, auto-tuning, and ASM.
2005 Oracle RAC at Amazon hits the Winter Group’s Top Ten in DB size at 25T.
2005 Oracle acquires PeopleSoft (includes JD Edwards), Oblix (Identity Management), Retek (Retail) for $630M, TimesTen (in memory DB), and Innobase (InnoDB Open Source).



2006 Oracle buys Siebel for $5.8B, Sleepycat Software (Open Source), and Stellant (Content Management). Oracle with an open source push offers “unbreakable” support for Red Hat Linux.
2006 Oracle 10g Release 2 comes out in fall
2007 Oracle buys Hyperion for $3.3B. Oracle 11g comes out (2009 was the first release of 11gR2).
2008 Oracle Exadata announced; Oracle buys BEA.
2009 Oracle releases 11gR2. Oracle buys Sun (which includes Java, MySQL, Solaris, hardware, Open Office, StorageTek).
2010 Oracle announces MySQL Cluster 7.1, Exadata 2-8, Exalogic, and 11.2.0.2 released.
2011 Oracle 11gR2 (11.2.0.4) terminal release (all Exadata line is 11gR2) and Oracle 11g Express Edition released (September 24, 2011). Oracle announces Exalytics, SuperCluster, Oracle Data Appliance, Exadata Expansion Rack, and Oracle Cloud 12c (late 2011).
2012 Exadata X3-2 released; Oracle expands cloud offerings; Solaris 11.1.

2013 12cR1 is released; Exadata X3-8 released; Oracle acquires Acme Packet and Reponsys.
2014 Oracle releases In-Memory on 12.1.0.2; X4 released; acquires Corente.
2015 X5-2 and X5-8 released; FS1 Flash Array; acquires StackEngine (Docker tool).

2016 12cR2 released on Exadata Express
Cloud Server at $175/mo; Ravello/CASB acquisitions.
2021 13cR2 database prediction.

Oracle is a company that has matured in breadth, ability, and character over the years. Oracle's leaders live to innovate, and they've always hired for that next leader and visionary like Larry Ellison, or the next quietly driven Bob Miner, that next superstar developer like Bruce Scott. Somehow Oracle finds that creative/innovative special something in every employee they hire. Oracle hires unique, incredibly intelligent, intensely driven, and innovative people! It started with the attitude of Larry, and his ability to get more out of people than they are aware they have within them, and his ability to reward them when they deliver. Oracle also has the genius, spirit, and "blue collar–like" hard-working drive of a Bob Miner in all of those in the development world who have followed him. Oracle is well run because they have leaders in Safra Catz and Mark Hurd balancing out operations; Judith Sim driving marketing at an always "catch us if you can," too-fast speed; and delivery on products due to Andy Mendelsohn and his tremendously intelligent team inventing the next bend in the road. Thomas Kurian and his ever-growing, accelerating team are always finding new ways to integrate applications on the cloud and make businesses even more successful. Then there's Mary Ann Davidson's silent warriors in security, and many more.

TUSC

Lastly, I want to provide a quick note on TUSC, The Ultimate Software Consultants. At TUSC, I was blessed to work with the best of the best. We were often called the Navy Seals or the Marines of the Oracle world (being a former Marine, I like the latter description). We were called into Fortune 500 companies across the globe to solve various complex problems, and we always delivered! Thanks Brad Brown, Joe Trezzo, and all TUSC members of yesteryear.

I've tuned systems across the globe and I believe you will find something in this book that will help you. I've traveled to Australia, Austria, Belgium, Canada, China, the Czech Republic, Denmark, Finland, Germany, Italy, India, Ireland, Luxembourg, Mexico, Poland, Slovakia, Spain, Sweden, Switzerland, the U.A.E., and the United Kingdom. I'm always available as an architect or advisor at richniemiec@gmail.com and work with a great tuning product at http://tuningace.com/partners/RichNiemiec.html.

To my fellow Marines, Semper Fi, and to all servicemen and women, government workers, and agencies that protect freedom, thanks for making the world a safer and better place. The Marines always taught me God, Family, Country, and Corps. Add to that, the golden rule, not the version that goes "He who has the gold makes the rules," but the true golden rule: "To love your neighbor as yourself." Somehow, these two versions of the golden rule contrast the worst values, at times, on Wall Street with the best values on Main Street. Although it's tough to do, loving your neighbor as yourself will take you a whole lot further in life, and even if it leads you to a tough life, it will certainly lead you to a better place just after life. That's the best advice I could give you to prepare for the challenging future ahead!

How This Book Is Organized and Changes in This Version

If you read this entire book and apply it, you will be in the top 1 percent of Oracle Tuning professionals. Over 425 Tuning experts have added to this book in some manner. For those who read the last version of the book, here are some changes and/or additions for each of the chapters:

- **Chapter 1** Rewritten completely for basic Oracle 12*c*R2 new features

- **Chapter 2** Expanded to cover all of the index types and tested for 12*c*R2
- **Chapter 3** Updated for 12*c*R2: ASM, LMT, Auto UNDO, and improved I/O sections
- **Chapter 4** Added PGA_AGGREGATE_LIMIT, INMEMORY_SIZE, and In-Memory sections and updated initialization parameters for 12*c*R2
- **Chapter 5** Added 12*c* screenshots and Application Performance Monitoring (APM)
- **Chapter 6** Updated EXPLAIN, SQL Plan Management, DBMS_MONITOR, and TRCSESS
- **Chapter 7** Added new hints and updated others—the best resource for hints!
- **Chapter 8** Updated for 12*c*R2; added Result Cache and SQL Performance Analyzer
- **Chapter 9** Updated and tested for 12*c*R2; includes block tuning and added DB Replay
- **Chapter 10** Expanded again as PL/SQL tuning expands; added 12*c*R2 changes
- **Chapter 11** Added cloud, updated Exadata, RAC, and Parallel Query operations
- **Chapter 12** Expanded again to show more V$ view queries, especially those new in 12*c*R2
- **Chapter 13** Expanded X$ view queries, trace section, and X$ naming conventions
- **Chapter 14** Updated AWR, Statspack for 12*c*R2; updated mutexes and block tuning
- **Chapter 15** Updated for 12*c*R2 and for much larger systems
- **Chapter 16** Unix chapter updated to include a couple more commands
- **Appendix A** Updated queries for 12*c*R2 and new Top 25 initialization parameters
- **Appendix B** Updated for 12*c*R2 with updated V$ view queries
- **Appendix C** Updated for 12*c*R2 with updated X$ queries

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CHAPTER

1

Introduction to Oracle Database 12*c* R1 & R2 New Features (DBA and Developer)

First, I want to note that this book is primarily focused on helping beginner and intermediate Oracle professionals understand and better tune Oracle systems. Many expert topics are also covered in the later chapters, but the objective is primarily to assist professionals who are frustrated and looking for simple tips to help improve performance. This book has one simple goal: to provide an arsenal of tips you can use in various situations to make your system faster.

Chapter 1 is a new features chapter covering the new features focused on tuning. The new features chapter has been so popular in past editions of this book that I continue to make it the first chapter. The rest of the chapters gradually increase in complexity and provide a wide range of tips to help you in your tuning adventures. I am sure that you will encounter at least some information that you won't find elsewhere. With Oracle's relatively new focus on the cloud, I've included a section on the cloud here as an introduction to the more detailed information in Chapter 11. It's important to note that on September 18, 2016, Larry Ellison introduced 12*c*R2 on the *cloud-first*. The Oracle Exadata Express Cloud Server had an introductory price of only $175/month including all database options!

If you want a single method or an all-encompassing way of tuning a database (in a single chapter), I provide a few options for those who don't have the time to read the whole book. The first is Chapter 14 on Statspack and the AWR Report (Statspack is free, but AWR is better). The second option is the combination of two incredible chapters that include most of the common scripts the majority of experts use to tune a system using V$ views and X$ tables (covered in Chapters 12 and 13). The third option is Chapter 5 on Oracle Enterprise Manager Cloud Control (OEM), which includes Database Control and Cloud Control; it is a tool of the future that provides a graphical way to tune your system, including many features for both RAC systems and large-scale cloud control. This tool gives you the ability to view and tune multiple systems through one single interface. There is also a great tuning product at http://tuningace.com/partners/RichNiemiec.html.

This first chapter will discuss, briefly, some of the more interesting new features that are included in Oracle Database 12*c* Releases 1 and 2 covering 12.1.0.1, 12.1.0.2, and 12.2. Many new and improved features are included in this latest version. Oracle's goal in 12*c* was not only to create a more robust database management system, but also to include a cloud solution, multitenant database, In-Memory column store, and management improvements to simplify the installation/administration activities, thereby enhancing availability. Oracle's strategic direction is to provide a fully integrated set of features that replaces the third-party software that DBAs typically use to help them manage their environments. Not all features listed in this chapter are detailed in the book (since they are not *directly* tuning related and the size of the book is limited), yet I wanted a chapter to mention some of the best features whether directly tuning related or not to give you an overview of the latest version of Oracle Database 12*c*. Security is the focus of several other books, but it is important to state here that 12*c* is a critical release for security features. Not only does 12*c* contain the most security changes in a long time, but it also has performance enhancements for auditing, access controls, and encryption as security becomes more embedded in the database engine. Lastly, we cannot cover all the new features here, since the *Oracle Database New Features Guide* for 12.1.0.1, 12.1.0.2, and 12.2 combine to make up 240 pages. We will just highlight the more significant improvements (note that in some sections of 12.1, there will be notes about enhancements to 12.2).

The new features covered in this chapter include the following, listed by release:

- Oracle Database 12*c*R1 (12.1.0.1)
    - Increased size limit to 32K for VARCHAR2 and NVARCHAR2
    - Partial indexes on partitioned tables
    - Invisible columns in 11*g* lead to multiple indexes on the same column(s) in 12*c*
    - Fetch first *x* rows
    - Pluggable databases (multitenant DB)
    - Oracle Database Cloud Service (Database as a Service)
    - Change compression at import time
    - Adaptive Query Optimization
    - PGA_AGGREGATE_LIMIT, new initialization parameter
    - Concurrent execution for UNION/UNION ALL
    - Invoker rights function can be Results Cached
    - New DBMS_UTILITY.EXPAND_SQL_TEXT
    - Default for columns based on sequence
    - Interval-REF partitioning
    - Multiple SSD devices for Smart Flash Cache
    - Concurrent cost-based optimizer statistics gathering
    - Enhanced system statistics
    - Resource Manager for runaway queries
    - Automatic Data Optimization (ADO)
    - Global index maintenance for DROP and TRUNCATE Partition operations
    - ASM disk scrubbing
    - Online capability improvements
    - Data Guard improvements

    - RMAN improvements
        - Active database duplication improvements
        - Cross-platform backup and restore
        - Table-level recovery
        - Pluggable database backup and recovery
        - Network-enabled restore
- Oracle Database 12*c*R1 (12.1.0.2)
    - In-Memory Database
    - Advanced index compression
    - Automatic big table caching
    - Flashback Data Archive support for container databases
    - Full database caching
    - JSON support
    - FIPS 140 parameter for encryption
    - PDB subset cloning
    - Rapid Home Provisioning
- Oracle Database 12*c*R2 (12.2)
    - Application development
        - Improved SQL and PL/SQL
        - Reduced costs and complexities for migration to Oracle
    - Availability
        - Accelerated Active Data Guard adoption
        - Best-of-breed logical replication
        - Online operations
        - Recovery Server and RMAN improvements
        - Sharding
        - Simplified upgrades and data redaction for testing
    - Big data
        - Big data management system infrastructure
        - Enhanced query processing and optimization
    - Compression and archiving

        - Hybrid Columnar Compression improvements
        - Index compression enhancements
    - Oracle RAC and Grid Infrastructure
        - Automatic Storage Management
        - Rapid Home Provisioning and patch management
    - Security
        - Increased adoption of encryption
- New background processes in 12*c*
- Exadata—new with X6!
- Version 12*c* feature comparison chart

CAUTION
Because these features are new, you should use them cautiously and test them completely until you are sure they work without causing problems for your database. If you have access to My Oracle Support, I strongly advise you to determine whether any known problems exist with the feature you are preparing to use. There are also many experts and Oracle Aces out there with blogs and websites that give information that is well worth searching for.

Oracle Database 12*c*R1 (12.1.0.1)

Oracle Database 12*c*R1 is often referred to as the pluggable database (PDB) version of Oracle. Oracle made it possible to aggregate the many databases that people had invested in over the years. Oracle also added several new features; many are contained in this chapter.

Increased Size Limit to 32K for VARCHAR2 and NVARCHAR2

The maximum value for a VARCHAR2 and an NVARCHAR2 column in tables has been increased from 4000 to 32,767. This greatly expands that ability to use a VARCHAR2 data type before having to consider moving to a LOB column type. You do need to set the MAX_STRING_SIZE initialization parameter to EXTENDED (and *you may not go back* to the original STANDARD size). You also must shut down, restart in UPGRADE mode, change MAX_STRING_SIZE to EXTENDED, run the $oracle_home/rdbms/admin/utl32k.sql script, and then restart in NORMAL mode.

Partial Indexes

Partitioned tables have been providing management and performance improvements for quite some time. However, partitioned tables were typically very large tables and therefore had very large indexes as well. In Oracle 12*c*, partial indexes enable you to create an index and apply it only to specific partitions of the table, reducing the size of the index and only indexing partitions that get frequent use. The partial index can apply to both local and global indexes. To utilize this new feature, specify with the partition of a table if the partitioned table is to be indexed using the INDEXING clause (INDEXING ON/INDEXING OFF). For example:

```
CREATE TABLE orders_partial_idx (
order_id NUMBER(12),
order_date DATE CONSTRAINT order_date_nn NOT NULL,
order_mode VARCHAR2(8),
customer_id NUMBER(6) CONSTRAINT order_customer_id_nn NOT NULL,
order_status NUMBER(2),
order_total NUMBER(8,2),
sales_rep_id NUMBER(6),
promotion_id NUMBER(6),
CONSTRAINT order_mode_lov CHECK (order_mode in ('direct','online')),
CONSTRAINT order_total_min CHECK (order_total >= 0))
INDEXING OFF
PARTITION BY RANGE (ORDER_DATE)
(PARTITION ord_p1 VALUES LESS THAN (TO_DATE('01-MAR-1999','DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p2 VALUES LESS THAN (TO_DATE('01-JUL-1999','DD-MON-YYYY'))
INDEXING OFF,
PARTITION ord_p3 VALUES LESS THAN (TO_DATE('01-OCT-1999','DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p4 VALUES LESS THAN (TO_DATE('01-MAR-2000','DD-MON-YYYY')),
PARTITION ord_p5 VALUES LESS THAN (TO_DATE('01-MAR-2010','DD-MON-YYYY')));
```

Then, create the index and indicate if it is a partial index with the PARTIAL INDEX clause. For example, on a global index:

```
CREATE INDEX ORDERS_GI1 ON orders_partial_idx (PROMOTION_ID) GLOBAL INDEXING
PARTIAL;
```

Here's an example on a local index:

```
CREATE INDEX ORDERS_LI1 on orders_partial_idx (order_date, customer_id) LOCAL
INDEXING PARTIAL;
```

Other partitioning new features in 12*c*R2 include being able to split and merge partitions online; convert nonpartitioned tables to partitioned tables online; use multiple column list partitions; use list partitioning as a subpartitioning strategy for composite partitioned tables; and use read-only partitions.

Invisible Columns

Invisible columns provide the ability for columns in a table to be invisible when someone tries to perform a SELECT *…; however, it is still possible to see the column if the column name is specified in the SELECT. Whether or not the column is displayed, it is still part of the table and continues to be subject to all DML UPDATE operations as well as DDL operations affecting the table. Marking a column invisible can be done with an ALTER TABLE command:

```
ALTER TABLE MYEMPLOYEES MODIFY (SSN INVISIBLE);
```

Multiple Indexes on the Same Column List

Oracle 12*c* now allows multiple indexes to exist on the same column list. For example, we can create a unique index on the DEPT table as follows:

```
create unique index dept_unique1 on dept(deptno);
```

If we try to create an index on the same column list, we get an error:

```
create index dept_normal on dept(deptno);
create index dept_normal on dept(deptno)
*
ERROR at line 1:
ORA-01408: such column list already indexed
```

However, if we make the unique index invisible, we can create the index on the same columns list:

```
alter index dept_unique1 invisible;
```

Keep in mind we still cannot insert duplicate values into the table even though the index is invisible. It is a valid index and will still maintain the uniqueness of the table when DML operations are performed. The index will not be used when SELECT using the column is performed. Also, now that it's invisible, we can create an additional index on the DEPT_NO column:

```
create index dept_normal on dept(deptno);
Index created.
```

It is possible to create two visible indexes on a column at once, if one of those indexes is a function-based index. Let's make the third index invisible and add a fourth (and fifth):

```
alter index dept_normal invisible;
Index altered.

create index dept_reverse on dept(deptno) reverse;
Index created.

alter index dept_reverse invisible;
Index altered.

create bitmap index dept_bitmap on dept(deptno);
Index created.

create index dept_fb on dept(substr(deptno,1,1));
Index created.
```

Now when we check the index views, we see that we have five indexes on the same column with two indexes (one being a bitmap and another a function-based index) being visible:

```
select a.table_name, a.index_name,
       b.column_name, a.uniqueness, a.visibility
from   user_indexes a, user_ind_columns b
where  a.index_name = b.index_name
and    a.table_name = 'DEPT';

TABLE_NAME INDEX_NAME      COLUMN_NAME  UNIQUENESS   VISIBILITY
---------- --------------- ------------ ------------ ----------
DEPT       DEPT_UNIQUE1    DEPTNO       UNIQUE       INVISIBLE
DEPT       DEPT_REVERSE    DEPTNO       NONUNIQUE    INVISIBLE
DEPT       DEPT_NORMAL     DEPTNO       NONUNIQUE    INVISIBLE
DEPT       DEPT_BITMAP     DEPTNO       NONUNIQUE    VISIBLE
DEPT       DEPT_FB         SYS_NC00004$ NONUNIQUE    VISIBLE
(Index types: NORMAL, NORMAL/REV, UNIQUE, BITMAP, FUNCTION-BASED NORMAL)
```

We now have five indexes on the same column. Three indexes are invisible. One bitmap and one function-based index are visible and can be used. See Chapter 2 for more information on indexes.

Fetch First *x* Rows

Not only are you able to fetch the first *x* rows without scanning all rows, you can even skip some rows (offset) to get rows from the middle of the table for a better sample. It is a fast way to retrieve a certain number of rows from a table. The syntax is

FETCH FIRST *x* ROWS ONLY

or

OFFSET *x* ROWS FETCH FIRST *x* ROWS ONLY

Here's a quick example that does not skip rows:

```
select count(cust_id), cust_id
from   customers2
group  by cust_id
fetch first 10 rows only;

COUNT(CUST_ID)     CUST_ID
--------------   -------
            15         1
            27         2
...
10 rows selected.
```

Here's a quick example *skipping* rows:

```
select count(cust_id), cust_id
from   customers2
group  by cust_id
offset 10000 rows fetch first 10 rows only;

COUNT(CUST_ID)      CUST_ID
--------------   -------
7700238            10001
1409320            10002
...
10 rows selected.
```

Pluggable Databases (PDBs)

The pluggable databases (PDBs) feature in 12*c* (covered in detail in Chapter 3) enables you to have a container database (CDB) with multiple PDBs within the container. Pluggable databases are also called *multitenant* databases because each "tenant" can have its own PDB. "Pluggable" databases can be unplugged from one container and plugged into another container easily, therefore making databases portable between environments and allowing the upgrade of a database by unplugging it from one environment at one version and plugging it into a new environment at a higher version. You can also unplug a PDB from on premises and plug it into the cloud (or vice versa). This new feature also allows a single PDB to be independently recovered (you can even flashback a PDB in 12*c*R2).

Each PDB looks to an application like any other traditional Oracle database (called a non-CDB), so no application changes are needed to work the PDB architecture. Non-CDBs are now deprecated as of 12.1.0.2.

The following are some notes to keep in mind when using container and pluggable databases:

- CDB = container database (has a root DB and also a seed PDB)
- PDB = pluggable database (plugged into a CDB)
- Non-CDB = traditional type of database (neither a CDB nor a PDB)
- Quickly create a new database (PDB) or clone an existing one (PDB)
- Move existing PDBs to a new platform or location or clone it (snapshot)
- Patch/upgrade a PDB by plugging it into a CDB at a later version
- Physical machine runs more PDBs and can be easier to manage/tune
- Back up entire CDB + any number of PDBs
- New syntax for commands: PLUGGABLE DATABASE
- Redo shared by CDB and all PDBs
- Undo shared by CDB and all PDBs
- TEMP can be created for each PDB
- SYSTEM and SYSAUX individually for each CDB and PDB
- Timezone, each PDB
- DB initialization parameters: some are CDB specific, but many are for each PDB

Figure 1-1 shows a container database (CDB$ROOT) with a seed PDB (PDB$SEED) and two application PDBs (erppdb and dwpdb). Along with the logical/physical layout, it also shows a CDB administrator and two separate administrators for the two application PDBs. The physical files that are shared between the CDB and PDBs and those that can be at the PDB level only are discussed in the previous list. Since many PDBs can share application objects, such as code or metadata, Oracle introduced application containers in 12*c*R2. Now you just update the shared application container instead of updating all the PDBs.

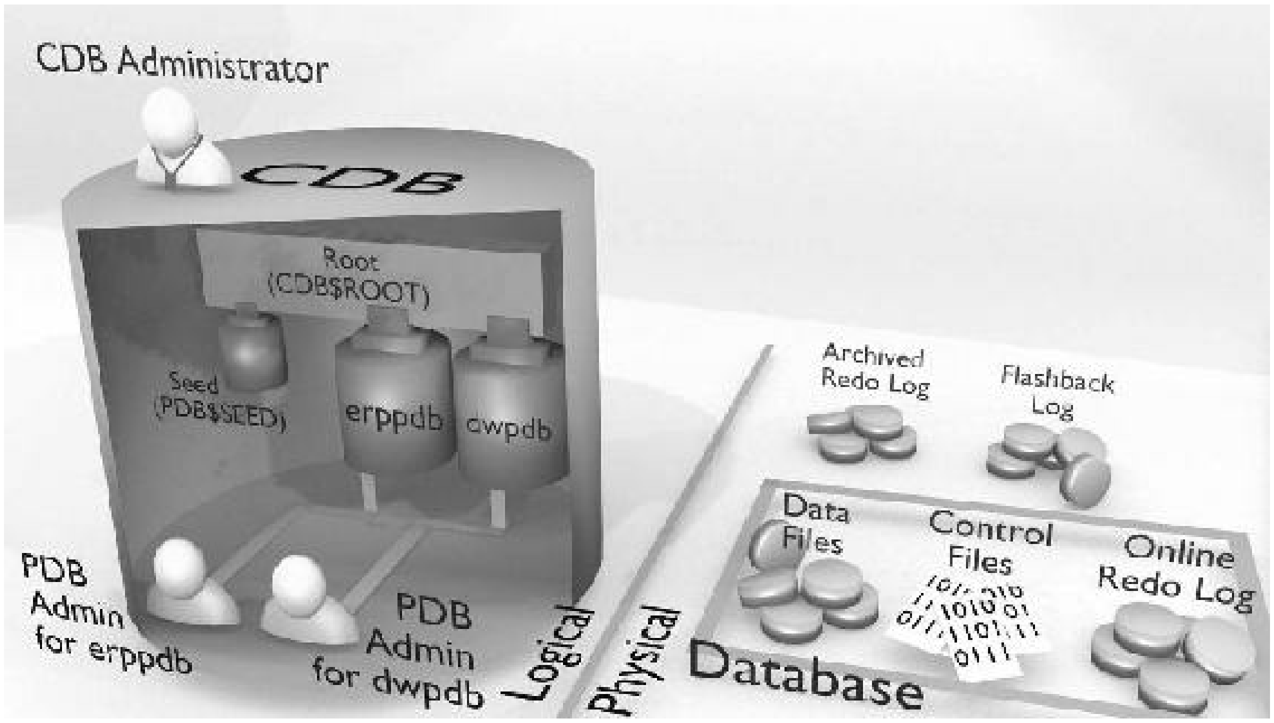


FIGURE 1-1. *A CDB with three PDBs (PDB$SEED and two application PDBs)*

One reason to use PDBs is that you can consolidate hundreds of databases on one machine. Separate machines can mean too many resources are required when you add up all of the SGAs! The need to easily move data around becomes increasingly important in scenarios such as these: big data sources are needed; a company makes acquisitions; a company moves data to and from the cloud; partners need shared research; governments share security or other data.

The following are a few nice example commands for the multitenant world (see Chapter 3 for more).

Is the database a CDB or non-CDB? (YES in CDB column = CDB)

```
SELECT NAME, CREATED, CDB, CON_ID
FROM   V$DATABASE;

NAME       CREATED   CDB     CON_ID
---------- --------- --- ----------
CDB1       19-FEB-12 YES          0
```

Query the PDBs (three PDBs in this example)

```
select name, open_mode, open_time
from v$pdbs;

NAME             OPEN_MODE  OPEN_TIME
---------------- ---------- --------------------------
PDB$SEED         READ ONLY  23-FEB-13 05.29.19.861 AM
PDB1             READ WRITE 23-FEB-13 05.29.25.846 AM
PDB_SS           READ WRITE 23-FEB-13 05.29.37.587 AM
```

Clone PDB (source *no longer* needs to be read-only in 12*c*R2—hot cloning)

```
CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
PATH PREFIX = '/disk2/oracle/pdb2'
FILE_NAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/');

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
FILE_NAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/')  STORAGE
(MAXSIZE 2G MAX_SHARED_TEMP_SIZE 100M);

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1@pdb1_link;
```

Move around and start up PDBs

```
ALTER SESSION SET CONTAINER=CDB$ROOT;
Session altered.

ALTER SESSION SET CONTAINER=PDB$SEED;
Session altered.

ALTER SESSION SET CONTAINER=pdb_ss; (not case sensitive)
Session altered.

Startup pluggable database pdb1 open;(read/write)
Pluggable Database opened.
(or while in pdb1 just run STARTUP)

Startup pluggable database pdb1 open read only;
Pluggable Database opened.

Startup pluggable database pdb1 force; (closes/opens)
Pluggable Database opened.
(or while in pdb1 just run STARTUP FORCE)
```

In 12*c*R2, you can also issue a FLASHBACK of a PDB and have restore points to *only* that PDB. This can be done using the SCN, Restore Point, Clean Restore Point, or Guarantee Restore Point. You can also use local UNDO in 12*c*R2. The FLASHBACK command for an individual PDB is shown here (you can get SCNs from V$ARCHIVED_LOGL, V$DATABASE, V$FLASHBACK_DATABASE_LOG, or V$LOG):

```
FLASHBACK PLUGGABLE DATABASE pdb1 TO SCN 830124;
```

Oracle Database Cloud Service (Database as a Service)

There is a push to the cloud as mobile applications become a dominant consumer need. This includes either "hosting" or "outsourcing" IT operations completely. The new cloud players (led by Oracle, Amazon, Microsoft, and Google) are the gold standard of the IT industry. They now predict that everyone will soon be on the cloud as the smartphone market continues to dwarf all other markets.

What's fueling the growth of the cloud:

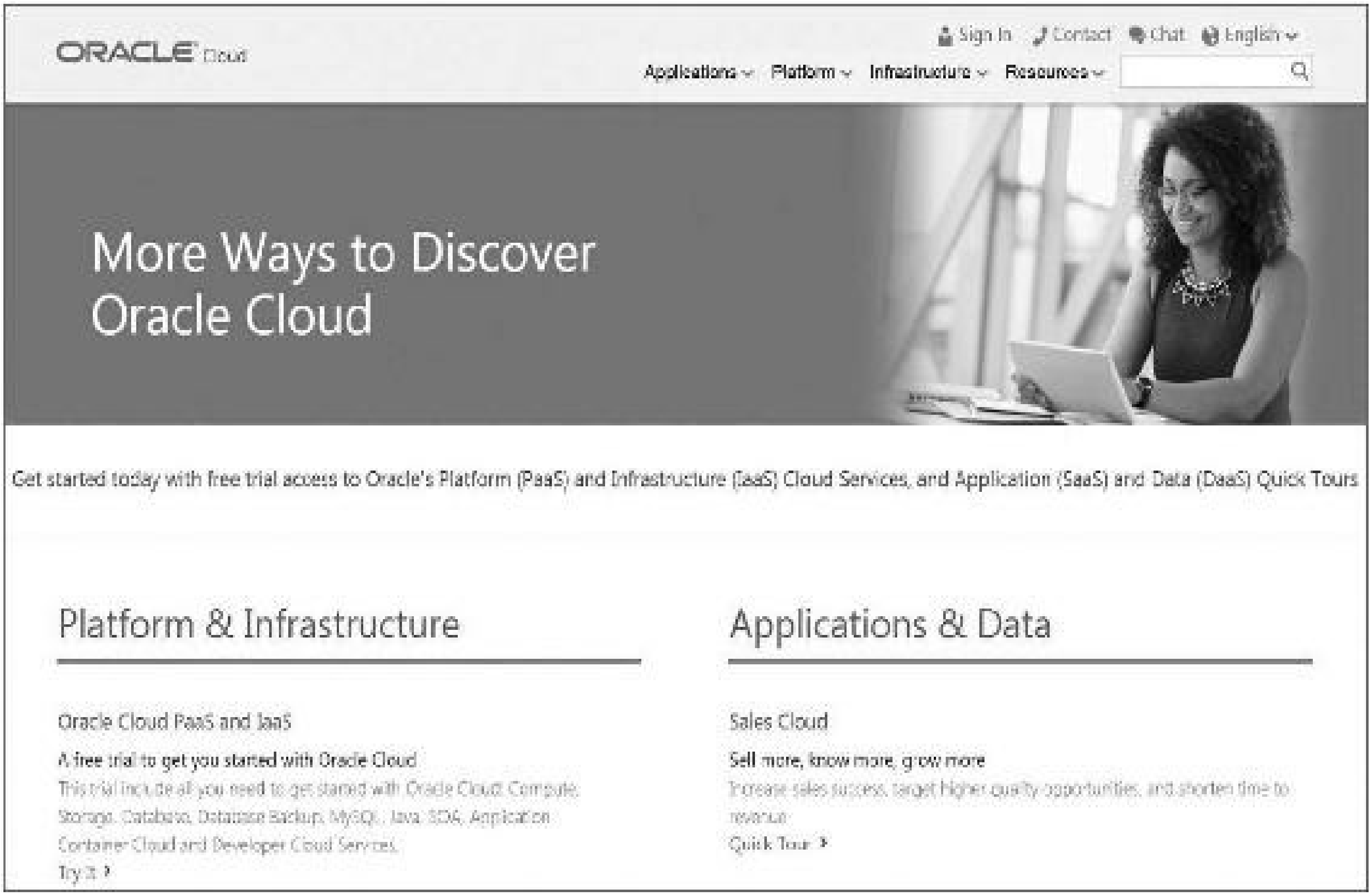
1. Connecting to social media and accessing marketing big data are faster over the cloud, as are leveraging this data and connecting it to mobile applications.
2. Every company can have an encrypted backup that's secure and offsite. This is a big plus to the many companies that still don't have this protection.
3. Cloud services are great for smaller companies that can't afford a real IT department. They can obtain IT servers and operations to any scale they'll ever need.
4. It's inexpensive to store archived data to the cloud for infrequent use.
5. You pay for what you use, scale up easily when you need to, and scale down easily when needed.
6. It's relatively inexpensive for testing new applications, new servers, or new versions.
7. The current generation of developers and DBAs is cloud-ready. They don't want to be tied to a specific computer and they already do almost everything in the cloud.

In the end, whether the cloud helps or detracts from your competitive advantage really depends on your costs, personnel, operations, and all of the preceding points. Keep in mind that, whether they realize it or not, everyone does *something* in the cloud already (known as the hybrid cloud model, a mix of cloud/on-premises, which is already at 100 percent). As Chapter 11 should convince you, a large portion of applications and IT operations will be hosted on the cloud. You need to be prepared for this generational switch to an era of cloud computing. Not *all* systems will move to the cloud though.

Setting up a Database Cloud Service instance for the first time takes a few hours, but setting up subsequent instances time takes only a few minutes. Database as a Service (DBaaS) will certainly be a reality for many shops to quickly spin up development servers for DevOps (Development and Operations).

Oracle announced in late 2016 that 12*c* Release 2 of the database will be released on the cloud first. This is not just a cloud-first event, but an Oracle-first event. This is similar to Oracle releasing less important platform database software (AIX comes to mind) later than Linux. Another example is Oracle releasing 12*c* on Express Edition (the free version) much later than Standard Edition (SE) or Enterprise Edition (EE). Oracle has a way of creating a bend in the road that you'll probably soon be following. Also, Oracle has available currently in the cloud a database that you can use anytime (https://livesql.oracle.com) to learn SQL and PL/SQL. When I tried it in early September of 2016, it was already the 12.1.0.2 database. When Larry Ellison introduced 12*c*R2, available on the cloud first via the Oracle Database Exadata Express Cloud Service, it had an introductory price of only $175/month—including all database options! This is one of the fastest servers on planet Earth I've ever seen, and for the lowest price in the cloud; it's also on the 12*c*R2 database. The ability to run or test your development applications on a server of this size and potential scale (when needed) is unprecedented. Oracle also introduced (on the same day) Application Performance Monitoring (APM) for DevOps. APM enables DBAs and developers to pinpoint performance problems at every layer of the application. Chapter 11 goes into great detail on setting up an Oracle Cloud Database Service instance, but I'll show a few of the major points here.

To begin to use the Oracle Cloud, you can simple go to https://cloud.oracle.com/tryit and choose to try it out for 30 days (see Figure 1-2). The website offers a lot of video tutorials and a lot of information about the different roles needed for the cloud. When we go to cloud.oracle.com/tryit, it will take us to this introductory page where we can click on the 30-Day Trial seen in Figure 1-2.



More Ways to Discover Oracle Cloud

Get started today with free trial access to Oracle's Platform (PaaS) and Infrastructure (IaaS) Cloud Services, and Application (SaaS) and Data (DaaS) Quick Tours

Platform & Infrastructure

Oracle Cloud PaaS and IaaS

A free trial to get you started with Oracle Cloud

This trial include all you need to get started with Oracle Cloud: Compute, Storage, Database, Database Backup, MySQL, Java, SOA, Application Container Cloud and Developer Cloud Services.

Try it ›

Applications & Data

Sales Cloud

Sell more, know more, grow more

Increase sales success, target higher quality opportunities, and shorten time to revenue

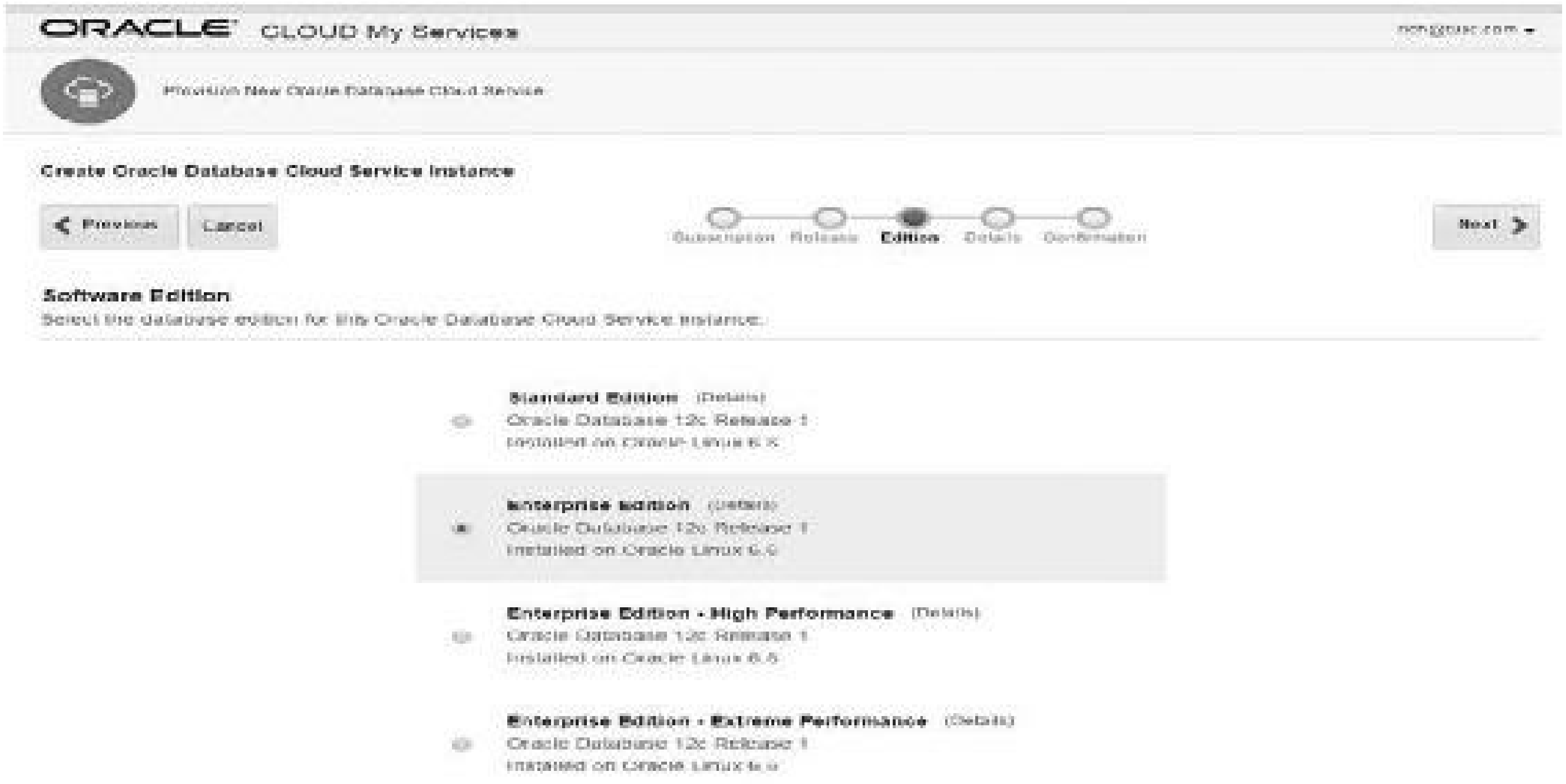
Quick Tour ›

FIGURE 1-2. *Oracle 30-Day Trial screen*

Click the Try It button and then choose Database (Your Oracle Database in the Cloud) to set up a Database Cloud Service instance. Note that these screens and information have changed three times in the past year. Information about your 30-Day Trial comes up next. It includes an overview of the process as well as the ability to start the Database as a Service Trial. You'll also be asked to log in to your Oracle account. After you sign on with your single sign-on to Oracle, you will be ready to get a connection to the Oracle Cloud. Fill in the basic information about you and your company, click Sign Up, and, upon approval, Oracle sends a verification to my phone followed by an e-mail to officially sign in to the Oracle Cloud (Figure 1-3).

FIGURE 1-3. *Sign in to the Oracle Cloud.*

You'll get a welcome message and an immediate offer to get some free training if you need it. Included in the Quick Start lesson is everything required to ensure you know how to set up Database as a Service. Those items include setting up SSH and using PuTTY, Creating a Service Instance, Finding the Connection Details about your Database Instance, Enabling Secure Access, Connecting via SQL Developer, Performing Operations on your Cloud Database, and Monitoring your Database Service. Once you're ready, click Get Started and then click Create Service to launch the Create Database Cloud Service Instance wizard. Choose whether you want a VM preinstalled or want to set it up using DBCA. Also choose a billing frequency, either hourly or monthly. Click Next, and choose either 11*g* (11.2.0.4) or 12*c* (12.1.0.2) as the database and then choose the edition of the database (Figure 1-4).


ORACLE CLOUD My Services

Provision New Oracle Database Cloud Service

Create Oracle Database Cloud Service Instance

Software Edition

Select the database edition for this Oracle Database Cloud Service instance.

Standard Edition (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

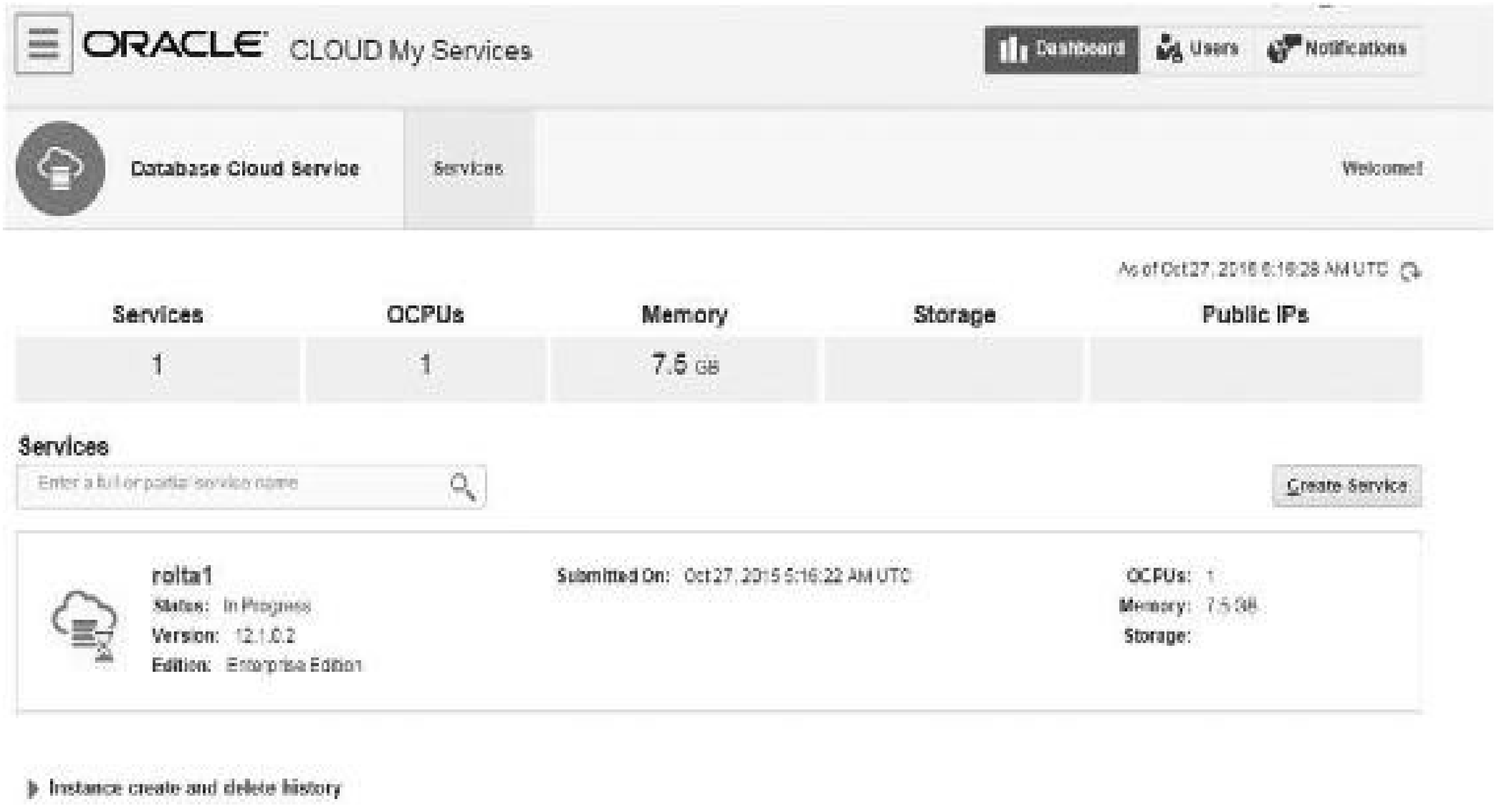
Enterprise Edition (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

Enterprise Edition - High Performance (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

Enterprise Edition - Extreme Performance (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

FIGURE 1-4. *Choose the edition of the database (pricing differs for each).*

Click Next, and on the Service Details page, choose the service name, size/shape of the server (very price specific), passwords, backup and recovery configuration, whether you'll use an encrypted file to build the database from your on-premises database, etc. You can also set up a Standby Database using Data Guard, enable GoldenGate, and install the demo PDB. Click Next, and you'll see that the process of building your Database Service is in progress (Figure 1-5) and then you will be told that your database is ready to use.



As of Oct 27, 2015 5:16:28 AM UTC

Services	OCPUs	Memory	Storage	Public IPs
1	1	7.5 GB		

Services

Enter a full or partial service name

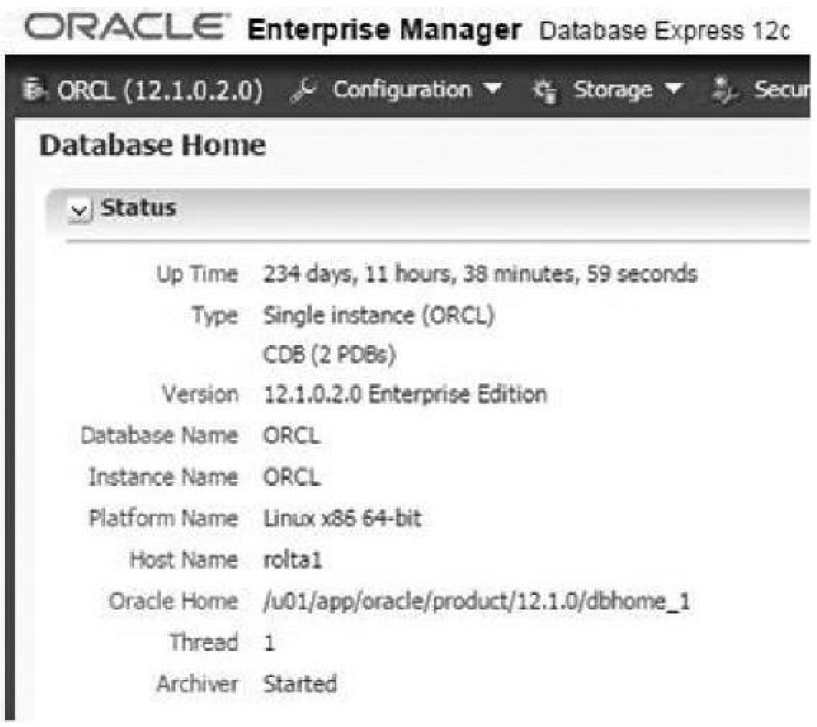
rolta1
Status: In Progress
Version: 12.1.0.2
Edition: Enterprise Edition

Submitted On: Oct 27, 2015 5:16:22 AM UTC

OCPUs: 1
Memory: 7.5 GB
Storage:

FIGURE 1-5. *A Database Cloud Service instance being created*

You've now successfully created an Oracle Database Cloud Service instance! You can use Oracle Enterprise Manager (OEM) to manage the Cloud Database with the pull-down menu (see Chapter 5 for OEM details that can be monitored). Click Open OEM Console to see details of your database (Figure 1-6 shows that my database has been up over 234 days). Also note that many of the settings and locations for files and the default that you would use if you installed the database.



Up Time	234 days, 11 hours, 38 minutes, 59 seconds
Type	Single instance (ORCL)
	CDB (2 PDBs)
Version	12.1.0.2.0 Enterprise Edition
Database Name	ORCL
Instance Name	ORCL
Platform Name	Linux x86 64-bit
Host Name	rolta1
Oracle Home	/u01/app/oracle/product/12.1.0/dbhome_1
Thread	1
Archiver	Started

FIGURE 1-6. *Information in the OEM Express Console in the cloud*

From the screen shown in Figure 1-6, I can click “CDB (2 PDBs)” and get to the details of the containers. Note that one of the PDBs is the DEMOS PDB that I chose to install when I created the Database Cloud Service instance and the other is PDB1. I can take a look at Memory Management to see the various settings and allocation of memory similar to OEM in my on-premises database. You have many different choices (see the discussion of OEM in Chapter 5 for greater detail). You can easily check things like memory initialization parameters to see if the In-Memory Size is set (if you are using the In-Memory column store. You can then click Set to change a parameter.

Similar, but separate from OEM, you can also use a new tool within Oracle Management Cloud called Application Performance Monitoring (APM, shown in Figure 1-7) to see greater detail in the cloud at every tier of operations. This is a cloud-only product. It shows performance and details at the database, application server, application, and even page level of the customer screen (thanks Oracle for this screenshot and the next one).

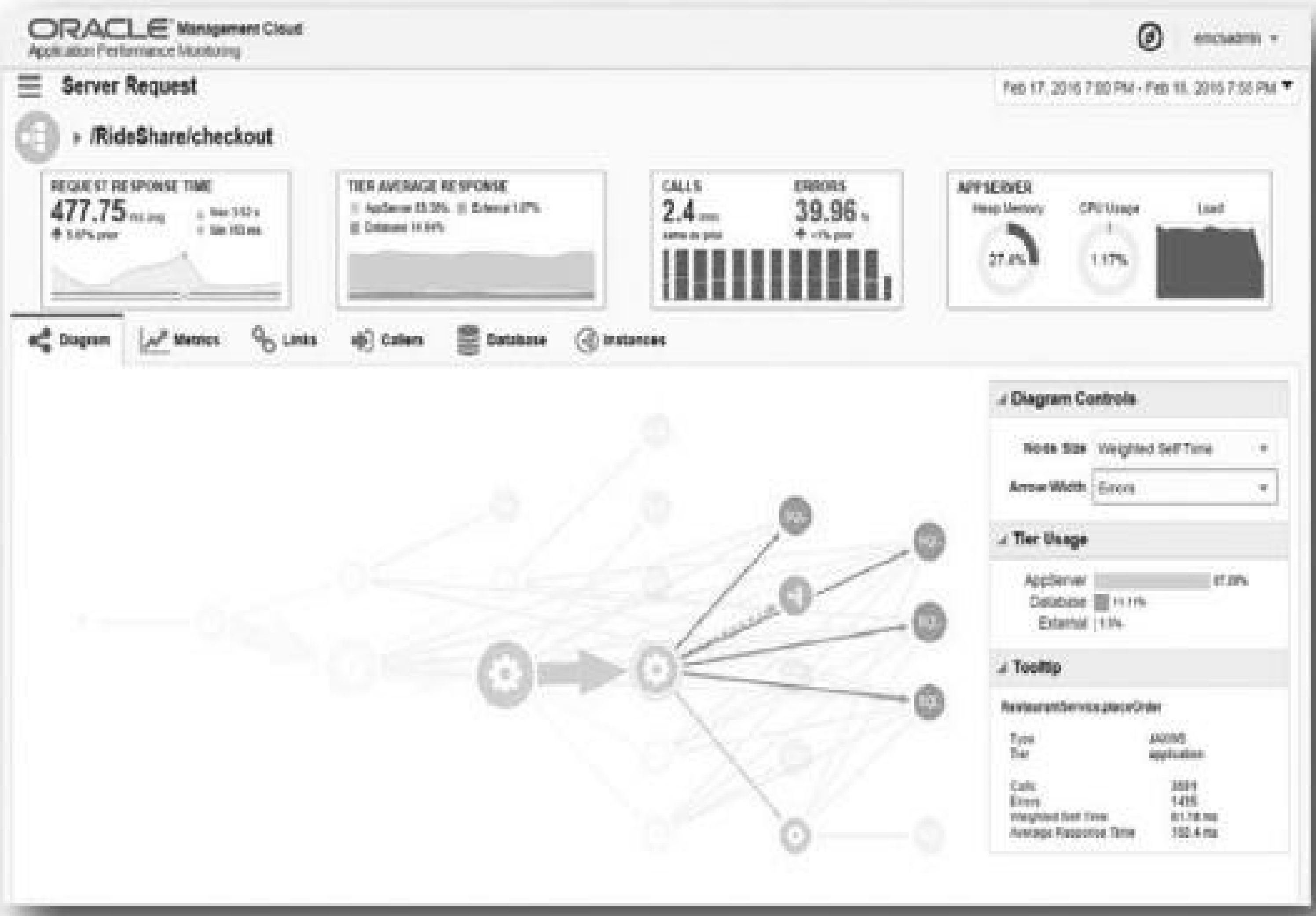


FIGURE 1-7. *Application Performance Monitoring (APM), a cloud-only product*

You can also get additional details of the customer experience in viewing the application with a special focus on the application web page, as shown in Figure 1-8.

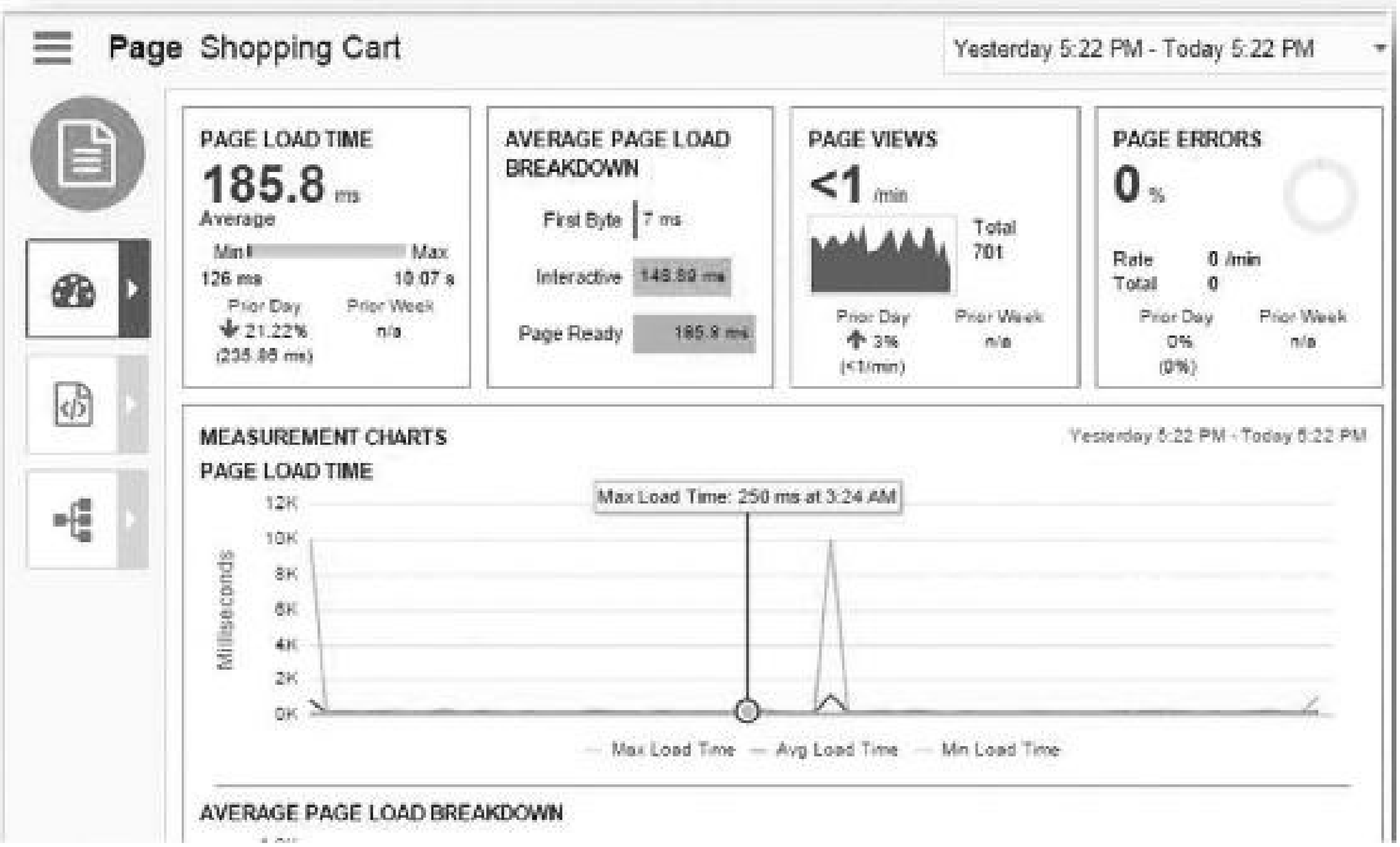


FIGURE 1-8. *APM customer shopping cart*

By using this information, you can gauge the customer experience and limit problems with speed or errors before the customer complains.

The Oracle Cloud is here to stay! As the next few years go by, Oracle will accelerate their cloud and mobile offerings. It's important to become educated on all of these products so that you can discern for your company which products fit now and which ones require a wait-and-see approach. See Chapter 11 for additional screenshots and information.

PDB Level: MEMORY_LIMIT and MEMORY_MINIMUM (12*c*R2)

In addition to the new MEMORY_TARGET initialization parameter to set all of memory for Oracle SGA+PGA, there are PDB-specific parameters to ensure a minimum amount and a maximum setting. Those parameters set at the PDB level using resource plan directives are

- **MEMORY_LIMIT** Limits the PDB to this percentage of PGA+SGA

- **MEMORY_MINIMUM** Guarantees the PDB this percentage of PGA+SGA

You'll also see in the In-Memory Database section in this chapter that there is an INMEMORY_SIZE parameter both at the CDB level and at the PDB level. Initialization parameters are covered in Chapter 4.

The following are some other 12*c*R2 new features with pluggable databases (see Chapter 3 for detailed coverage):

- The source no longer needs to be read-only when cloning a PDB (point-in-time clone).
- You can do a PDB refresh of clones manually or automatically (they must be read-only).
- You can create a class of PDB (Gold/Silver/Bronze) by setting DB_PERFORMANCE_PROFILE and then using Resource Manager to set directives for each class of PDB.
- You can do a FLASHBACK of a PDB and restore points to *only* that PDB!
- You can build a subset standby of just one or a portion of your PDBs!
- You can now have 4096 PDBs, not just 252.

Change Compression at Import Time

You use the `impdp` command-line option (or use DBMS_DATAPUMP) with the TABLE_COMPRESSION_CLAUSE to change the compression at import time. This is especially helpful for Exadata migrations where more compression options (HCC) are available. You can see listed below the following quick `impdp` example of changing the EMPLOYEES table to be NOCOMPRESS and the many options settings for the TABLE_COMPRESSION_CLAUSE:

```
$ impdp hr TABLES=hr.employees DIRECTORY=dpump_dir1 DUMPFILE=hr.dmp
TRANSFORM=TABLE_COMPRESSION_CLAUSE=NOCOMPRESS

TABLE_COMPRESSION_CLAUSE=NONE
TABLE_COMPRESSION_CLAUSE=NOCOMPRESS
TABLE_COMPRESSION_CLAUSE=COMPRESS BASIC
TABLE_COMPRESSION_CLAUSE=COMPRESS ROW STORE COMPRESS ADVANCED  (used for OLTP)

Warehouse compression (low is faster load):
TABLE_COMPRESSION_CLAUSE=COMPRESS COLUMN STORE COMPRESS FOR QUERY LOW
TABLE_COMPRESSION_CLAUSE=COMPRESS COLUMN STORE COMPRESS FOR QUERY HIGH

Archive compression (low is faster load):
TABLE_COMPRESSION_CLAUSE=COMPRESS COLUMN STORE COMPRESS FOR ARCHIVE LOW
TABLE_COMPRESSION_CLAUSE=COMPRESS COLUMN STORE COMPRESS FOR ARCHIVE HIGH
```

The next basic example demonstrates using `impdp` and COMPRESS to compress the DEPT2 table as it's being imported (note that the output below the `impdp` statement shows that the table is being transformed and compressed):

```
$ impdp scott2/tiger TABLES=dept2 TRANSFORM=TABLE_COMPRESSION_
CLAUSE:compress:table

Master table "SCOTT2"."SYS_IMPORT_TABLE_01" successfully loaded/unloaded
Starting "SCOTT2"."SYS_IMPORT_TABLE_01":  scott2/******** TABLES=dept2
TRANSFORM=TABLE_COMPRESSION_CLAUSE:compress:table
Processing object type TABLE_EXPORT/TABLE/TABLE
Processing object type TABLE_EXPORT/TABLE/TABLE_DATA
. . imported "SCOTT2"."DEPT2"                          5.937 KB       4 rows
Processing object type TABLE_EXPORT/TABLE/STATISTICS/TABLE_STATISTICS
Job "SCOTT2"."SYS_IMPORT_TABLE_01" successfully completed at Sat Mar 2
03:39:51 2013 elapsed 0 00:00:12
```

Adaptive Query Optimization

The Adaptive Query Optimization feature in Oracle Database 12*c* allows the optimizer to adjust the execution plan, even changing join methods, during runtime. This featured is on by default and utilizes discovery of additional information that can ultimately lead to better statistics. This additional information allows the optimizer to adjust query plans and is very useful in situations where current statistics are not enough to get an optimal plan. The two main components that adaptive query optimization focused on improving is the execution time of the query and checking adaptive statistics (ensuring the expected statistics are the actual statistics when the query is running). Adaptive statistics can also provide additional information for future executions. By getting more information and utilizing the information better over time, better query adjustments can be made, thereby improving execution plans, which can improve query performance. This feature is covered in detail in Chapter 8, but a few notes are listed here:

- Adaptive Query Optimization allows the optimizer to adjust the execution plan at runtime when additional/better information is available. Oracle will then use Adaptive Plans based on that information. Those plans may employ different Join Methods (i.e., change NL to HASH "on the fly") or different parallel query distribution. With adaptive statistics, the optimizer adapts plans based on not just the original tables' statistics, but also additional adaptive statistics. Dynamic statistics are gathered, automatic reoptimization occurs on the very next execution, and SQL plan directives allow for permanent changes based on those new statistics.
- Adaptive plans do not pick the final plan until execution time based on statistics collectors. Information learned at execution time is used in future executions. You'll see the following in the EXPLAIN PLAN table output (in the Note section):

```
Note
---------------------------
- this is an adaptive plan
```

- There are three types of adaptive statistics:
  - Dynamic statistics (previously dynamic sampling in 10*g*/11*g*) or runtime statistics
  - Automatic reoptimization of statistics generated after the initial execution
  - SQL plan directives direct the optimizer to use dynamic statistics and get accurate cardinality for the future.

In 12*c*R2, Oracle introduced Continuous Adaptive Query Plans (CAQP) where certain queries, based on input data, can benefit from continuous adaptive join methods (such as a recursive WITH that has different input data compared to previous iterations).

PGA_AGGREGATE_LIMIT

In 11*g*, you could set a target for the PGA with the initialization parameter PGA_AGGREGATE_TARGET. In 12*c*, there is a new initialization parameter called PGA_AGGREGATE_LIMIT to limit how high this value will go. The PGA makes up part of the MEMORY_TARGET. See Chapter 4 for a full discussion of initialization parameters, but here's a quick example:

```
ALTER SYSTEM SET PGA_AGGREGAT
ALTER SYSTEM SET PGA_AGGREGAT
```

When PGA_AGGREGATE_LIMIT is not set, it defaults to the largest of 2G, 200 percent of PGA_AGGREGATE_TARGET, or 3M times the number of processes.

Concurrent Execution for UNION/UNION ALL

Typically, the sections of a UNION and UNION ALL were executed serially; now with Oracle 12*c* the database is able to run the sections within a UNION and UNION ALL in parallel, which can greatly improve performance.

Invoker Rights Function Can Be Results Cached

The Results Cache can apply to both definer and invoker. This allows the results of all functions to utilize the Result Cache, helping to improve performance of function executions that have repeated executions. The results in the Results Cache, however, are not passed between the instances within a RAC cluster.

New DBMS_UTILITY.EXPAND_SQL_TEXT

This new feature is a big help for performance tuning when queries are using views. This allows the expanding of views to the base tables, which will allow better SQL performance investigation by being able to see the tables that make up the views to investigate table ordering, index utilization, and join types.

Default for Columns Based on Sequence

You no longer need to fetch a sequence value manually or through a trigger. This feature allows a column to be based on a sequence, which means a sequence can now be populated without the use of an INSERT trigger or the application having to prefetch the value from a sequence. For example:

```
CREATE SEQUENCE myseq;

CREATE TABLE mytable (id    NUMBER DEFAULT myseq.NEXTVAL,
description VARCHAR2(30);
```

Multiple SSD Devices for Smart Flash Cache

This feature improves the Smart Flash Cache feature to be able to utilize multiple SDD devices. The main challenge prior to this was that you needed to create an SSD disk device and utilize it for the Smart Flash Cache. However, to get larger spaces you sometimes had to use a volume manager, as the Smart Flash Cache could only use a single location. Now we can define and use multiple locations for the Smart Flash Cache. For example, the following sets the initialization parameters to use multiple devices with multiple sizes:

```
DB_FLASH_CACHE_FILE = /dev/sda, /dev/sdb, /dev/sdc
DB FLASH CACHE SIZE = 32G, 64G, 128G
```

Concurrent Cost-Based Optimizer Statistics

Gathering

The gathering of statistics before Oracle 12*c* was a serial operation and therefore gathering cost-based optimizer statistics could take a very long time on a large database. In Oracle 12*c*, we can now gather cost-based optimizer statistics on multiple tables or multiple partitions of the same table in parallel.

To use this feature:

1. Enable Resource Manager:
```
ALTER SYSTEM SET RESOURCE_MANAGER_PLAN = 'DEFAULT_PLAN';
```
2. Set the JOB_QUEUE_PROCESSES initialization parameter; recommended setting is two times the number of cores available (max):
```
alter system set job_queue_processes=12 scope=both ;
```
3. Enable concurrent statistics:
```
EXEC DBMS_STATS.SET_GLOBAL_PREFS('CONCURRENT','ALL');
```
4. Gather statistics:
```
EXEC DBMS_STATS.GATHER_SCHEMA_STATS('OE');
```

Enhanced System Statistics

Enhanced system statistics in 12*c* allow the cost-based optimizer to account for storage hardware in query plan generation. The enhanced system statistics can now recognize the speed of the database storage and utilize that when making plan determinations. This is very useful for environments where SSD and other fast storage solutions such as Exadata are utilized. You get better-performing SQL by generating plans that understand that faster disk speeds may allow scan operations and hash joins to perform faster than normal storage solutions.

To use this feature:

1. Gather system stats on a typical workload:
```
EXECUTE DBMS_STATS.GATHER_SYSTEM_STATS( gathering_mode => 'START' );
```
2. Allow the workload to run, to measure storage speed over time.
3. Stop the system stats gathering after a period of time:
```
EXECUTE DBMS_STATS.GATHER_SYSTEM_STATS( gathering_mode => 'STOP' );
```
4. Check the results:
```
SELECT PNAME, PVAL1 FROM SYS.AUX_STATS$ WHERE SNAME = 'SYSSTATS_MAIN';
```

There is also an Optimizer Statistics Advisor (in 12*c*R2) that tracks historical information on how statistics are gathered, the quality of the statistics gathered, and the status of automatic stats gathering. The advisor then suggests changes based on Oracle best practices, providing a report as well as a SQL script to run (see the *Oracle Database Performance Tuning Guide* for more information).

Resource Manager for Runaway Queries

The Resource Manager is a tool that creates limits for queries (and/or users) to prevent long-running, unimportant, resource-intensive queries from affecting the performance of the entire database. It also prevents one query from stopping an entire system. The database administrator can proactively prevent runaway queries by setting limits that are automatically enforced based on query thresholds (such as estimated execute time, actual execution time, amount of CPU used, physical I/Os used, and logical I/Os used). Based on the defined thresholds, once a query exceeds a threshold, the query will automatically be switched to a lower-priority consumer group or you can kill the session running the query, etc. The following example will kill a session that exceeds 60 seconds of CPU time:

```
BEGIN
DBMS_RESOURCE_MANAGER.CREATE_PLAN_DIRECTIVE (
PLAN => 'DAYTIME',
GROUP_OR_SUBPLAN => 'OLTP',
COMMENT => 'OLTP group',
MGMT_P1 => 75,
SWITCH_GROUP => 'KILL_SESSION',
SWITCH_TIME => 60);
END;
/
```

Automatic Data Optimization (ADO)

In 12*c*, we are given the ability to implement automatic data lifecycle management. The Automatic Data Optimization feature allows for policies that will automatically move data between storage tiers and compression levels. This is done through the *ilm_clause* of the CREATE and ALTER table statements. The feature determines when data meets the policy standard for movement by the Heat Map, which tracks changes to the table and table partitions. There are two types of policies, a *table_compression* or *tiering_clause*. When data meets the policy, the data is either compressed row level or segment level, or is moved to a new storage tier based on the policy criteria supplied in the AFTER clause of the policy.

Some parts of the *ilm_clause* are as follows:

- **ADD_POLICY** Specify the policy to add to the table.
- **DELETE** Delete a policy from the table.
- **ENABLE** Enable a policy for the table.
- **DISABLE** Disable a policy on the table.

The following are some parts of the AFTER clause of the policy:

- **LOW ACCESS** For policy to take effect after a period of time of low table access
- **NO ACCESS** For policy to take effect after a period of time of no table access
- **NO MODIFICATION** For policy to take effect after a period of time with no table changes
- **CREATION** For policy to take effect after a period of time after table creation

This example shows how to compress a row after it has not been modified for seven days:

```
ALTER TABLE orders ILM ADD POLICY ROW STORE COMPRESS ADVANCED ROW AFTER 7 DAYS
OF NO MODIFICATION;
```

Global Index Maintenance: Drop and Truncate Partition Operations

With 12*c* when you drop or truncate a partition, the global indexes are no longer invalid and managed automatically. Keep in mind that TRUNCATE now has a CASCADE function for tables, but you must be careful with this!

ASM Disk Scrubbing

In 12*c*, ASM has the ability to automatically repair logical corruption from the mirror disk within ASM. This feature can auto check, auto detect, and auto repair the logical corruption through the mirror that exists in normal and high redundancy diskgroups. See Chapter 3 for detailed ASM information. Here is an example:

```
ALTER DISKGROUP data SCRUB POWER LOW;
ALTER DISKGROUP data SCRUB FILE '+DATA_DG/DB1/DATAFILE/mytablespace.dbf'
REPAIR POWER HIGH FORCE;
```

Online Capability Improvements

Oracle Database 12*c* is taking availability to a new level with many new operations that can be performed online:

- New DDL online capability commands:

    - Drop index online
    - Drop constraint online
    - Set unused column online
    - Alter index unusable online
    - Alter index visible online
    - Alter index invisible online
- Move database *datafile* online
- Move table partition online:

  ```
  alter table dept move partition d1 tablespace data2 online;
  ```
- MERGE/SPLIT partitions online (12*c*R2)
- Change nonpartitioned tables to partitioned tables online (12*c*R2)

Data Guard Improvements

There are several Data Guard improvements in 12*c* that are worth mentioning:

- **Broker support for cascaded standby databases** A standby database is tied off of a standby database and not the primary. Redo is shipped to the first standby, and then the first standby sends the redo to another standby.
- **Real-time apply** Now the default.
- **Active Data Guard support for global temporary tables** Capability to write to global temporary tables when a physical standby is open in read-only mode and applying logs.
- **Active Data Guard real-time cascade** A cascaded standby can get real-time apply via redo and no longer has to wait for standby archive redo log. This keeps the cascaded standby database more in sync with the primary database. (Note: Requires Active Data Guard License.)
- **Disaster protection during rolling database upgrade** The standby can continue to receive redo while the database is in upgrade mode.
- **Broker support for rolling database upgrade** The broker configuration no longer has to be rebuilt after a rolling database upgrade.

RMAN Improvements

These are the notable RMAN improvements in 12*c*:

- **Active database duplication improvements** SECTION SIZE can be used to parallel an active duplicate with very large datafiles. This supports compression during the restore, which helps reduce duplicate time by better using the network.
- **Cross-platform backup and restore** Allows the backup from one platform to be restored on another platform without any extra work.
- **Table-level recovery** Enables recovery of a table or set of tables using an RMAN backup directly using RESTORE TABLE.
- **Pluggable database backup and recovery** A new feature added to support the PDB feature of 12*c*, allows a backup, restore, and recovery of a single PDB. It also allows a backup of a single tablespace within a CDB or PDB. Examples of this include the following:
  - BACKUP PLUGGABLE DATABASE pd1, pd3
  - BACKUP TABLESPACE USERS
  - BACKUP TABLESPACE pb1:SYSASUX
- **Network-enabled restore** Adds the ability to restore/recover one or more datafiles from a live database or running standby database. This feature supports compression and mutisection operations as well.

Oracle Database 12*c*R1 (12.1.0.2)

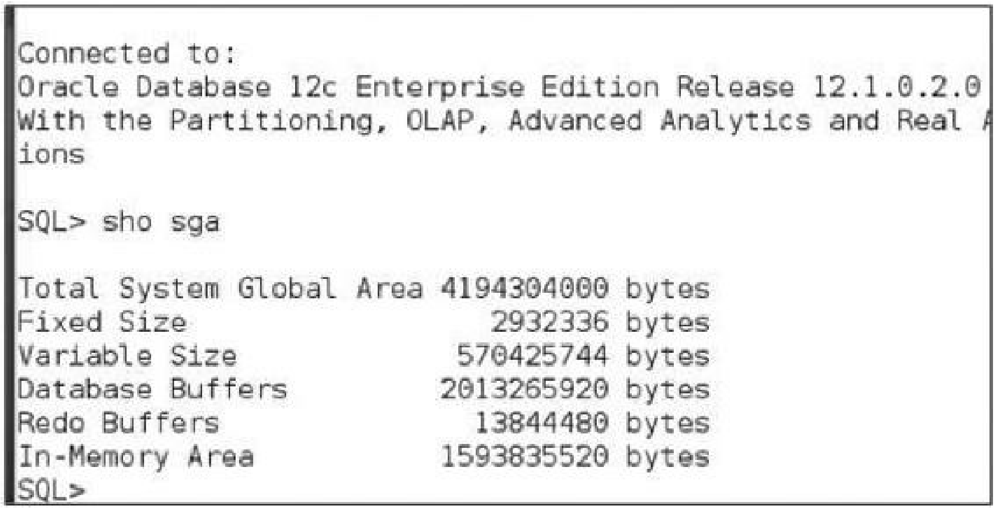
Oracle Database 12*c*R1 (12.1.0.2) is often referred to as the In-Memory (IM) version of Oracle. Oracle made it possible to have an additional memory area for data warehousing operations. This area is a compressed memory area with an In-Memory column store. In this area you are able to place specific columns in memory for faster warehousing applications while continuing to use Oracle's original memory area for transactional queries, as in past versions.

In-Memory Database

This is by far the best new feature for improving database performance in 12*c*. This capability is perfect for many types of workloads and, best of all, does not require any application changes to make use of it. Describing this new feature in full could fill an entire chapter, therefore we will cover it in more detail in Chapter 4.

This feature is made possible through the unique dual memory areas. The first is the main database memory cache (it used to be the only one) where the Oracle queries for individual rows are maintained primarily for OLTP (DB_CACHE_SIZE of the SGA). The second area is a new In-Memory column store (set using the *INMEMORY_SIZE* initialization parameter), which gives the capability to store compressed column(s) from tables (and other objects) and is primarily used for analytical processing (making it fast to perform functions on just a column). Now Oracle maintains both the row and columnar formats at the same time without any changes to the application. You can enable this feature without having to change a single line of code in your applications. It also is fully compatible with all existing Oracle database features and options, and can be used with RAC, partitioning, compression, pluggable databases, Exadata, and so on.

The In-Memory database option is an In-Memory column store that is an addition to the database System Global Area (SGA) buffer cache. It is known as the In-Memory (IM) area or the In-Memory column store. This will not "double" memory requirements for the database. It is estimated that only 20 percent overhead is expected to make full use of this feature with a huge impact. This feature maintains the buffer cache as it normally would in a row-format-based store, which is most efficient for DML activity. However, at the same time it will maintain a columnar-based format (the data is also compressed), which is most effective for query and analytical activities. Not all tables or columns should be part of the In-Memory area. The IM should only be populated with the tables that are most critical to overall database performance related to analytics. When the IM and the buffer cache are combined with now lower-cost flash storage, huge performance improvements can be realized. The In-Memory database option is turned on by setting the INMEMORY_SIZE to a non-zero value (don't set this until you are ready to be licensed for it). It must be set to at least 100M and it is part of the SGA_TARGET (and therefore the MEMORY_TARGET depending on if one or both of these parameters are used). Figure 1-9 shows an SGA which is using the In-Memory column store as set below using the INMEMORY_SIZE initialization parameter.



```
Connected to:
Oracle Database 12c Enterprise Edition Release 12.1.0.2.0
With the Partitioning, OLAP, Advanced Analytics and Real A
ions

SQL> sho sga

Total System Global Area 4194304000 bytes
Fixed Size                  2932336 bytes
Variable Size             570425744 bytes
Database Buffers         2013265920 bytes
Redo Buffers               13844480 bytes
In-Memory Area           1593835520 bytes
SQL>
```

FIGURE 1-9. *SGA listing showing the In-Memory area*

The following is an example of using this new feature (see Chapter 4 for setting initialization parameters):

```
inmemory_size=1520M
```

For an object to be populated in the new In-Memory area, the INMEMORY attribute is set for the given object. Setting the attribute can be a default at the tablespace level, for a table, set for specific column(s) of a table, and partition(s) of a table. Here are some examples:

Tablespace	`alter tablespace users default INMEMORY;`
Table	`alter table mytable INMEMORY;`
Column	`alter table mytable INMEMORY NO INMEMORY (prod_id);`
Partition	`alter table mytable modify partition mytable_part1 NO INMEMORY;`

The In-Memory area has the option for objects to be populated immediately upon database startup or when the object is first read/queried. This is controlled by the PRIORITY keyword. It allows some objects to be immediately populated to the In-Memory area upon database startup so that those objects are in memory upon first access, which helps avoid the performance hit of a first-time read. The PRIORITY keyword also allows you to assign to objects a priority for entering the In-Memory column store. This is all controlled by the following five priority levels, which control the loading of objects into the In-Memory area:

- **CRITICAL** Object is populated immediately after the database is opened.
- **HIGH** Object is populated after all CRITICAL objects have been populated, if space remains available in the IM column store.
- **MEDIUM** Object is populated after all CRITICAL and HIGH objects have been populated, if space remains available in the IM column store.
- **LOW** Object is populated after all CRITICAL, HIGH, and MEDIUM objects have been populated, if space remains available in the IM column store.
- **NONE** Objects only populated after they are scanned for the first time (default), if space is available in the IM column store.

Setting the priority determines how and when the objects are loaded into the In-Memory column store and in which order. For example, to set mytable into the In-Memory column store at database startup (to be one of the first loaded), set the priority to CRITICAL:

```
alter table mytable INMEMORY PRIORITY CRITICAL ;
```

The In-Memory area also is compressed and creates In-Memory compression units. There are several In-Memory compression options:

- **NO MEMCOMPRESS** Data is populated without any compression
- **MEMCOMPRESS FOR DML** Minimal compression optimized for DML performance
- **MEMCOMPRESS FOR QUERY LOW** Optimized for query performance (default)
- **MEMCOMPRESS FOR QUERY HIGH** Optimized for query performance and space saving
- **MEMCOMPRESS FOR CAPACITY LOW** Balanced, with a greater bias toward space saving

- **MEMCOMPRESS FOR CAPACITY HIGH** Optimized for space saving

By default, the In-Memory compression is FOR QUERY LOW. This provides the best performance while still getting some benefits from compression. The amount of compression experienced can vary anywhere from 2× to 20× and is based on data type, compression type, and the physical data within the table. The following example shows how we can apply compression, as well as other In-Memory settings, all in the same operation. In this example, we specify where we do *not* want In-Memory for a large LOB column (c4) and that we want to compress the table for In-Memory at QUERY HIGH, but want to use CAPACITY HIGH for column c2.

```
CREATE TABLE mytable
( c1 NUMBER,
  c2 NUMBER,
  c3 VARCHAR2(10),
  c4 CLOB )
INMEMORY MEMCOMPRESS FOR QUERY
NO INMEMORY(c4)
INMEMORY MEMCOMPRESS FOR CAPACITY HIGH(c2);
```

Oracle also automatically creates and maintains storage indexes on each column in the In-Memory Compression Unit (IMCU). The performance benefits for In-Memory get even better with these storage indexes (as needed based on queries), which allow data pruning from the SQL WHERE clause directly. This lessens the number of rows returned to the optimizer. SIMD (single instruction, multiple data values) vector processing scans multiple data values in the same CPU instruction (this is commonly used in gaming; consider the online game *League of Legends* has 27M daily users). In-Memory joins take advantage of Bloom filters to transform a join and improve the overall performance during the scan of larger tables. In 12*c*R2, the join group (column joined between two tables) is also compressed so that decompression is not needed when tables are joined (a potential issue prior to 12*c*R2). Also in 12*c*R2 is the ability to have In-Memory virtual columns, and Active Data Guard can now use the In-Memory column store while open in read-only mode.

In 12*c*R2, Automatic Data Optimization (covered in Chapter 3) is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics. In 12*c*R2, you can now dynamically resize the INMEMORY_SIZE while the system is running, provided you have the memory available in SGA_TARGET (and MEMORY_TARGET). In-Memory is supported with PDBs since 12.1.0.2, and 12*c*R2 Data Guard can now use the In-Memory column store. You can also now use DBMS_STATS functions on In-Memory statistics. While statistics are managed automatically by Oracle based on objects In-Memory and evictions, in 12*c*R2, Oracle has improved the transparency of the statistics.

Advanced Index Compression

Oracle 12.1.0.2 improved index compression so that the size of all indexes is reduced, including those that did not benefit from prior index compression due to not having leading columns in the index that repeated. Even unique indexes are smaller and benefit from this new index compression.

Automatic Big Table Caching

Database 12*c* adds a big table cache that provides huge performance improvements for full table scans where the table being scanned will not fit inside the database buffer cache. To turn this feature on, set the DB_BIG_TABLE_CACHE_PERCENT_TARGET initialization parameter to the amount of the database buffer cache memory that should be targeted for use. The PARALLEL_DEGREE_POLICY initialization parameter must be set to AUTO or ADAPTIVE as well for the feature to be turned on.

FDA Support for Container Databases

Flashback Data Archive now provides support for multitenant database configurations (pluggable databases).

Full Database Caching

This feature provides the ability to cache the entire database in memory. With server RAM capabilities getting larger, some databases really are able to completely fit in the server RAM. In a RAC environment where services divide the application data to multiple database instances, the ability to fit in the combined RAC configuration is even more likely. Keep in mind that there is additional room required for duplicate blocks/objects across the instances, so the combined RAM of the buffer caches has to be larger than the database. This new feature can provide huge performance boosts to database performance by eliminating I/O to disks or flash.

JSON Support

Oracle 12*c* added support for storing JavaScript Object Notification (JSON). The Oracle database allows the storage and enforcement of JSON rules for JSON objects stored in the database. It also allows the access to the data stored via PATH notation and integrated into SQL.

FIPS 140 Parameter for Encryption

Oracle 12*c* has a new parameter, DBFIPS_140, which provides the ability to utilize the Federal

Information Processing Standards (FIPS) 140 cryptographic processing mode. This feature allows companies and government agencies to meet this standard.

PDB Subset Cloning

PDB subset cloning enables you to specify the tablespaces that need to be available in a new pluggable database via the USER_TABLESPACES clause. This can be used in cases where you have a schema that is divided by tablespace that will go into multiple pluggable databases.

Rapid Home Provisioning—Creating "Gold Images"

Rapid Home Provisioning (RHP) provides the ability to have multiple predefined ORACLE_HOMEs creating "gold_image" homes stored in a catalog of pre-created ORACLE_HOMEs. This allows ORACLE_HOMEs to be provisioned from the catalog of "gold images." This decreases deployment or ORACLE_HOMEs to new environments and updating of ORACLE_HOMEs based on updates to the "gold images" and sharing, which can reduce storage space.

Oracle Database 12*c*R2 (12.2)

Oracle Database 12*c*R2 is the version of Oracle that most companies will migrate to and continue to run for many years. Oracle 12*c*R2 has many new features that enhance pluggable databases and the In-Memory column store. There are also additions that make it easier to move things to and from the cloud in this release. Additionally, there are many security enhancements.

Application Development

In addition to some of the features listed above, there are some fantastic features for the developers as well. While I will cover some of the SQL and PL/SQL improvements, they are too numerous to list them all here.

Improved SQL and PL/SQL

Improvements in SQL and PL/SQL are always welcome. PL/Scope Reports allow common SQL statements within PL/SQL code to be identified. This includes SELECT, INSERT, UPDATE, and DELETE statements. The reporting identifies the statement type, SQL text, and the sql_id of the statement. This is useful when you identify a poorly performing SQL statement and need to identify *all* PL/SQL locations where that SQL is utilized (which is achieved via the new DBA_STATEMENTS view).

There is an enhancement of the CAST function with error handling so that a user-specified value can be returned when a conversion error happens, rather than an error. The next highlight for SQL and PL/SQL is a new function that will allow you to pass a value and determine if it can be converted to a requested data type.

The best enhancement in 12*c*R2 is that a 32K VARCHAR is available by default. This allows the extending of the VARCHAR data types without having to enable the extended mode specifically.

Approximate query processing is a new feature that counts distinct values and adds approximate percentile aggregation. This allows faster processing of large data sets using approximation instead of exact aggregation. Since this is an aggregation, it is not assured to be completely accurate; however, in most cases it is very close and acceptable considering the large performance boost it provides. Note that the results returned are 100 percent accurate—only how the query is processed is approximated (lowers time to figure out how to execute the query efficiently). In 12*c*R2, there are additional approximate percentile functions and the capability to reuse approximate aggregations for multiple queries (via materialized views and query rewrite).

Instead of using this to achieve 100 percent accuracy:

```
select count(distinct(empno)) from emp;
```

use this for speed (97 percent accurate):

```
select approx_count_distinct(empno) from emp;
```

Oracle says the approximate amount will be within 97 percent or so from the actual.

Enhanced Features to Reduce Costs and Issues for Migration to Oracle

In 12*c*, object names for users, roles, tables, columns, indexes, constraints, and so forth have been increased from 30 bytes to 128 bytes, with a few limitations. The limit for tablespace names and pluggable databases is still 30 bytes, but others all increase to 128 bytes. You will notice this change in the dictionary views, where the VARCHAR2 columns will show as 128 bytes instead of 30 bytes. This is to overcome some limitations for multibyte character set languages, where in some languages, when non-Unicode, the name fits fine, but changing database to Unicode character set the name became too long. It also helps in migrations from non-Oracle systems where the name is longer than 30 characters.

Availability

There are several improvements to increase availability when implemented. Many options will accelerate Active Data Guard adoption such as accepting more data types, distributed transaction support, and a compare tool. Logical replication and more ONLINE operations will help keep your system up 24/7.

Accelerated Active Data Guard Adoption—12*c*R2 Improvements

There are several improvements in 12*c*R2 focused on the adoption of the Active Data Guard option. Distributed transactions are now allowed on CLOB, BLOB, and XMLType data types. Distributed transactions are transactions that occur over a database link. These new capabilities for these data types over database links open the possibility for more transactions over database links. This flexibility is important for pluggable databases, especially where schemas that used to live in the same database and could communicate directly and share data now go across database links, as they now live in separate PDBs.

Next, there is an improvement to multi-instance redo apply. In prior releases, RAC primary databases funneled all redo apply to a single standby instance. This limited the standby apply to one instance. With 12*c*R2, redo apply can be configured to one or more instances on the standby side, which allows redo apply performance to scale where previously, in some cases, the standby would fall behind when it was doing multiple instance redo apply on a single instance on the standby. Also, allowing multi-instance standby databases is incorporated into the broker so that broker configuration can handle multi-instance apply.

On Oracle Data Guard for Data Warehouses, we now have NOLOGGING operations on the primary that can be tracked. Originally, blocks on the standby would be marked unrecoverable when NOLOGGING was used on the primary. With the new tracking, Data Guard can track the blocks for loads with NOLOGGING and, using RMAN, recover the blocks using the new RMAN command RECOVER DATABASE NOLOGGING.

There is also an Oracle Data Guard Database compare tool that compares the blocks in a primary database to the blocks in a physical standby database. This helps to find disk errors that otherwise are not located by tools such as DBVERIFY. The DBA can now identify block issues in a standby that could otherwise be missed, ensuring the standby has no physical corruption.

With pluggable databases, Oracle 12*c*R2 introduces the concept of a subset standby. This allows a standby database in a multitenant environment to have a standby without having to take all the PDBs into the standby. Keep in mind this impacts switchover and failover operations, so you should understand the impact that only a subset of PDBs has on switchover and failover operations.

In 12*c*R2, the Data Guard Broker can handle multiple automatic failover targets for fast-start failover capability. When multiple standby databases exist and have multiple fast-start failover targets, if one standby is not in a state to fail over, another standby allows the failover to complete to this alternate standby rather than having the failover outright fail. The Data Guard Broker also now supports multiple observers from many fast-start failover configurations.

Data Guard now supports the ability to transport redo to a database destination with a different Endian than the primary. This is to allow the redo transport to the Zero Data Loss Recovery Appliance (ZDRLA), where the Endian format is different from that of the primary database.

Lastly, Data Guard provides an auto sync of database password files between primary and standby. This feature will automatically sync the password file between the primary and standby databases in a Data Guard Configuration when the password file changes on the primary.

Best-of-Breed Logical Replication

Oracle Database 12*c*R2 made some improvements geared toward replication, including GoldenGate. GoldenGate integrated capture mode error-handling improvements have been made to allow the viewing of conflict management configuration within the database using a new set of views:

- DBA_APPLY_REPERROR_HANDLERS
- DBA_APPLY_HANDLECOLLISIONS
- DBA_APPLY_DML_CONF_HANDLERS
- DBA_APPLY_DML_CONF_COLUMNS

GoldenGate also adds a new view for conflict detection and resolution exception handling: DBA_APPLY_EXCEPTIONS

There is also the ability to handle DDL with Oracle GoldenGate Integrated Replicat using a stored procedure, as well as the ability to replicate procedure executions for certain DBMS packages such as DBMS_REDEFINTION.

Online Operations

Several improvements have been made to improve availability in Database 12*c*R2, including many operations that can be performed online. Oracle now also introduces the ability to restart a redefinition from a failure. There is also the ability to roll back a redefinition using DBMS_REDEFINITION.ROLLBACK, which essentially swaps the original table back into place. There is also a redefinition progress-monitoring capability view (V$ONLINE_REDEF). The redefinition has support for BFLIE columns in tables.

Some of the online features include the online conversion of a nonpartitioned table to a partitioned table, and the ability to online split or merge a partition or subpartition of a partitioned table.

We can now move a table to a new tablespace online, which helps reduce downtime when we do a table reorg/move. We can also move to a new tablespace using information lifecycle management with no outages.

Recovery Server and RMAN Improvements

RMAN improvements in Database 12*c*R2 include disk space checking for the recover table feature and the ability to import pluggable databases into a multitenant database across platforms. This allows cross-platform migration by plugging the database into a new container database on a different platform (or the cloud). There is also support for cross-platform migration for encrypted tablespaces, enabling you to migrate databases to a new platform where encrypted tablespaces are utilized. There is DUPLICATE command support for encrypted backups that are not auto login wallet based. Lastly, there is cross-platform migration support (over the network) allowing a duplicate over the network in that process. See Oracle-specific documentation on these new very helpful improvements.

Sharding

Sharding is the concept of physically dividing the database objects for an entire application between multiple separate databases called *shards* (for horizontal scaling). From the application point of view, things are presented as a single large database (logically). This has been done for applications and environments for a long time before RAC and other cluster solutions became available (to scale an application without using sharding). However, 12*c*R2 adds capabilities to sharding for automated deployments, high-performance routing, and lifecycle management. Sharding is used for OLTP applications as a way to scale at the database level and is designed to be used with applications that were specifically designed to be sharded. See Oracle documentation for further details.

Simplified Upgrades and Data Redaction for Testing

Upgrade improvements include online patching for critical updates so that security patches no longer should require database downtime! Oracle Data Guard Rolling Upgrade now has Label Security support and Database Vault support, therefore databases using Label Security and/or Database Vault can now perform rolling upgrades. Database Vault now has support for flashback operations such as PURGE TABLE, PURGE TABLESPACE, PURGE RECYCLEBIN, and PURGE DBA_RECYCLEBIN. Oracle also provides a DBMS_REDACT package for Data Redaction (DBMS_REDACT is now available in 11*g* and 12*c*R1 because it was backported). This is great for testing! You can also GRANT only READ privilege, instead of SELECT (which could be used to lock a table with SELECT...FOR UPDATE).

Big Data

One of the biggest paradigm shifts in the business world is the rapid shift to finding, retaining, and helping customers through the use of big data. Oracle has several new features that help companies use big data along with the Oracle database. Oracle also offers solutions to securely access big data from the Oracle database, eliminating the massive security hole that big data created in most IT systems.

Big Data Management: External Tables Can Access Data Stored in Hadoop

Oracle Database 12*c*R2 has incorporated some improvements geared toward “big data” such as partitioned external tables, which allows you to map partitioned Hive tables into the Oracle environment and also allows you to define partitioning on top of Hadoop Distributed File System (HDFS). These features extend external tables to access data stored in HDFS and HIVE via the external table functionality of the Oracle database. In 12*c*R2, there is also Parallel Query Services for Oracle RAC environments with read-only nodes. This allows a RAC environment with read-only nodes to spread parallel query execution across many read-only nodes within a RAC cluster. This in turn allows large amounts of data to be queried very quickly.

Enhanced Query Processing and Optimization

The Oracle database is constantly being enhanced with improvements that help performance. In 12*c*R2, the following are enhanced query processes and optimization improvements:

- **Optimizer Statistics Advisor** Provides a way for the database to track and analyze how the optimizer statistics are collected and then utilize that information to report issues with current statistics collection and make suggestions for improvement.
- **SQL Plan Management** Has been enhanced to be able to use AWR data as a source for SQL plan baselines.

Compression and Archiving

Oracle also improved the storage and speed of accessing data. With Oracle you store much more data in less space due to compression algorithms that Oracle employs. Oracle also allows different ways to archive information.

Hybrid Columnar Compression (HCC) Improvements

Oracle 12*c*R2 adds the capability for HCC to be used with array-level inserts, essentially allowing HCC compression with the SQL INSERT SELECT without having to use the APPEND hint. This also applies to array-level inserts from applications using the Oracle Call Interface (OCI) and PL/SQL. Oracle Database 12*c*R1 introduced the ability to do information lifecycle management within the database (ADO). With 12*c*R2, HCC can compress data with a ADO row-level policy.

Index Compression Enhancements

In Oracle 12*c*, better index compression is available with the HIGH compression option now available for compressing indexes (LOW compression is the default). Since index reads are a huge activity for most databases, compressing indexes can offer performance improvements as well as disk space improvements.

Oracle RAC and Grid Infrastructure

Oracle has also made many improvements to ASM, including better use of "gold images." ASM continues to be the standard when setting up Oracle.

Automatic Storage Management

Oracle 12*c*R2 adds a few improvements for Automatic Storage Management (ASM), such as ASM Split Mirror for Oracle Exadata. This feature supports the split of an ASM mirror to allow a read-only copy for an Exadata clone-db copy.

Another improvement is the Flex disk group quota management in ASM. The “Flex” disk groups allow the control of storage consumption by a database via a “quota” in environments where multiple databases utilize the same ASM disk groups. Additionally, “Flex” disk groups offer the capability to prioritize rebalance operations. This will be useful in multitenant environments because not all databases in a multitenant environment need the same priority (due to differences in the critical nature of the PDBs to the business).

Rapid Home Provisioning and Patch Management

A “gold image” of Oracle database software and Grid homes can be used to automatically provision, patch, and upgrade the ORACLE_HOMEs from the “gold image.”

Security

Oracle has led the way in database security for over forty years! Many newer Wall Street backed databases lack even basic security that Oracle employed decades ago. Despite that lead, Oracle continues to implement better security with every version of the database with the expansion of TDE, encryption at multiple object levels, and encryption at the chip level with the M7.

Increase Adoption of Encryption

Oracle Database 12*c*R2 adds the ability to encrypt, decrypt, and rekey tablespaces with Transparent Data Encryption (TDE). This allows a live conversion and initial encryption of a tablespace to a new encrypted tablespace, allowing easy deployment of TDE into the database. This also allows the encryption keys to be rotated without downtime, which allows keys to be changed, for security reasons, without impact to availability. You can also set the INACTIVE_ACCOUNT_TIME parameter within a user profile to lock out a login if it’s been idle for a specified amount of time.

Also, SYSTEM, SYSAUX, and UNDO can have tablespace encryption applied to them. In prior versions, we could have encrypted tablespaces, but the database in SYSTEM, SYSAUX, and UNDO was left unencrypted.

New Background Processes in 12*c*

Here is a table listing the new Oracle Background Processes in 12*c*.

Acronym	Process Name	Description
BW*nn*	Database Writer Process (20 possible)	Writes modified blocks from the database buffer cache to the datafiles. The names of the 37th through 100th Database Writer Processes are BW36–BW99. See DBW*n* for more information on these processes.
LG*n*	Log Writer Slave	On multiprocessor systems, LGWR creates slave processes to improve the performance of writing to the redo log. LGWR slaves are not used when there is a SYNC standby destination.
LREG	Listener Registration Process	LREG notifies the listeners about instances, services, handlers, and endpoint.
RM	RAT Masking Slave Process	This background process is used with Data Masking and Real Application Testing.
RPOP	Instant Recovery Repopulation Daemon	The RPOP process is responsible for re-creating and repopulating datafiles from snapshots files. It works with the instant recovery feature to ensure immediate datafile access. The local instance has immediate access to the remote snapshot file's data, while repopulation of the recovered primary datafiles happens concurrently. Any changes in the data are managed between the instance's DBW processes and RPOP to ensure the latest copy of the data is returned to the user.
SA*nn*	SG Allocator	A small fraction of SGA is allocated during instance startup. The SA*nn* process allocates the remainder of the SGA in small chunks. The process exits and no longer exists once SGA allocation is completed.

Exadata—New with Exadata X6!

Oracle 12*c*R2 was officially released on September 18, 2016 on *cloud-first* and on an Exadata Database Machine. Oracle is officially a software, cloud, and hardware company! Exadata is introduced in this first chapter because hardware determines where you tune next (Chapter 11 looks at Exadata and Cloud in detail). Oracle has accelerated the hardware world in the same way they accelerated the software world. Exadata is great, but HP, EMC, IBM, and many others continue to put out great hardware to run your Oracle database. The Exadata X6-2 (just came out in 2016) has 14.6T of DRAM and an all flash option with 179.2T of all flash storage, or 1.3P of disk storage (although higher numbers are possible in other configurations). It also has around 1200 CPUs when you count the ones on the storage as well. Speed ranges from 2M to over 5M reads or writes per second.

The Exadata X6 got a CPU upgrade using the latest 22-core Intel Xeon E5-2699 v4 processors, which gives each Exadata compute node 8 extra cores per server over the X5 but gives each core a boost in performance as well. The storage cell CPUs got an upgrade using the latest 10-core Intel Xeon E5-2630 v4 processors. This is a big improvement over the older 8-core processors used in the X5, which was the same as in the X4. This is a welcome improvement in core performance and an increase of 4 cores per storage cell, which should help those times we have seen the storage cell performance on a Hybrid Columnar Compressed table using a Smart Scan (in the past hindered by CPU in the storage).

Storage has been significantly increased for both Flash and High Capacity storage. Flash has been increased from 1.6T per flash card to 3.2T per flash card, which doubles the size of the solid-state storage for the Exadata X6 over the X5. There are four flash cards per server, increasing flash storage per server from 6.4T per server to 12.8T per server. The full rack has a total of 179.2T of flash (230T of all flash in some configurations). The High Capacity disk size has been increased to 8T, which is double the size of the X5, which was 4T. The X6-2 has a maximum disk storage capacity of 1.344P (1.7P in some configurations is possible).

The upgraded storage cell performance allows you to apply an upgrade in just over an hour. In the past, storage cell upgrades have taken over 2 hours, so in some cases this has been cut in half. Storage indexes are now preserved through a cell reboot; until now you always lost your storage indexes when you rebooted a cell. This means not only that you can upgrade your storage cell software in an hour, but that the storage cells indexes are still safe after the cell reboots as part of the upgrade. Another huge improvement for the storage indexes is that they will also now move along with the data for device-predictive or true failures. This means that when a drive fails, the storage indexes are not lost and move along with the data to another drive.

Using the Oracle Exadata Deployment Assistant, you can set up VLAN tagging; prior to this any VLAN tagging had to be done after the initial installation and setup of the Exadata.

The capacity on-demand minimums have been slightly adjusted. The minimum for an X6-2 is 14 cores per server, and the X6-8 minimum cores total is 56. This makes the minimum basically the same as the X5 even though there were core count increases in the X6.

Version Comparison Chart

The following chart shows which components or options are available in the various editions of Oracle 12*c* (and if they are an additional cost). Note that a free limited version of Oracle called Oracle Express Edition (XE) is also available; in 11*g*, it had an 11G database, 1 CPU, and 1G of memory. This is subject to change for 12*c*, so please check Oracle.com to verify any features. If you can afford it, you definitely want the Enterprise Edition! This chart shows features that are available for a given version of Oracle, but keep in mind, some cost extra to add (i.e., RAC, Oracle Tuning Pack, Advanced Compression, In-Memory column store, Multitenant [pluggable databases], etc.). Standard Edition (SE/SE1) is available for 12.1.0.1 and Standard Edition 2 (SE2) is available starting with 12.1.0.2. Consult with your salesperson for pricing and licensing and see www.oracle.com/us/products/database/index.html for the latest information.

Option or Feature (*Extra Cost)	**12c Standard Edition One**	**12c Standard Edition (SE/SE2)**	**12c Enterprise Edition**	**12c Express Edition**
In-Memory Column Store*	N	N	Y	N
In-Memory Aggregation*	N	N	Y	N
Multitenant (PDBs)*	N	N	Y	N
Advanced Security*	N	N	Y	N
Advanced Compression*	N	N	Y	N
Database Vault*	N	N	Y	N
Diagnostic Pack*	N	N	Y	N
Oracle OLAP*	N	N	Y	N
Partitioning*	N	N	Y	N
Oracle RAC* (for EE)	N	Y	Y	N
Oracle RAC One Node*	N	N	Y	N
Oracle Spatial*	N	N	Y	N
Real Application Testing*	N	N	Y	N
Active Data Guard*	N	N	Y	N
Tuning Pack* (need Diagnostics Pack)	N	N	Y	N
DB Resource Manager	N	N	Y	N
VLDB, Data Warehousing, Business Intelligence				
Bitmapped indexes	N	N	Y	N
Export transp ts	N	N	Y	N
Import transp ts	Y	Y	Y	Y
Summary Management	N	N	Y	N
Advanced Analytics	N	N	Y	N
Hybrid Columnar Compression* (Exadata, ZFS, FS1)	N	N	Y	N
Descending indexes	Y	Y	Y	Y
Direct Path Load API	Y	Y	Y	Y
External tables	Y	Y	Y	Y
Function-based indexes	Y	Y	Y	Y
Long operations monitor	Y	Y	Y	Y
Materialized views	Y	Y	Y	Y
MERGE	Y	Y	Y	Y
Optimizer stats mgt	Y	Y	Y	Y

Pipelined table functions	Y	Y	Y	Y
Sample scan	Y	Y	Y	Y
Star query optimization	Y	Y	Y	PL/SQL Only
Parallel Operations				
Parallel query	N	N	Y	N
Parallel DML	N	N	Y	N
Parallel index build	N	N	Y	N
Parallel stats gathering	N	N	Y	N
Parallel Data export and Data Pump	N	N	Y	N
In-Memory Parallel (needs In-Memory*)	N	N	Y	N
Parallel backup & recovery	N	N	Y	N
Parallel analyze	N	N	Y	N
Parallel bitmap star query	N	N	Y	N
Parallel index scans	N	N	Y	N
High Availability				
Oracle Data Guard*	N	N	Y	N
Fast-start fault recovery	N	N	Y	N
Online operations	N	N	Y	N
Parallel Backup	N	N	Y	N
Oracle Flashback features (Table, Database, Transaction, Total Recall)	N	N	Y	N
Automatic Storage Management (ASM)	Y	Y	Y	N
Information Integration				
Oracle Streams	N	N	Y	Y
Oracle Messaging Gateway	N	N	Y	Y
Database Features				
Database event triggers	Y	Y	Y	Y
DBMS_REPAIR package	Y	Y	Y	Y
Drop column	Y	Y	Y	Y

Flashback Query	Y	Y	Y	Y
Globalization	Y	Y	Y	Y
Index coalesce	N	N	Y	N
Invisible index	Y	Y	Y	Y
Query Result Cache	Y	Y	Y	Y
Index-organized tables	Y	Y	Y	Y
INSTEAD OF Triggers	Y	Y	Y	Y
Plan stability	Y	Y	Y	Y
Reverse key indexes	Y	Y	Y	Y
SQL Plan Management	N	N	Y	N
Temporary tables	Y	Y	Y	Y
		Development		
Autonomous transactions	Y	Y	Y	Y
Client-Side Query Cache	N	N	Y	N
Java support	Y	Y	Y	N
JDBC drivers	Y	Y	Y	Y
MS Trans Server	Y	Y	Y	Y
Object/Relational Ext	Y	Y	Y	Y
PL/SQL native compilation	Y	Y	Y	Y
PL/SQL Function Result Cache	N	N	Y	N
PL/SQL stored procedures in triggers	Y	Y	Y	Y
PL/SQL Server embedded	Y	Y	Y	Y
SQL*Plus	Y	Y	Y	Y
XML	Y	Y	Y	Y
		Distributed		
Advanced replication	N	N	Y	N
Basic replication	Y	Y	Y	Y
Distributed queries	Y	Y	Y	Y
Distributed transactions	Y	Y	Y	Y
		Networking		
Connection Manager	N	N	Y	N
SDP for InfiniBand	N	N	Y	N

Connection pooling	Y	Y	Y	Y
Oracle Net services	Y	Y	Y	Y
System Management				
Basic standby database	Y	Y	Y	Y
Global index maintenance—DDL	Y	Y	Y	Y
Multiple block size	Y	Y	Y	Y
Online backup & recovery	Y	Y	Y	Y
Lifecycle Management Pack*	N	N	Y	N
Oracle Cloud Management Pack*	N	N	Y	N
Oracle Enterprise Manager	Y	Y	Y	N
Oracle Fail Safe (Windows only)	Y	Y	Y	N
Recovery Manager	Y	Y	Y	N
Resumable Space Allocation	Y	Y	Y	Y
Transparent Application Failover	Y	Y	Y	Y
Identify unused index	Y	Y	Y	Y
Security				
Virtual private database	N	N	Y	N
Fine-grained auditing	N	N	Y	N
Enterprise User security	N	N	Y	N
Password management	Y	Y	Y	Y
Encryption Toolkit	Y	Y	Y	Y
Proxy authentication	Y	Y	Y	N

This is by no means a complete list of features in Oracle Database 12*c*. Overall, Oracle has made major strides in providing enhanced functionality and automating many administrative tasks, reducing the total cost of ownership. RAC and Grid Computing are mature technologies that have now been extended to multitenant and the cloud. Oracle is leading the effort at integrating this technology and engineering it together with their Exadata and Exalogic, providing features like Flash Data

Compression, Hybrid Columnar Compression, and Hybrid Columnar Compression Row-Level Locking.

New Features Review

- 12*c*R2 increases the size limit for VARCHAR2 and NVARCHAR2 to 32K.
- In 12*c*, there is a feature for partial indexes on partitioned tables.
- In 12*c*R2, new partitioning features include: SPLIT and MERGE partitions online, convert nonpartitioned tables to partitioned tables online, and leverage read-only partitions.
- In 12*c*R1 you can build multiple indexes on a column by leveraging invisible indexes.
- For fast testing, you can fetch first *x* rows, and also skip rows before fetching them.
- You can change the compression of a table at import time (great for migrations).
- Pluggable databases are new with 12*c* and help with consolidation or moving to the cloud.
- PGA_AGGREGATE_LIMIT now limits the PGA original set with PGA_AGGREGATE_TARGET in 12*c*R1.
- Oracle now has an Adaptive Query Optimization method that changes a driving method for queries to fix slow queries (as they are executing).
- There is a new Resource Manager for preventing runaway queries.
- In 12.1.0.2, Oracle introduced the In-Memory (IM) column store, giving the ability to have an In-Memory data warehouse (columns are stored compressed in this new memory area).
- The source no longer needs to be read-only when cloning a PDB (point-in-time clone).
- You can do a PDB refresh of clones manually or automatically (they must be read-only).
- You can do a FLASHBACK of a PDB and restore points to *only* that PDB in 12*c*R2. This can be done using the SCN, Restore Point, Clean Restore Point, or Guarantee Restore Point. You can also use local UNDO in 12*c*R2.
- You can build a subset standby of just one or a portion of your PDBs in 12*c*R2.
- You can now have 4096 PDBs, not just 252, in 12*c*R2.
- Oracle introduced a number of online operations in 12*c*R2.
- Oracle now features sharding for horizontal scaling.
- Oracle provides a big data management system infrastructure including a feature that uses external tables to read Hadoop data.
- With Oracle Database 12*c*R2 the ability to encrypt, decrypt, and rekey tablespaces with Transparent Data Encryption (TDE) has been added.
- Oracle added a number of new background processes in 12*c*, detailed in this chapter.
- X6-2 is what is new with Exadata, including over 1P of storage or 180T of flash. Oracle also

has an all-flash server (FS1), which includes around 1P of flash.

References

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Rich Niemiec, "Oracle 12*c* New Features," Oracle OpenWorld Presentation, 2015.
*Oracle Database Administrator's Guide, 12*c *Release 1 (12.1)* (Oracle Corporation).
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*Oracle Database New Features Guide, 12*c *Release 2 (12.2)* (Oracle Corporation).
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"Oracle Database In-Memory," an Oracle White Paper, July 2015.

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CHAPTER 2

Basic Index Principles (Beginner Developer and Beginner DBA)

This chapter is neither for the experts nor for those looking for fast answers. This is a chapter (maybe the only one) that looks at very basic indexing theory, including some new features in version 12*c* Release 2 (12*c*R2), such as multiple types of indexes on the same column(s). The toughest part of being a beginner is finding information that will fill in the most basic gaps and enable visualization of Oracle's indexing capabilities. This chapter is intended to serve that purpose. While a considerable amount of material is published at the intermediate and advanced level, the beginner's information that is useful is usually scarce, yet highly desirable. Chapter 5 has additional index information on query tuning and the Access Advisor (using Cloud Control—or as some still call it, Oracle Enterprise Manager [OEM]), which suggests indexes that should be created. Chapters 8 and 9 cover specific query tuning and driving tables (which heavily influence which indexes are used). Index information related solely to Exadata or the Oracle Cloud is located in Chapter 11.

Oracle offers a variety of indexing options. Knowing which option to use in a given situation can be crucial to an application's performance. A wrong choice may cause performance to come to a grinding halt or cause processes to be terminated because of deadlock situations. By taking processes that previously took large amounts of resources and hours or even days to run and having them finish in minutes can make you an instant hero. This chapter will discuss each of the indexing options and point out the benefits and limitations of each. The introduction of the invisible index in Oracle Database 12*c*R2 adds a new way to turn off unused or potentially harmful indexes before you delete them (when you are sure that you don't need them). Tips covered in this chapter include the following:

- Basic index concepts
- Leveraging invisible indexes
- Multiple indexes on the same column(s)—12*c* only
- Finding which tables are indexed and which have concatenated indexes
- How concatenated indexes are used
- The Oracle ROWID
- Using functions and indexes

- How to avoid comparing unmatched data types, causing index suppression
- Cluster factors as an index strategy
- Using the INDEX_STATS view
- The binary height of an index
- About histograms
- Fast full scans
- How to use the index skip-scan feature
- Explanation of b-tree indexes
- When to use bitmap indexes
- When to use hashing indexes
- When to use the index-organized table
- When to use reverse key indexes
- When to use function-based indexes
- Local and global partitioned indexes
- Additional 12*c*R2 features on partitioned tables

Basic Index Concepts

When accessing data from tables, Oracle has two options: to read every row in the table (also referred to as a *full table scan*) or to access a single row at a time via ROWID. When accessing a small percentage of the rows of a large table, you would want to use an index. For example, if you only wanted to select 5 percent of the rows in a very large table, you would do fewer I/Os if you used the index to identify which blocks to read. If you don't use an index, you will read all of the blocks in the table (this changes with INMEMORY; see Chapter 4 for more information).

The degree to which indexes help performance depends partly on the selectivity of the data and the way in which the data is distributed among the table's blocks. If the data is very selective, there will be few rows in the table that match the indexed value (such as a passport number). Oracle will be able to query the index quickly for the ROWIDs that match the indexed value, and the small number of related table blocks can be quickly queried. If the data is not very selective (such as the country name), then many ROWIDs may be returned by the index, resulting in many separate blocks being queried from the table.

If the data is selective but the related rows are not stored near each other in the table, then the benefit of indexing is further reduced. If the data that matches the indexed value is scattered throughout the table's blocks, then you may have to select many individual blocks from the table to satisfy your query. In some cases, you will find that when the data is dispersed throughout the table's blocks you are better off bypassing the index and performing a full table scan instead (or doing an INMEMORY scan). When doing a full table scan, Oracle uses a multiblock read, enabling it to scan a table quickly. Index-based reads are single-block reads, so your goal when using an index should be to reduce the number of single blocks needed to resolve the query.

With some of the options available in Oracle, such as partitioning, parallel DML, parallel query operations, and larger I/O using the DB_FILE_MULTIBLOCK_READ_COUNT, the balance point between full table scans and index lookups is changing. Hardware is getting faster, disks cache more information in on-disk caching, and memory and flash continue to get cheaper. At the same time, Oracle has enhanced the indexing features to include skip-scan indexes and other internal operations that reduce the time needed to retrieve your data.

TIP
As you upgrade Oracle versions, be sure to test your application's queries to determine whether the execution paths for your queries still use the indexes that were used prior to the upgrade. See if the execution plan has changed and if it is better or worse.

Indexes will generally improve performance for queries. The SELECT statement, the WHERE clauses of UPDATE commands, and the WHERE clauses of DELETE statements (when few rows are accessed) can benefit from indexes. In general, adding indexes will decrease performance for INSERT statements (since INSERTs to both the table and the index must be performed). UPDATEs of indexed columns will be slower than if the columns were unindexed because the database has to manage the changes to both the table *and* the index. Additionally, DELETEs of large numbers of rows will be slowed by the presence of indexes on the table.

A DELETE statement deleting half of a table will also need to delete half of the rows for the index (very costly for this specific situation). In general, every index on a table slows INSERTs into the table by a factor of 3. Two indexes generally make the INSERT twice as slow as one does; however, a two-column single index (either concatenated index or two-part single index) is not too much worse than a one-column single index (a one-part single index). UPDATEs of the indexed columns and DELETEs may be similarly slowed. You need to balance the query performance benefits of indexes against their impact on your data manipulation performance.

To get a listing of all of the indexes on a table, query the DBA_INDEXES view. Also, note that you can retrieve the indexes for your schema by accessing USER_INDEXES. To see the indexes on all tables to which you have access, query ALL_INDEXES.

Shown here, for example, is a creation of indexes on the EMP table owned by SCOTT from the original Oracle demo tables provided as part of the product. You can use any of the old or new demo tables to test queries:

```
create index emp_id1 on emp(empno, ename, deptno);
create index emp_id2 on emp(sal);
```

When you issue those commands, the database creates two separate indexes on the EMP table. Each of the indexes contains the specified values from the EMP table along with the ROWID values for the rows that match them. If you want to find an EMP record that has a SAL value of 1000, the optimizer could use the EMP_ID2 index to find that value, find the related ROWID in the index, and then use that ROWID to find the right row(s) in the table.

The following USER_INDEXES (you could also look in DBA_INDEXES) query shows the new indexes on the EMP table:

```
select table_name, index_name
from   user_indexes
where  table_name = 'EMP' ;

TABLE NAME                     INDEX NAME
------------------------------ ------------------------------
EMP                            EMP_ID1
EMP                            EMP_ID2
```

The output shows the two indexes, but it does not show the columns in each index. To get the specific columns that are indexed for a given table for the current user, access the USER_IND_COLUMNS view. Also note that DBAs can retrieve the columns that are indexed for all schemas by accessing DBA_IND_COLUMNS, and you can see the indexed columns for all of the tables you can access via ALL_IND_COLUMNS. To get the specific columns that are indexed for a given table, access the USER_IND_COLUMNS view, shown next.

```
column index_name format a12
column column_name format a8
column table_name format a8
select table_name, index_name, column_name, column_position
from   user_ind_columns
order  by table_name, index_name, column_position;

TABLE_NA INDEX_NAME   COLUMN_N COLUMN_POSITION
-------- ------------ -------- ---------------
EMP      EMP_ID1      EMPNO                  1
EMP      EMP_ID1      ENAME                  2
EMP      EMP_ID1      DEPTNO                 3
EMP      EMP_ID2      SAL                    1
```

The EMP table has two indexes. The first, EMP_ID1, is a concatenated index that indexes the EMPNO, ENAME, and DEPTNO columns. The second, EMP_ID2, indexes the SAL column only. The COLUMN_POSITION displayed in the listing shows the order of columns in a concatenated index—in this case, EMPNO, then ENAME, then DEPTNO.

TIP

Query DBA_INDEXES and DBA_IND_COLUMNS to retrieve a list of the indexes on a given table. Use USER_INDEXES and USER_IND_COLUMNS to retrieve information for only your schema.

Invisible Indexes

Deciding which columns to index is hard. The primary key is automatically indexed, the foreign keys *should* also be indexed, but then what? Even more difficult is deciding which index to remove that might be a bad index. Every time a record is inserted, all of the indexes have to be updated. If the column of an index is updated, the index has to be updated. Deciding which index to drop without causing a slew of full table scans or Cartesian joins for subsequent user queries is difficult, especially when tuning third-party applications where the code cannot be changed. The solution just might be the invisible index! Oracle allows you to turn off the index (make it invisible), yet continue to maintain the index (during any DML operation—INSERT/UPDATE/DELETE) in case you need to turn it back on quickly. You can do this by making the index visible or invisible:

- ALTER INDEX *idx1* INVISIBLE;
- ALTER INDEX *idx1* VISIBLE;
- CREATE INDEX … INVISIBLE;

The following query shows the creation of a new invisible index on the DEPTNO column of the EMP table and subsequent query where the index is not seen:

```
create index dept_rich_inv_idx on dept_rich(deptno) invisible;
Index created.

select count(*)
from   dept_rich
where  deptno = 30; (doesn't see the index)

COUNT(*)
--------
     512

Execution Plan
----------------------------------------------------------
Plan hash value: 3024595593

-------------------------------------------------------------------------------
| Id  | Operation           | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT    |           |     1 |     2 |     4   (0)| 00:00:01 |
|   1 |  SORT AGGREGATE     |           |     1 |     2 |            |          |
|*  2 |   TABLE ACCESS FULL| DEPT_RICH |   512 |  1024 |     4   (0)| 00:00:01 |
```

I can still force the use of the index if I use a hint. This only worked in the earliest versions of 11*g* with an INDEX hint; in 12*c*R2, with a USE_INVISIBLE_INDEXES hint—or by setting the initialization parameter OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE (see Appendix A):

```
select /*+ USE_INVISIBLE_INDEXES */ count(*)
from   dept_rich
where  deptno = 30;    (forces the index with hint)

COUNT(*)
--------
     512

Execution Plan
----------------------------------------------------------
Plan hash value: 3699452051
--------------------------------------------------------------------------------
| Id  | Operation         | Name              | Rows  | Bytes | Cost  (%CPU)|      Time|
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT  |                   |     1 |      2 |  1  (0)|      00:00:01|
|   1 |  SORT AGGREGATE   |                   |     1 |      2 |        |              |
| * 2 |   INDEX RANGE SCAN| DEPT_RICH_INV_IDX|   512 |   1024 |  1  (0)|      00:00:01|
```

If I make the index visible, I no longer need to use the hint:

```
alter index dept_rich_inv_idx visible;
Index altered.

select count(*)
from   dept_rich
where  deptno = 30;   (it does see the index)

COUNT(*)
--------
     512

Execution Plan

Plan hash value: 3699452051
--------------------------------------------------------------------------------
| Id    Operation          | Name               | Rows  | Bytes | Cost  (%CPU)| Time|
--------------------------------------------------------------------------------
|    0  SELECT STATEMENT   |                    |     1 |      2 |  1    (0)|00:00:01 |
|    1   SORT AGGREGATE    |                    |     1 |      2 |           |         |
|*   2    INDEX RANGE SCAN| DEPT_RICH_INV_IDX  |   512 |   1024 |  1    (0)|00:00:01 |
```

I can also use the NO_INDEX hint to turn off an index (before making it invisible) to see if another index (or no other index) will be used, other than the one that I intend to make invisible. In other words, use any index *except* the one listed in the NO_INDEX hint. Here is an example:

```
select /*+ no_index(dept_rich dept_rich_inv_idx) */ count(*)
from   dept_rich
where  deptno = 30; (forces not using the index with hint)

COUNT(*)
----------
     512

Execution Plan
----------------------------------------------------------
Plan hash value: 3024595593

--------------------------------------------------------------------------------
| Id  | Operation            | Name      | Rows  | Bytes | Cost  (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT     |           |     1 |     2 |     4    (0)| 00:00:01 |
|   1 |  SORT AGGREGATE      |           |     1 |     2 |             |          |
|*  2 |   TABLE ACCESS FULL  | DEPT_RICH |   512 |  1024 |     4    (0)| 0:00:01  |
```

I can make the index invisible again at any time:

```
alter index dept_rich_inv_idx invisible;
Index altered.
```

I can check visibility by querying USER_INDEXES or DBA_INDEXES:

```
select index_name, visibility
from   dba_indexes  (or go to USER_INDEXES)
where  index_name = 'DEPT_RICH_INV_IDX';

INDEX_NAME                              VISIBILITY
--------------------------------    ------------------
DEPT RICH INV IDX                       INVISIBLE
```

TIP
By using invisible indexes, you can "turn off" indexes temporarily (make them invisible) to check how queries perform without them. Because invisible indexes continue to be maintained while

invisible, turning them back on (making them visible again), if needed, is easy.

Multiple Types of Indexes on the Same Column(s)

There can be multiple types of indexes *on the same column(s)*, but only one index may be set to visible at the same time, unless the other index is a function-based index (since a function-based index isn't really on the same column; it's on the function of the column). This feature is great for variable workloads on the same table. It is great to use different types of indexes for batch, query, or data warehousing at different times of the day or night. There are some restrictions: For a given column(s), you cannot create a B-tree and B-tree cluster index. Also, you cannot create a B-tree and an index-organized table (IOT). All indexes are maintained during DML operation (even when set to invisible). Keep in mind, DML operations may run slow if too many indexes are created.

The following is a basic SELECT to DEPT table that we will use for the examples in this section:

```
select *
from   dept;

    DEPTNO DNAME          LOC
---------- -------------- ----------
        10 ACCOUNTING     NEW YORK
        20 RESEARCH       DALLAS
        30 SALES          CHICAGO
        40 OPERATIONS     BOSTON
```

First, create a unique index into which duplicates may not be inserted:

```
create unique index dept_unique1 on dept(deptno);
Index created.

insert into dept(deptno) values (10);
insert into dept(deptno) values (10)
*
ERROR at line 1:
ORA-00001: unique constraint (SYS.DEPT UNIQUE1) violated
```

Even if indexes are set to invisible, duplicates still cannot be inserted:

```
alter index dept_unique1 invisible;
Index altered.

insert into dept(deptno) values(10);
insert into dept(deptno) values(10)
*
ERROR at line 1:
ORA-00001: unique constraint (SYS.DEPT UNIQUE1) violated
```

The following example checks to see that the indexes are set to invisible:

```
select a.table_name, a.index_name,
       b.column_name, a.uniqueness, a.visibility
from   user_indexes a, user_ind_columns b
where  a.index_name = b.index_name
and    a.table_name = 'DEPT';

TABLE_NAME INDEX_NAME      COLUMN_NAME  UNIQUENESS   VISIBILITY
---------- --------------- ------------ ------------ ----------
DEPT       DEPT_UNIQUE1    DEPTNO       UNIQUE       INVISIBLE
```

To make indexes visible again:

```
alter index dept unique1 visible;
Index altered.

select a.table_name, a.index_name,
       b.column name, a.uniqueness, a.visibility
from   user_indexes a, user_ind_columns b
where  a.index_name = b.index_name
and    a.table_name = 'DEPT';

TABLE_NAME INDEX_NAME      COLUMN_NAME  UNIQUENESS   VISIBILITY
---------- --------------- ------------ ------------ -----------
DEPT       DEPT UNIQUE1    DEPTNO       UNIQUE       VISIBLE
```

We can't create another index on the same column:

```
create index dept_normal on dept(deptno);
create index dept_normal on dept(deptno)
                                 *
ERROR at line 1:
ORA-01408: such column list already indexed
```

But, we can if we make the *first* index invisible and then create the *second* index:

```
alter index dept_unique1 invisible;
Index altered.

create index dept_normal on dept(deptno);
Index created.
```

Now if we check our index views, we find *two* indexes are on the *exact* same column:

```
select a.table_name, a.index_name,
       b.column_name, a.uniqueness, a.visibility
from   user_indexes a, user_ind_columns b
where  a.index_name = b.index_name
and    a.table_name = 'DEPT';
TABLE_NAME INDEX_NAME      COLUMN_NAME  UNIQUENESS   VISIBILITY
---------- --------------- ------------ ------------ ----------
DEPT       DEPT_UNIQUE1    DEPTNO       UNIQUE       INVISIBLE
DEPT       DEPT_NORMAL     DEPTNO       NONUNIQUE    VISIBLE
```

If we try to make both indexes visible, it will result in an error, as shown next. Only *one* index may be visible at a time (except function-based indexes).

```
alter index dept_unique1 visible;
*
ERROR at line 1:
ORA-14147: There is an existing VISIBLE index defined on the same set of columns.
```

Note that despite a unique index (that is invisible), only the visible index is used:

```
select  deptno
from    dept
where   deptno 10;

DEPTNO
------
    10

---------------------------------------------------------------------------------
| Id  | Operation         | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
---------------------------------------------------------------------------------
|   0 | SELECT STATEMENT  |             |     1 |    13 |     1   (0)| 00:00:01 |
|*  1 |  INDEX RANGE SCAN| DEPT_NORMAL |     1 |    13 |     1   (0)| 00:00:01 |
---------------------------------------------------------------------------------

alter index dept_normal invisible;
Index altered.
```

To add a third index, we must make the first two indexes invisible:

```
create index dept_reverse on dept(deptno) reverse;
Index created.

select a.table_name, a.index_name,
       b.column_name, a.uniqueness, a.visibility
from   user_indexes a, user_ind_columns b
where  a.index_name = b.index_name
and    a.table_name = 'DEPT';

TABLE_NAME INDEX_NAME      COLUMN_NAME  UNIQUENESS   VISIBILITY
---------- --------------- ------------ ------------ ----------
DEPT       DEPT_UNIQUE1    DEPTNO       UNIQUE       INVISIBLE
DEPT       DEPT_REVERSE    DEPTNO       NONUNIQUE    VISIBLE
DEPT       DEPT_NORMAL     DEPTNO       NONUNIQUE    INVISIBLE
```

It is possible to create two visible indexes on a column at once, if one of those indexes is a function-based index. Let's make the third index invisible and add a fourth (and fifth):

```
alter index dept_reverse invisible;
Index altered.

create bitmap index dept_bitmap on dept(deptno);
Index created.

create index dept_fb on dept(substr(deptno,1,1));
Index created.
```

Now when we check the index views, we see that we have five indexes on the same column, with two (one being a function-based index) indexes being visible:

```
select a.table_name, a.index_name,
       b.column_name, a.uniqueness, a.visibility
from   user_indexes a, user_ind_columns b
where  a.index_name = b.index_name
and    a.table_name = 'DEPT';

TABLE_NAME INDEX_NAME      COLUMN_NAME  UNIQUENESS   VISIBILITY
---------- --------------- ------------ ------------ ----------
DEPT       DEPT_UNIQUE1    DEPTNO       UNIQUE       INVISIBLE
DEPT       DEPT_REVERSE    DEPTNO       NONUNIQUE    INVISIBLE
DEPT       DEPT_NORMAL     DEPTNO       NONUNIQUE    INVISIBLE
DEPT       DEPT_BITMAP     DEPTNO       NONUNIQUE    VISIBLE
DEPT       DEPT_FB         SYS_NC00004$  NONUNIQUE    VISIBLE
(Index types: NORMAL, NORMAL/REV, UNIQUE, BITMAP, FUNCTION-BASED NORMAL)
```

TIP
By using invisible indexes, in 12c, you can now create multiple indexes on the same column or columns. This can be helpful with variable workloads. Perhaps use a b-tree index for the daily workload and use a reverse key index at night. But, keep in mind that there is internal index maintenance and also costs for INSERT, DELETE and when you update the indexed column on all of these indexes.

Concatenated Indexes

When a single index has multiple columns that are indexed, it is called a *concatenated* or *composite* index. While Oracle's introduction of skip-scan index access has increased the optimizer's options when using concatenated indexes, you should be careful when selecting the order of the columns in the index. In general, the leading column of the index should be the one most likely to be used in WHERE clauses and also the most selective column of the set.

Prior to the introduction of skip-scan functionality, queries could only use the index if the leading column of the index was in the WHERE clause. Consider the example in the following listing where the EMP table has a concatenated index (three parts) on EMPNO, ENAME, and DEPTNO. Note that EMPNO is the first part; ENAME is the second part; and DEPTNO is the third part. If you are not making use of the skip-scan functionality, Oracle will generally *not* use this index unless your WHERE clause specifies a value for the leading column (EMPNO).

```
select job, empno
from   emp
where  ename = 'RICH';
```

Since ENAME is not the leading column of the index, the optimizer may elect not to use the index. With the skip-scan functionality the optimizer may choose to use the index, even though an EMPNO value is not specified in the WHERE clause. Instead, the optimizer could choose to perform a fast full scan of the index or a full scan of the table.

The same holds true if the third column of the index is used in the WHERE clause:

```
select job, empno
from   emp
where  deptno = 30;
```

In this listing, the WHERE clause specifies a value for the third column in the index. The optimizer may select to perform an index skip-scan access, an index fast full scan, or a full table scan. By creating the index, you have given the database more choices to consider when executing the query, hopefully improving overall performance. Note that the user's code does not change; the optimizer is aware of the index and bases its decisions on the anticipated cost of each alternative.

In the following example, a part of the index is used. The leading column, EMPNO, is used as a limiting condition in the WHERE clause so that Oracle can use the first *part* of the index (if the second part, ENAME, was in the WHERE clause in addition to EMPNO, it would use two parts; if all three parts were there, it would use the whole index—the best and most limiting solution). In this example, we just use the first part of the index by a condition on EMPNO:

```
select job, empno
from   emp
where  empno = 'RICH';
```

The two most common types of index scans are unique scans and range scans. In a *unique* scan, the database knows that the index contains a list of unique values. In a *range* scan, the database returns multiple values from the index according to the query criteria. To create a unique index, use the CREATE UNIQUE INDEX command when creating the index.

When you create a primary key or a UNIQUE constraint, Oracle automatically creates a unique index based on the columns you specify (unless the constraint is created with the DISABLE clause). If you create a multicolumn primary key, Oracle creates a concatenated index with the columns in the same order in which you specified them when creating the primary key.

Creating range scan indexes provides Oracle with the ability to access a single row of data by supplying the ROWID of the individual row as it is returned for a given query. The ROWID is a pointer directly to the physical location of the individual row.

TIP
Avoid hard-coding Oracle's ROWID into specific code. The ROWID structure in the past has changed from version to version and will probably change again in future releases. I recommend never hard-coding a ROWID.

Suppressing Indexes

Unintentionally suppressing indexes is one of the most common mistakes made by an inexperienced developer. SQL contains many traps that cause indexes not to be used. Some of the most common problems are discussed in the following sections.

The Oracle optimizer works behind the scenes to try to choose and exploit the most effective methods possible for retrieving your data. For example, there are multiple cases in which you don't need to specify a WHERE clause for Oracle to use an index. If you query the MIN or MAX value of an indexed column, Oracle retrieves that value from the index rather than from the table. Similarly, if you perform a COUNT function on an indexed column, Oracle can count the index instead of the column. In the following sections, you will see situations in which the logic of the WHERE clause prevents Oracle from using an index.

Using the NOT EQUAL Operators: <>, !=

Indexes can only be used to find data that exists within a table. Whenever the NOT EQUAL operators are used in the WHERE clause, indexes on the columns being referenced cannot be used. Consider the following query on the CUSTOMERS table, which has an index on the CUST_RATING column. The following statement would result in a full table scan (since most records would *usually* be retrieved) even though the CUST_RATING column has an index:

```
select  cust_id, cust_name
from    customers
where   cust_rating <>'AAA';
```

When you analyze your tables, Oracle collects statistics about the distribution of data within the table. Using that analysis, the cost-based optimizer may decide to use the index for some values in your WHERE clause but not for other values. During application development and testing, you should use a representative set of rows so you can simulate the actual distribution of data values in the production environment.

TIP
You can create your indexes and analyze them in a single step by using the COMPUTE STATISTICS clause of the CREATE INDEX command, but, as of 10g, Oracle always computes statistics on all index create/rebuild operations when the index is not empty. You can also import statistics from a production database to test out execution paths (refer to the Oracle 12cR2 Database Performance Tuning Guide). Oracle 12cR2 also has a V$INDEX_USAGE_INFO view for additional information.

Using IS NULL or IS NOT NULL

When you use IS NULL or IS NOT NULL in your WHERE clauses, index usage is suppressed because the value of NULL is undefined. There is no value in the database that will equal a NULL value; not even NULL equals a NULL.

NULL values pose several difficulties for SQL statements. Indexed columns that have rows containing a NULL value do not have an entry in the index (except for bitmapped indexes—which is why bitmap indexes are usually fast for NULL searches). Under normal circumstances, the following statement would cause a full table scan to be performed, even if the SAL column is indexed:

```
select  empno, ename, deptno
from    emp
where   sal is null;
```

To disallow NULL values for the columns, use NOT NULL when creating or altering the table. Note that if the table already contains data, you can only set a column to NOT NULL if it has a non-NULL value for every row or if you use the DEFAULT clause of the ALTER TABLE command. The following listing shows the modification of the EMP table's SAL column to disallow NULL values:

```
alter table emp modify
(sal not null);
```

Note that an error will be returned if insertion of a NULL value is attempted for the SAL column.

TIP
Creating a table specifying NOT NULL for a column causes NULL values to be disallowed and eliminates the performance problems associated with querying NULL values.

The following table creation statement provides a default value for the DEPTNO column. When a value for the column is not specified during INSERTs, the default value is used. If a default value is specified and you *do* want a NULL value, then you need to insert a NULL into the column.

```
create table employee
(empl_id number(8) not null, first_name varchar2(20) not null,
 last_name varchar2(20) not null, deptno number(4) default 10);

insert into employee(empl_id, first_name, last_name)
values (8100, 'REGINA', 'NIEMIEC');
1 row created.

select *
from   employee;

  EMPL_ID FIRST_NAME           LAST_NAME                DEPTNO
---------- -------------------- -------------------- ----------
     8100 REGINA               NIEMIEC                      10

insert into employee
values (8200, 'RICH', 'NIEMIEC', NULL);
1 row created.

select *
from   employee;

  EMPL_ID FIRST_NAME           LAST_NAME                DEPTNO
---------- -------------------- -------------------- ----------
     8100 REGINA               NIEMIEC                      10
     8200 RICH                 NIEMIEC
```

TIP
NULL values often cause indexes to be suppressed. Create a table specifying NOT NULL and DEFAULT for an unspecified column to help avoid a potential performance issue.

Using LIKE

LIKE, in some cases, uses an index, while in others, it does not. The most common uses of LIKE are LIKE '%*somevalue*%' or LIKE '*somevalue*%' (where the % is only at the end of the search string). Only one of these cases uses the index—the case where the value is first, LIKE '*somevalue*%'.

Let's examine this using a set of examples. First, create an index on the SCOTT.EMP table for the ENAME column so you can use an index when looking up employee names. This allows you to see when the index is used with a LIKE and when it is not.

```
SQL> create index emp_ename_nu on emp (ename);
Index created.
```

Now let's examine what happens when using LIKE with '%*somevalue*%':

```
SQL> set autotrace traceonly
SQL> select empno, ename, hiredate
 2  from   scott.emp
 3  where  ename like '%BLAKE%';

Execution Plan
----------------------------------------------------------
Plan hash value: 3956160932
--------------------------------------------------------------------------
| Id  | Operation         | Name | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------
|   0 | SELECT STATEMENT  |      |     1 |    18 |     3   (0)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| EMP  |     1 |    18 |     3   (0)| 00:00:01 |
```

Now let's put the value first, before the '%':

```
SQL> set autotrace traceonly
SQL> select empno, ename, hiredate
 2  from   scott.emp
 3  where  ename like 'BLAKE%' ;

Execution Plan
------------------------------------------------------------
Plan hash value: 3445075938
--------------------------------------------------------------------------------------------
| Id  | Operation                   | Name         | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT            |              |     1 |    18 |     2   (0)|00:00:01  |
|   1 |  TABLE ACCESS BY INDEX ROWID| EMP          |     1 |    18 |     2   (0)|00:00:01  |
|*  2 |   INDEX RANGE SCAN          | EMP_ENAME_NU |     1 |       |     1   (0)|00:00:01  |
--------------------------------------------------------------------------------------------
```

Notice that when the '%' appears first, the index is not used, but when you put the value first, Oracle is able to utilize the index.

Using Functions

Unless you are using function-based indexes, applying functions on indexed columns in the WHERE clause of a SQL statement causes the optimizer to bypass indexes. Some of the most common functions are TRUNC, SUBSTR, TO_DATE, TO_CHAR, and INSTR. All of these functions alter the value of the column. Therefore, the indexes on the columns being referenced are not used. The following statement causes a full table scan to be performed, even if there is an index on the HIRE_DATE column (as long as it isn't a function-based index):

```
select empno, ename, deptno
from   emp
where  trunc(hiredate) = '01-MAY-01';
```

Changing the statement to the following would allow for an index lookup:

```
select empno, ename, deptno
from   emp
where  hiredate >'01-MAY-01'
and    hiredate < (TO DATE('01-MAY-01') + 0.99999);
```

TIP
By altering the values being compared to the column, and not the columns themselves, the indexes become available. Use this to eliminate full table scans.

For further details on function-based indexes, see the "Function-Based Indexes" section later in this chapter.

Comparing Mismatched Data Types

One of the more difficult performance issues to resolve is caused by comparing differing data types. Oracle does not complain about the types being incompatible—quite the opposite. For example, Oracle implicitly converts the data in the VARCHAR2 column to match the numeric data type that it is being compared to. Consider the following example where ACCOUNT_NUMBER is a VARCHAR2.

If the ACCOUNT_NUMBER column uses a VARCHAR2 data type, the following statement may cause a full table scan to be performed, even if the ACCOUNT_NUMBER column is indexed:

```
select bank_name, address, city, state, zip
from   banks
where  account_number = 990354;
```

Oracle internally changes the WHERE clause to be

```
to_number(account_number)=990354
```

which suppresses the index. An EXPLAIN PLAN of this query only shows that the table was accessed using a “FULL SCAN” (usually to the coder’s bewilderment). To some DBAs and developers, this appears to be a rare situation, but in many systems, numeric values are zero-padded and specified as VARCHAR2. Rewrite the preceding statement as follows to use the index on the account number by correctly including the single quote marks for the field:

```
select bank_name, address, city, state, zip
from   banks
where  account_number = '000990354';
```

Alternatively, the ACCOUNT_NUMBER column could be defined to use the NUMBER data type, providing the leading zeros are not critical information for the column.

TIP
Comparing mismatched data types can cause Oracle to suppress an index internally. Even an EXPLAIN PLAN on the query will not help you understand why a full table scan is being performed. Only knowing your data types can help you solve this problem.

Selectivity

Oracle offers several methods to determine the benefit of using an index. Which method you should choose depends upon both the query and the data. First, determine the number of unique or distinct keys in the index. You can determine the number of distinct values by analyzing the table or the index. You can then query the DISTINCT_KEYS column of the USER_INDEXES view to examine the results of the analysis. By comparing the number of distinct keys to the number of rows in the table (as shown in the NUM_ROWS column of USER_INDEXES), you can determine the index’s selectivity. The greater the selectivity, the better an index will be for returning small numbers of rows.

TIP

An index's selectivity is what helps the cost-based optimizer determine an execution path. The more selective the index is, the fewer the number of rows that are returned, on average, for each distinct value. For concatenated indexes, the additional columns added to the index do not improve the selectivity greatly, and the cost of the additional columns may outweigh the gain.

The Clustering Factor

The *clustering factor* is a measure of the ordered-ness of an index in comparison to the table that it is based on. It is used to check the cost of a table lookup following an index access (multiplying the clustering factor by the index's selectivity gives you the cost of the operation). The clustering factor records the number of blocks that will be read when scanning the index. If the index being used has a *large* clustering factor, then more table data blocks have to be visited to get the rows in each index block (because adjacent rows are in different blocks). If the clustering factor is close to the number of *blocks* in the table, then the index is well ordered, but if the clustering factor is close to the number of *rows* in the table, then the index is *not* well ordered. The clustering factor is computed by the following (explained briefly):

1. The index is scanned in order.
2. The block portion of the ROWID pointed at by the current indexed value is compared to the previous indexed value (comparing adjacent rows in the index).
3. If the ROWIDs point to different TABLE blocks, the clustering factor is incremented (this is done for the entire index).

The CLUSTERING_FACTOR column in the USER_INDEXES view gives an indication as to how organized the data is compared to the indexed columns. If the value of the CLUSTERING_FACTOR column value is close to the number of leaf blocks in the index, the data is well ordered in the table. If the value is *not* close to the number of leaf blocks in the index, then the data in the table is not well ordered. The *leaf blocks* of an index store the indexed values as well as the ROWIDs to which they point.

For example, say the CUSTOMER_ID for the CUSTOMERS table is generated from a sequence generator, and the CUSTOMER_ID is the primary key on the table. The index on CUSTOMER_ID would have a clustering factor very close to the number of leaf blocks (well ordered). As the customers are added to the database, they are stored sequentially in the table in the same way the sequence numbers are issued from the sequence generator (well ordered). An index on the CUSTOMER_NAME column would have a very high clustering factor, however, because the arrangement of the customer names is random throughout the table.

The clustering factor can impact SQL statements that perform range scans. With a low clustering factor (relative to the number of leaf blocks), the number of blocks needed to satisfy the query is reduced. This increases the possibility that the data blocks are already in memory. A high clustering factor relative to the number of leaf blocks may increase the number of data blocks required to satisfy a range query based on the indexed column.

TIP

The clustering of data within the table can be used to improve the performance of statements that perform range scan–type operations. By determining how the column is being used in the statements, indexing these column(s) may provide a great benefit.

The Binary Height

The binary height of an index plays a major role in the amount of I/O that needs to be performed to return the ROWID to the user process. Each level in the binary height adds an extra block that needs to be read, and because the blocks are not being read sequentially, they each require a separate I/O operation. In Figure 2-1, an index with a binary height of three returning one row to the user would require four blocks to be read: three from the index and one from the table. As the binary height of an index increases, so does the amount of I/O required to retrieve the data.

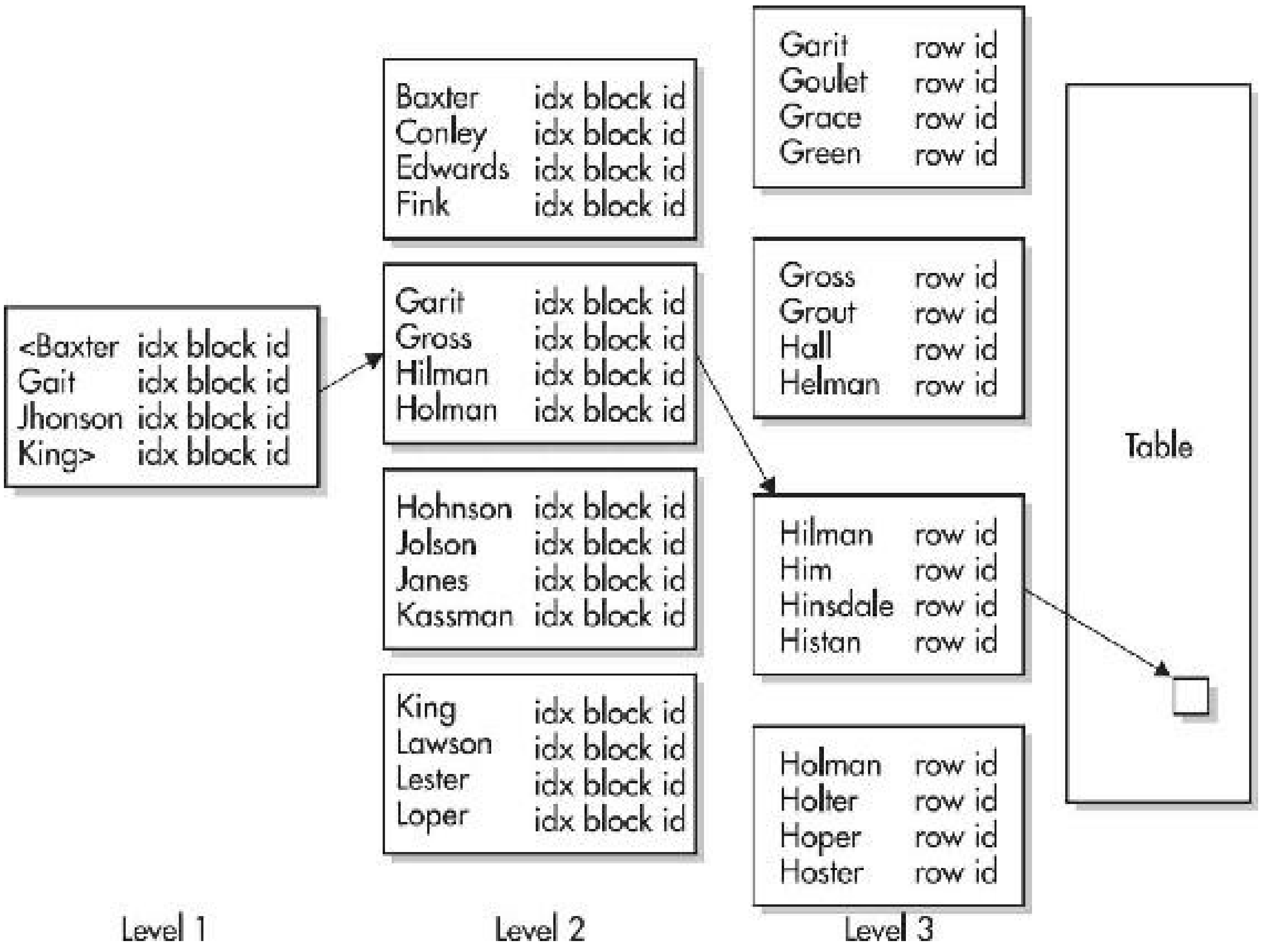


FIGURE 2-1. *Index with binary height or BLEVEL = 3 (Level 3 is where the leaf blocks reside.)*

After analyzing an index, you can query the BLEVEL column of DBA_INDEXES to see its binary height:

```
EXECUTE DBMS_STATS.GATHER_INDEX_STATS ('SCOTT','EMP_ID1');
PL/SQL procedure successfully completed.

select blevel, index_name
from   dba_indexes
where  index_name = 'EMP_ID1';
   BLEVEL INDEX_NAME

---------- ------------------------------
        0 EMP_ID1
```

TIP
Analyzing the index or the table will provide the binary height of the index. Use the BLEVEL column in the USER_INDEXES view to check the binary height of the indexes.

The binary height increases mainly because of the number of non-NULL values for the indexed column in the table and the narrowness of the range of values in the indexed columns. Having a large number of deleted rows in the index can also increase the height. Rebuilding the index may help to decrease the height. While these steps reduce the number of I/Os performed against the index, the performance benefits may be small. If the number of deleted rows within an index approaches 20–25 percent, then rebuild the indexes to help reduce the binary height and the amount of empty space that is being read during an I/O.

TIP
In general, the larger the database block size, the smaller the binary height of the index. Each additional level in binary height (BLEVEL) adds additional performance costs during DML operations.

Additional Details Concerning BLEVEL and Index Height

The b-tree level (BLEVEL) is the depth of the index from its *root block* to its *leaf blocks*. A depth of 0 indicates that the root block and leaf block are the same. All indexes start out with a single leaf node (block), which represents a b-tree level of 0. As rows are added to the index, Oracle puts the data into the block/leaf node. Once the initial block fills as rows are inserted, two new blocks are created. Oracle handles this in two ways, typically known as a *90-10 index split* or a *50-50 index split*. Each type of split (only one or the other is executed) depends on the value being inserted:

- If the new value is greater than any values already in the index, then Oracle executes a 90-10 split by copying the values of the block into one of the new blocks and placing the new value in the other block.
- If the new value being inserted is not the maximum indexed value, then Oracle splits the block 50-50. It places the lower half of the indexed values in one of the new blocks and the higher half of the indexed values into the other new block.

The existing block, which was originally full, is updated to contain only pointers to the new leaf nodes and becomes a branch, specifically the root branch of the index. The resulting index now has a branch level of 1. As rows continue to be inserted into the index, when a leaf node fills, Oracle creates a new leaf block. If the value being inserted is greater than any value currently in the leaf node block, then Oracle places the new value into the new block. If the value is not MAX value, then Oracle splits the values of the block in half (50-50) by value, keeping the lower values in the current block and placing the higher values in the new block. Then the branch block for these leaf nodes is updated with the pointer for the new block and existing block. This continues until the branch node/block fills. When the branch node fills, the same block-split operation is performed. A new branch block is added and half the block is copied to the new block and the other half remains in the existing branch block. This does not increase either the height or BLEVEL of the index; it simply provides a new branch for a query to take when traversing the index. Only when a root branch block fills and splits does the height of the index increase.

NOTE
The only time two new blocks are created for an index is when the root branch block splits. The content in the current root block is split between the two new branch blocks, which form the top level of a higher index tree. The root block does not change its block address, and by adding two blocks when the split occurs at the root, the index tree is always balanced.

Effects on Index from UPDATE Operations

The index is only affected by an UPDATE if the columns in the table that make up the index are updated. Therefore, in many cases, UPDATE operations do not affect an index at all. When the table columns that make up the index are updated, the operation within the index is a DELETE and INSERT. The old value is marked as deleted, and a new value for the entry is inserted. Therefore, no true "update" is performed within the index, in the way you would typically think of an update being performed. Index entries are also cleaned out by Oracle's delayed block cleanout feature. Only after the index entry is deleted and the block cleaned can the space in the index block be reused by new entries.

Effects on Index from DELETE Operations

DELETE operations for an index do not really remove the entry from the index to create empty space. When a DELETE operation occurs on a row in the table, the corresponding index entry is marked as deleted but remains in the index until it is cleaned out. The most common way to clean out an index entry is during an INSERT operation on that block. Index entries are also cleaned out by Oracle's delayed block cleanout feature (this happens on a subsequent query, which could be a SELECT statement). After the index entry is deleted and the block cleaned, the space in the index block can be reused by new entries.

Effects on Index from UPDATE and DELETE Operations

There has been much debate and many myths about indexes regarding the effects DELETEs and UPDATEs have on them. I have explained how basic DELETEs and UPDATEs work in Oracle indexes, so let's examine the true effect in detail. In DELETE operations, deletes are done by marking the index entry as deleted in the index, meaning that DELETE operations leave behind data in the leaf blocks that needs to be cleaned up. An INSERT operation in a leaf block, with rows marked for deletion, forces the cleanout of these rows, allowing the space to be "reused" by further inserts in that leaf block. Are there circumstances when that insert will not occur? Yes, but the index block is eventually cleaned out by the delayed block cleanout process.

UPDATE operations, along with DELETEs/INSERTs within the same transaction, tend to increase the size of an index greatly, but only if you perform these operations in large numbers within the same transaction (which is not recommended anyway). DELETEs in and of themselves do not cause higher index heights or BLEVELs, but are merely a symptom of the larger issue of reusing deleted row areas. This means that a high number of DELETE operations or UPDATE operations, or a large number of deleted/updated entries in a single transaction, can potentially cause the size, height, and BLEVEL to increase (but Oracle does not recommend you perform lots and lots of DML operations within the same transaction). The solution for this is to break up your transactions with commits, effectively creating multiple transactions for larger numbers of DELETE+INSERT operations. This helps reuse space and does not cause the index to grow artificially larger than it needs to be. This also explains why large DELETE operations that contain large INSERTs within the same transaction usually cause index growth.

In Oracle's useful Ask Tom blog (https://asktom.oracle.com), Tom Kyte puts it this way:

Well, the fact is that indexes, like people, have a certain "weight" they like to be at. Some of us are chubby—some skinny—some tall—some short. Sure, we can go on a diet—but we tend to gravitate BACK to the weight we were. The same is true for indexes—what happened to this person is their index wanted to be wide and fat and EVERY MONTH they rebuilt it (put it on a diet). It would spend the first half of the month then getting fat again and generating gobs of redo due to the block splits it was undergoing to get there.

The moral of the story is to use locally managed tablespaces to avoid fragmentation and to rebuild indexes rarely (build them right the first time and only rebuild when performance degrades versus on a regular basis).

Effects on BLOCKSIZE

As just covered, the height and branch level of an index only increase when a block split occurs and causes all the branch blocks up to the root block to also be split. The number of block splits, or more specifically, branch block splits, can be minimized by using larger block sizes for indexes. This is a reason why some experts believe that indexes should be created in larger block size tablespaces. If each block can hold more data, the need to split would occur far less frequently. Therefore, the overall number of branches and leafs could be reduced. This greatly depends on the size of the data for the indexed values—old block size versus new block size. Be careful when measuring the impact of a higher block size tablespace on an index. Moving an index to a larger block size tablespace involves rebuilding the index, which removes all entries marked for deletion and compresses space within the index, reclaiming the space of not only entries marked for deletion, but also entries deleted where space was not reclaimed or reused. Therefore, the full impact of a larger block size may not be as expected or as impressive when you consider what is truly going to occur.

Using Histograms

Histograms record the distribution of data when you analyze a table or index. With this information in hand, the cost-based optimizer can decide to use an index for conditions it knows will return a small number of rows and bypass the index when the condition will return many rows based on the limiting condition. The use of histograms is not limited to indexes. Any column of a table can have a histogram built on it.

The main reason for generating histograms is to help the optimizer plan properly if the data in a table is heavily skewed. For example, if one or two values make up a large percentage of a table, the related indexes may not help to reduce the number of I/Os required to satisfy the query. Creating a histogram lets the cost-based optimizer know when using the index is appropriate, or when 80 percent of the table is going to be returned because of the value in the WHERE clause.

When creating histograms, specify a size. This size relates to the number of buckets for the histogram. Each bucket will contain information about the value of the column(s) and the number of rows.

```
EXECUTE DBMS_STATS.GATHER_TABLE_STATS
('scott','company', METHOD_OPT =>'FOR COLUMNS SIZE 10 company_code');
PL/SQL procedure successfully completed.
```

The preceding query creates a ten-bucket histogram on the COMPANY table, as shown in Figure 2-2. The values for the COMPANY_CODE column are divided into the ten buckets as displayed in the figure. This example shows a large number (80 percent) of the COMPANY_CODE is equal to 1430. As is also shown in the figure, most of the width-balanced buckets contain only 3 rows; a single bucket contains 73 rows. In the height-balanced version of this distribution, each bucket has the same number of rows and most of the bucket endpoints are 1430, reflecting the skewed distribution of the data.

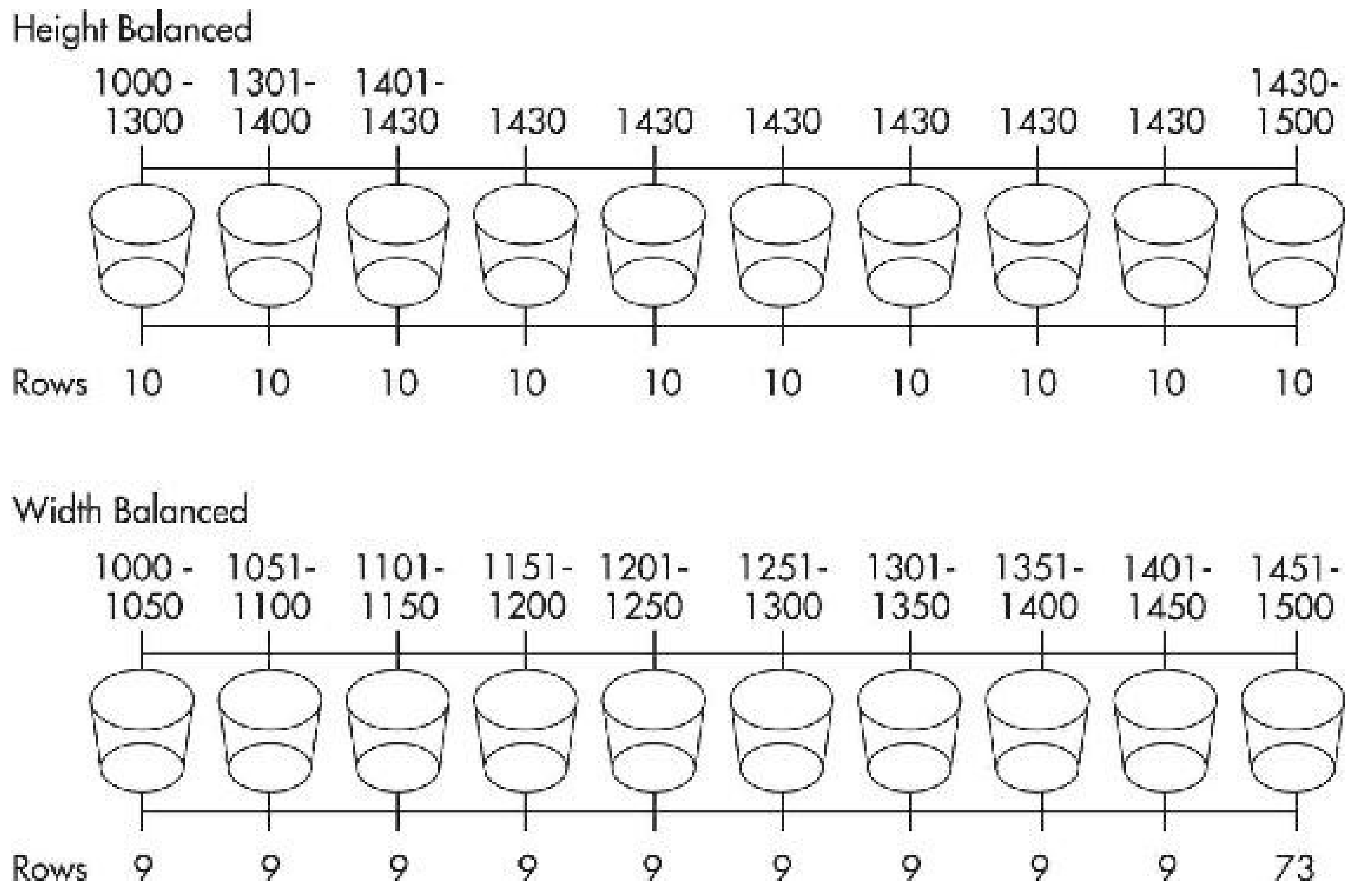


FIGURE 2-2. *A histogram is built on a COMPANY_CODE field with a size of 10 (buckets).*

Oracle's histograms are height-balanced as opposed to width-balanced. Consequently, all of the buckets in the histogram contain the same number of rows. The starting and ending points for a bucket are determined by the number of rows containing those values. The width-balanced histogram specifies the range values for each bucket and then counts the number of rows within that range, not an ideal option.

TIP

If the data in a table is skewed, histograms will provide the cost-based optimizer with a balanced picture of the distribution (by balancing it into buckets). Using the histograms on columns that are not skewed will not provide an increase in performance.

TIP
By default, Oracle creates 254 buckets in a histogram. You can specify SIZE values ranging from 1 to 254.

Fast Full Scans

During a fast full scan of an index, Oracle reads all of the leaf blocks in a b-tree index. The index is being read sequentially, so multiple blocks can be read at once. The DB_FILE_MULTIBLOCK_READ_COUNT parameter in the initialization file controls the number of blocks that can be read simultaneously. The fast full scan usually requires fewer physical I/Os than a full table scan, allowing the query to be resolved faster.

The fast full scan can be used if all of the columns in the query for the table are in the index with the leading edge of the index not part of the WHERE condition (you may need to specify the INDEX_FFS hint as detailed in Chapter 7). In the following example, the EMP table is used. As shown earlier in this chapter, it has a concatenated index on the columns EMPNO, ENAME, and DEPTNO.

```
select  empno, ename, deptno
from    emp
where   deptno = 30;
```

Because all of the columns in the SQL statement are in the index, a fast full scan is available. Index fast full scans are commonly performed during joins in which only the indexed join key columns are queried. As an alternative, Oracle may perform a skip-scan access of the index; the optimizer should consider the histogram for the DEPTNO column (if one is available) and decide which of the available access paths yields the lowest possible performance cost.

TIP
If the indexes are relatively small in comparison to the overall size of the table, the fast full scan may provide the performance burst necessary for the application. With concatenated indexes that contain most of the columns of a table, the index may be larger than the actual table and the fast full scan could cause performance degradation.

Skip-Scans

As discussed in the section "Concatenated Indexes" earlier in this chapter, the index skip-scan feature enables the optimizer to use a concatenated index even if its leading column is not listed in the WHERE clause. Index skip-scans are faster than full scans of the index, requiring fewer reads to be performed. For example, the following queries show the difference between a full index scan and a skip-scan. See Chapter 6 to better understand the execution plan or the statistics displayed in the following listing. In this listing, the EMP5 table has many hundreds of thousands of rows.

Following the execution of the queries, the listing shows the time the query took, its execution path within the database, and statistics showing the number of logical reads (consistent gets) and physical reads required to resolve the query:

```
create index skip1 on emp5(job, empno);
Index created.

select count(*)
from   emp5
where  empno = 7900;
Elapsed: 00:00:03.13 (Result is a single row…not displayed)

Execution Plan
  0      SELECT STATEMENT Optimizer=CHOOSE (Cost=4 Card=1 Bytes=5)
  1    0   SORT (AGGREGATE)
  2    1     INDEX (FAST FULL SCAN) OF 'SKIP1' (NON-UNIQUE)

Statistics
6826  consistent gets
6819  physical reads

select /*+ index_ss(emp5 skip1) */ count(*)
from   emp5
where  empno = 7900;
Elapsed: 00:00:00.56

Execution Plan
  0      SELECT STATEMENT Optimizer=CHOOSE (Cost=6 Card=1 Bytes=5)
  1    0   SORT (AGGREGATE)
  2    1     INDEX (SKIP SCAN) OF 'SKIP1' (NON-UNIQUE)

Statistics
21  consistent gets
17  physical reads
```

As shown in the listing, the second option used an INDEX_SS (SKIP SCAN) operation to read the index. That execution path required 21 logical reads, which, in turn, required 17 physical I/Os. The first option performed an INDEX (FAST FULL SCAN) operation, which required a significantly greater number of logical and physical I/Os.

To influence the optimizer to choose a skip-scan, you may need to use a hint in the query as shown in the listing. The hint influences the optimizer and biases it toward the execution path you specify.

TIP

For large tables with concatenated indexes, the index skip-scan feature can provide quick access even when the leading column of the index is not used in a limiting condition.

Types of Indexes

The following is a list of indexes discussed in this section:

- B-tree
- Bitmap
- Hash
- Index-organized table
- Reverse key
- Function-based
- Partitioned (local and global)
- Bitmap join indexes

B-Tree Indexes

B-tree indexes are the general-purpose indexes in Oracle. They are the default index types created when creating indexes. B-tree indexes can be single-column (simple) indexes or composite/concatenated (multicolumn) indexes. B-tree indexes can have up to 32 columns.

In Figure 2-3, a b-tree index is created on the LAST_NAME column of the EMPLOYEE table. This index has a binary height of three; consequently, Oracle must go through two branch blocks to get to the leaf block containing the ROWID. Within each branch block, there are branch rows containing the block ID of the next block ID within the chain.

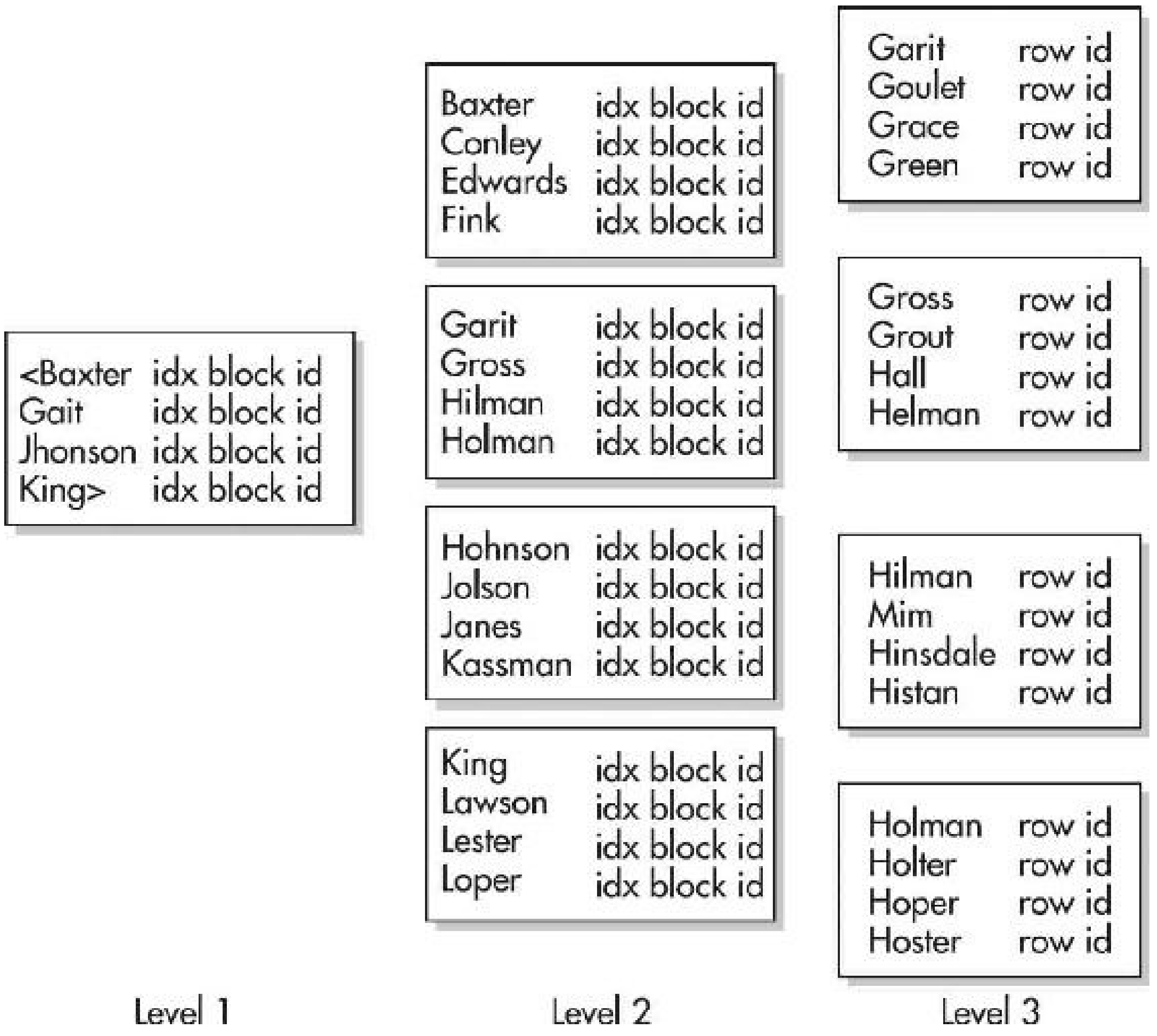


FIGURE 2-3. *B-tree index creation*

A leaf block contains the index values, the ROWID, and pointers to the previous and next leaf blocks. Oracle has the ability to transverse the binary tree in both directions. B-tree indexes contain the ROWIDs for every row in the table that has a value in the indexed column. Oracle does not index rows that contain NULL values in the indexed column. If the index is a concatenation of multiple columns and one of the columns contains a NULL value, the row will be in the index and the column containing the NULL value will be left empty.

TIP

The values of the indexed columns are stored in an index. For this reason, you can build concatenated (composite) indexes that can be used to satisfy a query without accessing the table. This eliminates the need to go to the table to retrieve the data, reducing I/O.

Bitmap Indexes

Bitmap indexes are ideal for decision support systems (DSSs) and data warehouses. They should not be used for tables accessed via transaction-processing applications. Bitmap indexes provide fast access to very large tables using low to medium cardinality (low to medium number of distinct values) columns. Although bitmap indexes can have up to 30 columns, they are generally used for a small number of columns.

For example, your table may contain a column called GENDER with two possible values: male and female. The cardinality would be only 2, and it would be a prime candidate for a bitmap index if users frequently query the table by the value of the GENDER column. The real power of the bitmap index is seen when a table contains multiple bitmap indexes. With multiple bitmap indexes available, Oracle has the ability to merge the result sets from each of the bitmap indexes to eliminate the unwanted data quickly.

The following listing shows an example of creating a bitmap index:

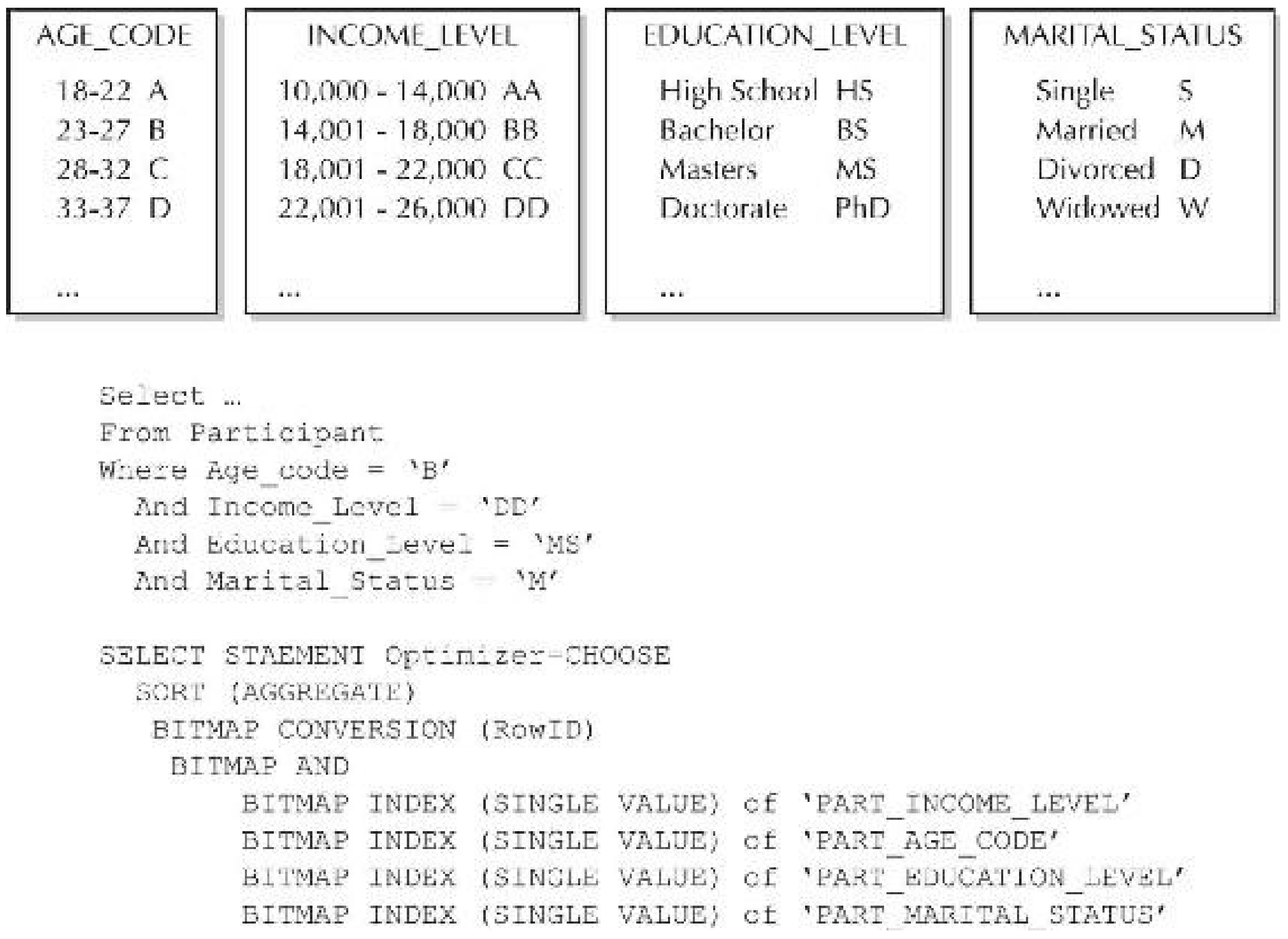
```
create bitmap index dept_idx2_bm on dept (deptno);
Index created.
```

TIP
Use bitmap indexes for columns with a low cardinality. An example would be a column called GENDER with two possible values of "male" or "female" (the cardinality is only 2). Bitmaps are very fast for low-cardinality columns (few distinct values) because the size of the index is substantially smaller than a b-tree index. Since they are very small when compared to a low-cardinality b-tree index, you can often retrieve over half of the rows in the table and still use a bitmap index.

Bitmap indexes usually outperform b-trees when loading tables (INSERT operations) in batch (single-user) operations when the bulk of the entries do not add new values to the bitmap. You should not use bitmap indexes when multiple sessions will be concurrently inserting rows into the table, as occurs in most transaction-processing applications.

Bitmap Index Example

Consider a sample table called PARTICIPANT that contains surveys from individuals. Each of the columns AGE_CODE, INCOME_LEVEL, EDUCATION_LEVEL, and MARITAL_STATUS has a separate bitmap index built on it. The balance of the data in each histogram and the execution path for a query accessing each of the bitmap indexes are displayed in Figure 2-4. The execution path in the figure shows how the multiple bitmap indexes have been merged, creating a significant performance gain.



AGE_CODE	
18-22	A
23-27	B
28-32	C
33-37	D
...	

INCOME_LEVEL	
10,000 - 14,000	AA
14,001 - 18,000	BB
18,001 - 22,000	CC
22,001 - 26,000	DD
...	

EDUCATION_LEVEL	
High School	HS
Bachelor	BS
Masters	MS
Doctorate	PhD
...	

MARITAL_STATUS	
Single	S
Married	M
Divorced	D
Widowed	W
...	

```
Select …
From Participant
Where Age_code = 'B'
  And Income_Level = 'DD'
  And Education_Level = 'MS'
  And Marital_Status = 'M'

SELECT STAEMENT Optimizer=CHOOSE
  SORT (AGGREGATE)
   BITMAP CONVERSION (RowID)
    BITMAP AND
        BITMAP INDEX (SINGLE VALUE) of 'PART_INCOME_LEVEL'
        BITMAP INDEX (SINGLE VALUE) of 'PART_AGE_CODE'
        BITMAP INDEX (SINGLE VALUE) of 'PART_EDUCATION_LEVEL'
        BITMAP INDEX (SINGLE VALUE) of 'PART_MARITAL_STATUS'
```

FIGURE 2-4. *Bitmap index creation*

As shown in Figure 2-4, the optimizer uses each of the four separate bitmap indexes whose columns were referenced in the WHERE clause. Each bitmap contains binary values (like 1 or 0) that indicate which rows (often ranges of rows, making it smaller than a normal index) contain the indexed value. Given that, Oracle then performs a BITMAP AND operation on the table containing the indexed value. Given that, Oracle then performs another BITMAP AND operation to find which rows would be returned from all four of the bitmaps. That value is then converted into a ROWID value and the query proceeds with the rest of the processing. Note that all four of the columns had very low cardinality, yet the index allowed the matching rows to be returned very quickly.

TIP

Merging multiple bitmap indexes can lead to significant performance improvement when combined in a single query. Bitmap indexes also work better with fixed-length data types than they do with variable-length data types. Large block sizes improve the storage and read performance of bitmap *indexes*.

The following query displays index types. B-tree indexes are listed as 'NORMAL'; bitmap indexes will have an INDEX_TYPE value of 'BITMAP'.

```
select index_name, index_type
from   user_indexes;
```

TIP
To query a list of your bitmap indexes, query the INDEX_TYPE column in the USER_INDEXES view.

Bitmap indexes are not generally recommended for online transaction processing (OLTP) applications. B-tree indexes contain a ROWID with the indexed value. So, when *updating* tables and their indexes, Oracle has the ability to lock individual rows. Bitmap indexes are stored as compressed indexed values, which can contain a range of ROWIDs. Therefore, Oracle has to lock the entire range of the ROWIDs for a given value. This type of locking has the potential to cause deadlock situations with certain types of DML statements. SELECT statements are not affected by this locking problem. A solution to updates is to drop the index, do the updating in batch during off-hours, and then rebuild the bitmap index (you could also add/drop an index on a column(s) that makes the update faster possibly as well).

Bitmap indexes have several restrictions:

- Bitmap indexes are not considered by the rule-based optimizer.
- Performing an ALTER TABLE statement and modifying a column that has a bitmap index built on it invalidates the index.
- Bitmap indexes do not contain any of the data from the column and cannot be used for any type of integrity checking.
- Bitmap indexes cannot be declared as unique.
- Bitmap indexes have a maximum length of 30 columns.

TIP
Don't use bitmap indexes in heavy OLTP environments. Bitmap indexes are often much smaller than other indexes.

Hash Indexes

Using *hash* indexes requires the use of hash clusters. I don't see many people using these! When you create a cluster or hash cluster, you define a cluster key. The cluster key tells Oracle how to store the tables in the cluster. When data is stored, all the rows relating to the cluster key are stored in the same database blocks, regardless of what table they belong to. With the data being stored in the same database blocks, using the hash index for an exact match in a WHERE clause enables Oracle to access the data by performing one hash function and one I/O—as opposed to accessing the data by using a b-tree index with a binary height of three, where potentially four I/Os would need to be performed to retrieve the data. As shown in Figure 2-5, the query is an equivalence query, matching the hashed column to an exact value. Oracle can quickly use that value to determine where the row is physically stored, based on the hashing function.

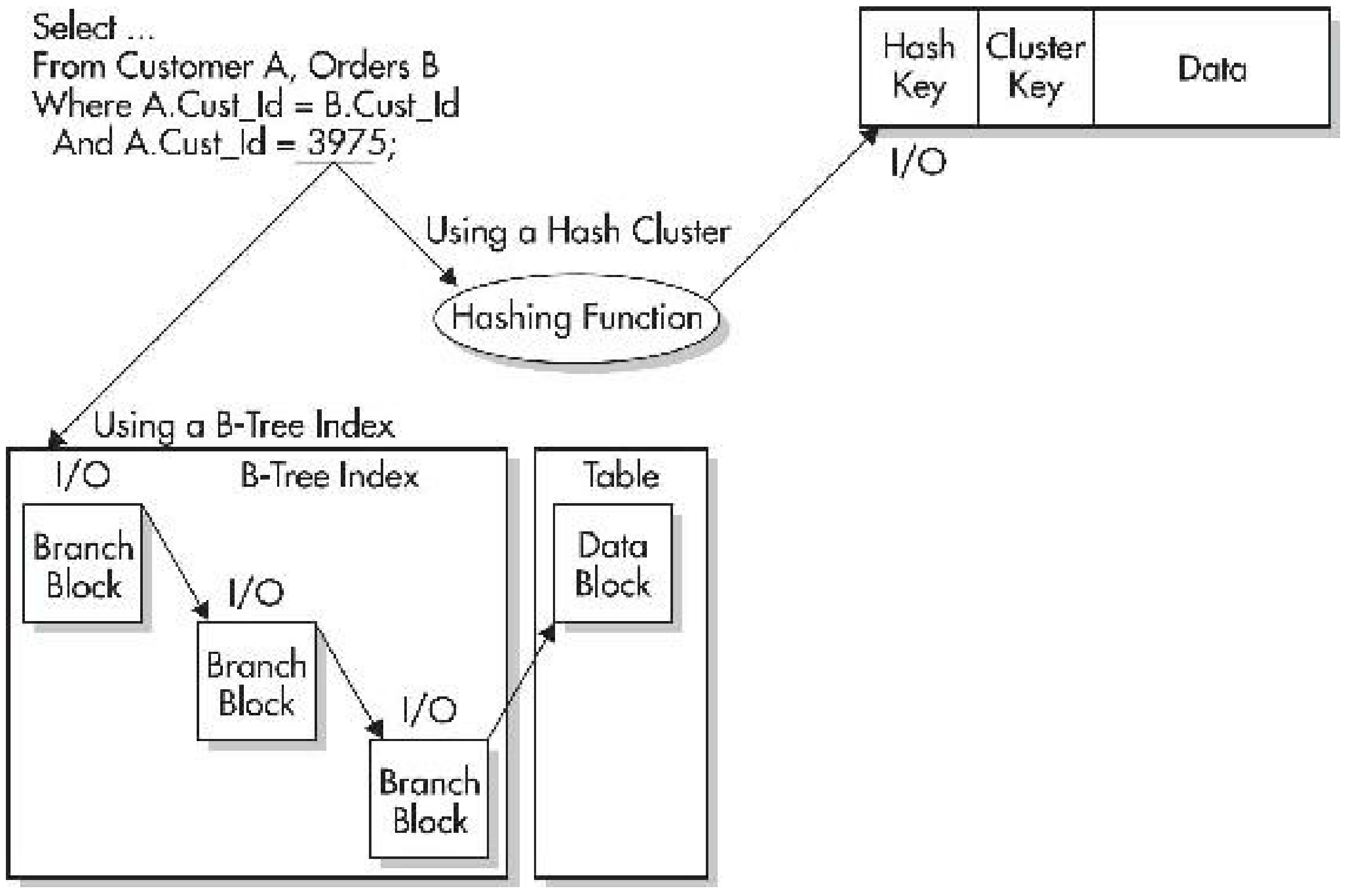


FIGURE 2-5. *Using hash indexes*

Hash indexes can potentially be the fastest way to access data in the database, but they do come with their drawbacks. The number of distinct values for the cluster key needs to be known before creating the hash cluster. This value needs to be specified at the time of creation. Underestimating the number of distinct values can cause *collisions* (two cluster key values with the same hash value) within the cluster, which are very costly. Collisions cause overflow buffers to be used to store the additional rows, thus causing additional I/O. If the number of distinct hash values has been underestimated, the cluster will need to be re-created to alter the value. An ALTER CLUSTER command cannot change the number of HASHKEYS.

Hash clusters have a tendency to waste space. If it is not possible to determine how much space is required to hold all of the rows for a given cluster key, space may be wasted. If it is not possible to allocate additional space within the cluster for future growth, then hash clusters may not be the best option.

If the application often performs full table scans on the clustered table(s), hash clusters may not be the appropriate option. Because of the amount of empty space within the cluster to allow for future growth, full table scans can be very resource-intensive.

Caution should be taken before implementing hash clusters. Revise the application fully to ensure that enough information is known about the tables and data before implementing this option. Generally, hashing is best for static data with primarily sequential values.

TIP
Hash indexes are most useful when the limiting condition specifies an exact value rather than a range of values.

Index-Organized Tables

An *index-organized table* alters the storage structure of a table to that of a b-tree index, sorted on the table's primary key. This unique type of table is treated like any other table—all DML and DDL statements are allowed. ROWIDs are not associated with the rows in the table because of the structure of the table.

Index-organized tables provide faster key-based access to the data for statements involving exact match and range searches on the primary key columns. UPDATE and DELETE statements based on the primary key values should perform better because the rows are physically ordered. The amount of storage required is reduced because values of the key columns are not duplicated in the table and then again in an index.

If you do not frequently query the data by the primary key column, then you will need to create secondary indexes on other columns in the index-organized table. Applications that do not frequently query tables by their primary keys do not realize the full benefits of using index-organized tables. Consider using index-organized tables for tables that are always accessed using exact matches or range scans on the primary key.

TIP

You can create secondary indexes on index-organized tables.

Reverse Key Indexes

When sequential data is loaded, the index may encounter I/O-related bottlenecks. During the data loads, one part of the index, and one part of the disk, may be used much more heavily than any other part. To alleviate this problem, you should store your index tablespaces on disk architectures that permit the files to be physically striped across multiple disks.

Oracle provides reverse key indexes as another solution to this performance problem. When data is stored in a *reverse key* index, its values are reversed prior to being stored in the index. Thus, the values 1234, 1235, and 1236 are stored as 4321, 5321, and 6321. As a result, the index may update different index blocks for each inserted row.

TIP
If you have a limited number of disks and large concurrent sequential loads to perform, reverse key indexes may be a viable solution.

You cannot use reverse key indexes with bitmap indexes or index-organized tables.

Function-Based Indexes

You can create *function-based* indexes on your tables. Without function-based indexes, any query that performed a function on a column could not use that column's index. For example, the following query could not use an index on the JOB column unless it is a function-based index:

```
select *
from   emp
where  UPPER(job) = 'MGR';
```

The following query *could* use an index on the JOB column, but it would not return rows where the JOB column had a value of 'Mgr' or 'mgr':

```
select *
from   emp
where  job = 'MGR';
```

You can create indexes that allow function-based columns or data to be supported by index accesses. Instead of creating an index on the JOB column, you can create an index on the column expression UPPER(job), as shown in the following listing:

```
create index EMP_UPPER_JOB on
emp(UPPER(job));
```

Although function-based indexes can be useful, be sure to consider the following questions when creating them:

- Can you restrict the functions that will be used on the column? If so, can you restrict all functions from being performed on the column?
- Do you have adequate storage space for the additional indexes?
- How will the increased number of indexes per column impact the performance of DML commands against the table?

Function-based indexes are useful, but you should implement them sparingly. The more indexes you create on a table, the longer all DML statements (INSERTs, UPDATEs, and DELETEs) will take.

NOTE
For function-based indexes to be used by the optimizer, you must set the QUERY_REWRITE_ENABLED initialization parameter to TRUE.

To see the magnitude of the benefit of function-based indexes, consider the following example that queries a table named SAMPLE that contains 1.4 million rows (note that you must first create the RATIO function; it is not built in):

```
select  count(*)
from    sample
where   ratio(balance,limit) >.5;

Elapsed time: 3.61 seconds

create index ratio_idx1 on
sample (ratio(balance, limit));

select  count(*)
from    sample
where   ratio(balance,limit) >.5;

Elapsed time: 0.07 seconds (over 50x faster)!!!
```

Partitioned Indexes

A *partitioned* index is simply an index broken into multiple pieces. By breaking an index into multiple physical pieces, you are accessing much smaller pieces (faster), and you may separate the pieces onto different disk drives (reducing I/O contention). Both b-tree and bitmap indexes can be partitioned. Hash indexes cannot be partitioned. Partitioning can work several different ways. The tables can be partitioned and the indexes are not partitioned; the table is not partitioned but the index is; or both the table and index are partitioned. Either way, the cost-based optimizer must be used. Partitioning adds many possibilities to help improve performance and increase maintainability.

There are two types of partitioned indexes: local and global. Each type has two subsets, prefixed and non-prefixed. A table can have any number or combination of the different types of indexes built on its columns. If bitmap indexes are used, they must be local indexes. The main reason to partition the indexes is to reduce the size of the index that needs to be read and to enable placing the partitions in separate tablespaces to improve reliability and availability.

Oracle also supports parallel query and parallel DML when using partitioned tables and indexes (see Chapter 11 for more information), adding the extra benefit of multiple processes helping to process the statement faster.

Local (Commonly Used Indexes)

Local indexes are indexes that are partitioned using the same partition key and same range boundaries as the partitioned table. Each partition of a local index will only contain keys and ROWIDs from its corresponding table partition. Local indexes can be b-tree or bitmap indexes. If they are b-tree indexes, they can be unique or non-unique.

Local indexes support partition independence, meaning that individual partitions can be added, truncated, dropped, split, taken offline, etc., without dropping or rebuilding the indexes. Oracle maintains the local indexes automatically. Local index partitions can also be rebuilt individually while the rest of the partition is unaffected.

Prefixed *Prefixed* indexes are indexes that contain keys from the partitioning key as the leading edge of the index. For example, let's take the PARTICIPANT table again. Say the table was created and range-partitioned using the SURVEY_ID and SURVEY_DATE columns and a local prefixed index is created on the SURVEY_ID column. The partitions of the index are *equipartitioned*, meaning the partitions of the index are created with the same range boundaries as those of the table (see Figure 2-6).

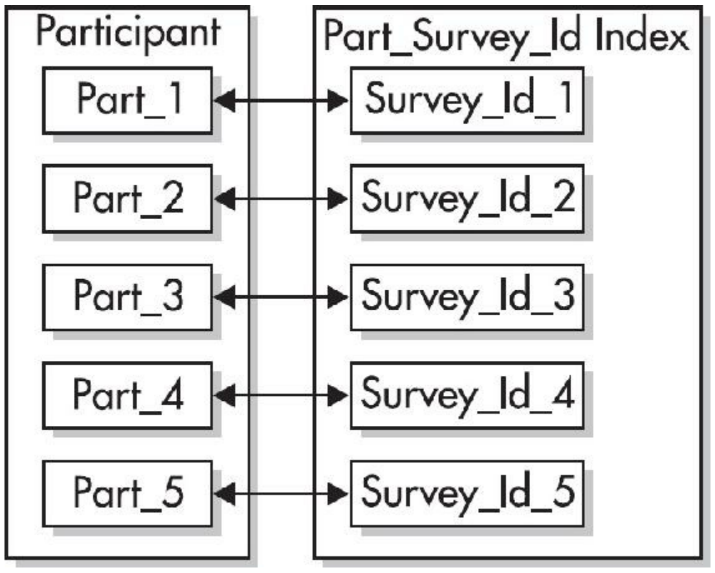


FIGURE 2-6. *Partitioned, prefixed indexes*

TIP
Local prefixed indexes allow Oracle to prune unneeded partitions quickly. The partitions that do not contain any of the values appearing in the WHERE clause will not need to be accessed, thus improving the statement's performance.

Non-prefixed *Non-prefixed* indexes are indexes that do not have the leading column of the partitioning key as the leading column of the index. Using the same PARTICIPANT table with the same partitioning key (SURVEY_ID and SURVEY_DATE), an index on the SURVEY_DATE column would be a local non-prefixed index. A local non-prefixed index can be created on any column in the table, but each partition of the index only contains the keys for the corresponding partition of the table (see Figure 2-7).

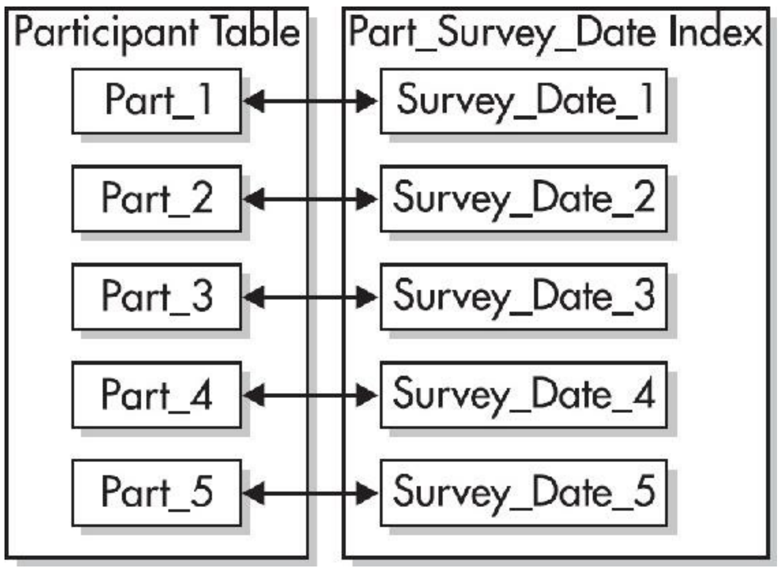


FIGURE 2-7. *Partitioned, non-prefixed indexes*

For a non-prefixed index to be unique, it must contain a subset of the partitioning key. In this example, you would need a combination of columns, including the SURVEY_DATE and/or the SURVEY_ID columns (as long as the SURVEY_ID column was not the leading edge of the index, in which case it would be a prefixed index).

TIP
For a non-prefixed index to be unique, it must contain a subset of the partitioning key.

Global

Global partitioned indexes contain keys from multiple table partitions in a single index partition. The partitioning key of a global partitioned index is different or specifies a different range of values from the partitioned table. The creator of the global partitioned index is responsible for defining the ranges and values for the partitioning key. Global indexes can only be b-tree indexes. Global partitioned indexes are not maintained by Oracle by default. If a partition is truncated, added, split, dropped, etc., the global partitioned indexes need to be rebuilt unless you specify the UPDATE GLOBAL INDEXES clause of the ALTER TABLE command when modifying the table. With Oracle Database 12*c*, when you drop or truncate a partition, the global indexes are no longer invalid and managed automatically.

Prefixed Normally, global prefixed indexes are not equipartitioned with the underlying table. Nothing prevents the index from being equipartitioned, but Oracle does not take advantage of the equipartitioning when generating query plans or executing partition maintenance operations. If the index is going to be equipartitioned, it should be created as a local index to allow Oracle to maintain the index and use it to help prune partitions that will not be needed (see Figure 2-8). As shown in the figure, the three index partitions each contain index entries that point to rows in multiple table partitions.

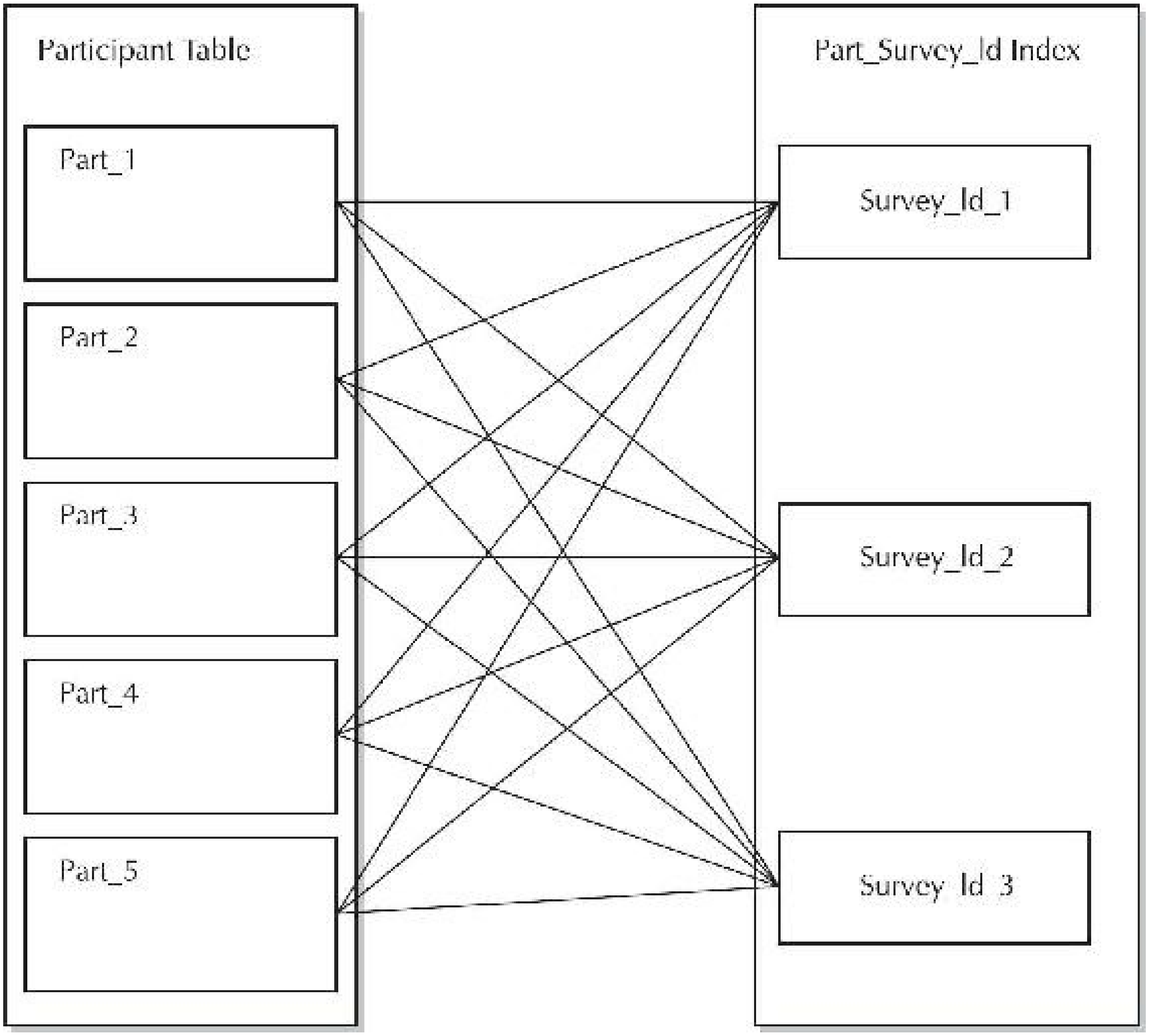


FIGURE 2-8. *Partitioned, global prefixed index*

TIP

If a global index is going to be equipartitioned, it should be created as a local index to allow Oracle to maintain the index and use it to help prune partitions, or exclude those partitions that are not needed by the query.

Non-prefixed Global non-prefixed indexes should not be used as Oracle does not support them. They do not provide any benefits over normal B-tree indexes on the same columns, so they have no value.

New 12*c*R2 Features for Partitioned Indexes

Several new features for partitioned tables are discussed in Chapter 3, which covers partitioned tables in detail. Those new features affect the underlying partitioned index, so I list them here (see Chapter 3 for more detail):

- SPLIT and MERGE PARTITION are now online operations for heap-organized tables.
- A nonpartitioned table can be converted online to a partitioned table (including indexes).
- List partitioning may now be on multiple partitioned columns.
- Composite partitioned tables may use list partitions on subpartitions.
- Partitions and subpartitions can be set to read-only.

TIP
In 12cR2 you can do an online conversion of a nonpartitioned table to a partitioned table, including the indexes. You can also set partitions and subpartitions to be read-only.

Bitmap Join Indexes

A *bitmap join* index is a bitmap index based on the join of two tables. Bitmap join indexes are used in data warehousing environments to improve the performance of queries that join dimension tables to fact tables. When creating a bitmap join index, the standard approach is to join a commonly used dimension table to the fact table within the index. When a user queries the fact table and the dimension table together in a query, the join does not need to be performed because the join results are already available in the bitmap join index. Further performance benefits are gained from the compression of ROWIDs within the bitmap join index, reducing the number of I/Os required to access the data.

When creating a bitmap join index, you specify both tables involved. The syntax should follow this model:

```
create bitmap index FACT_DIM_COL_IDX
   on FACT(DIM.Descr_Col)
 from FACT, DIM
 where FACT.JoinCol = DIM.JoinCol;
```

The syntax for bitmap joins is unusual in that it contains both a FROM clause and a WHERE clause, and it references two separate tables. The indexed column is usually a description column within the dimension table—that is, if the dimension is CUSTOMER and its primary key is CUSTOMER_ID, you would normally index a column such as CUSTOMER_NAME. If the FACT table is named SALES, you might create an index using the following command:

```
create bitmap index SALES_CUST_NAME_IDX
  on SALES(CUSTOMER.Customer_Name)
 from SALES, CUSTOMER
 where SALES.Customer_ID=CUSTOMER.Customer_ID;
```

If a user then queries the SALES and CUSTOMER tables with a WHERE clause that specifies a value for the CUSTOMER_NAME column, the optimizer can use the bitmap join index to return the rows quickly that match both the join condition and the CUSTOMER_NAME condition.

The use of bitmap join indexes is restricted; you can only index the columns in the dimension tables. The columns used for the join must be primary key or unique constraints in the dimension tables, and if it is a composite primary key, you must use each of the columns in your join. You cannot create a bitmap join index on an index-organized table, and the restrictions that apply to regular bitmap indexes also apply to bitmap join indexes.

Fast Index Rebuilding

The REBUILD option of the ALTER INDEX statement is executed to rebuild an index quickly using the existing index instead of the table:

```
alter index cust_idx1 rebuild parallel
tablespace cust_tblspc1
storage (pctincrease 0);
Index altered.
```

Modifications to the STORAGE clause can be made at this time and the parallel option may also be used.

TIP
Use the REBUILD option of the ALTER INDEX statement for quickly rebuilding an index using the existing index instead of the table. You must have enough space to store both indexes during this operation.

Rebuilding Indexes Online

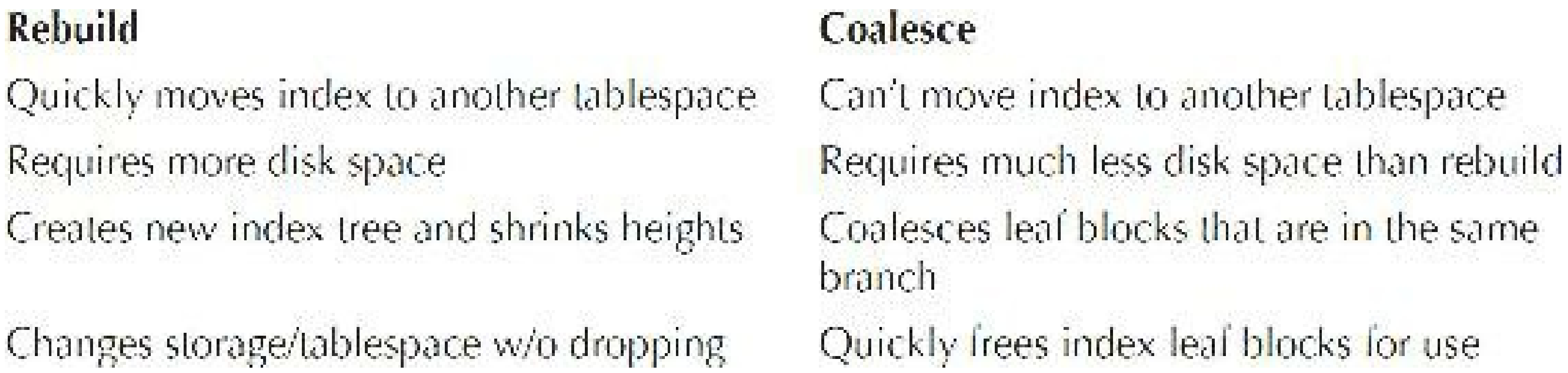
You can create or rebuild indexes even when doing DML (INSERT/UPDATE/DELETE) statements on the base table. However, rebuilding during low DML activity is *still* better. Prior to Oracle 11*g*, this required an exclusive lock at the beginning and end of the rebuild. This lock could cause DML delays and a performance spike. This lock is no longer required for this operation, and rebuilding indexes online is now much faster! Rebuilding is also faster than a DROP and CREATE index.

Here's the basic syntax:

```
CREATE INDEX index_name ON table (col1,...) ONLINE;
Index created.

ALTER INDEX index_name REBUILD ONLINE;
Index altered.
```

Note that rebuilding an index is not the same as coalescing an index. A nice comparison is shown here:



Rebuild	Coalesce
Quickly moves index to another tablespace	Can't move index to another tablespace
Requires more disk space	Requires much less disk space than rebuild
Creates new index tree and shrinks heights	Coalesces leaf blocks that are in the same branch
Changes storage/tablespace w/o dropping	Quickly frees index leaf blocks for use

TIP
You can use the REBUILD ONLINE option to allow DML operations on the table or partition during the index rebuild. You cannot specify REBUILD ONLINE for bitmap indexes or for indexes that enforce referential integrity constraints.

TIP
Rebuilding indexes online during high levels of DML activity in 12cR2 is much faster than it was in 10g.

Tips Review

- As you upgrade Oracle versions, be sure to test your application's queries to determine whether the execution paths for your queries still use the indexes that were used prior to the upgrade. See if the execution plan has changed and if it is better or worse.
- Query DBA_INDEXES and DBA_IND_COLUMNS to retrieve a list of the indexes on a given

table. Use USER_INDEXES and USER_IND_COLUMNS to retrieve information for only your schema.

- By using invisible indexes, you can "turn off" indexes temporarily (make them invisible) to check how queries will perform without them. Since invisible indexes continue to be maintained while invisible, turning them back on (making them visible again) if needed is fast and simple.
- In 12*c*, invisible indexes are also the means for creating multiple indexes on the same column(s). This allows for one type of index for daytime processing and another for nightly processing, and perhaps even another type for monthly processing. Only one index may be visible at a time (other than function-based indexes).
- You can create your indexes and analyze them in a single step by using the COMPUTE STATISTICS clause of the CREATE INDEX command, but, as of 10*g*, Oracle *always* computes statistics on all index create/rebuild operations when index is not empty.
- Using the default values clause for a table column causes NULL values to be disallowed and eliminates the performance problems associated with using NULL values.
- By using functions (such as a TO_DATE or TO_CHAR) that alter the values being compared to a column and not the columns themselves, the indexes are used. The indexes might have been suppressed had you used the function on the column itself.
- Comparing mismatched data types can cause Oracle to suppress an index internally. Even an EXPLAIN PLAN (covered in Chapter 6) on the query will not help you understand why a full table scan is being performed.
- An index's selectivity is what helps the cost-based optimizer determine an execution path. The more selective, the fewer number of rows will be returned. Improve selectivity by creating concatenated/composite (multicolumn) indexes.
- Analyzing the index or the table provides the binary height of the index. Use the BLEVEL column in the USER_INDEXES view to check the binary height of the index.
- If the number of deleted rows within an index approaches 20–25 percent, rebuild the index to help reduce the binary height and the amount of empty space that is being read during an I/O.
- If the data in a table is skewed, histograms provide the cost-based optimizer with a picture of the distribution. Using the histograms on columns that are not skewed will not provide a performance increase but will probably degrade it.
- For large tables with concatenated indexes, the index skip-scan feature provides quick access even when the leading column of the index is not used in a limiting condition.
- The values of the indexed columns are stored in an index. For this reason, you can build concatenated (composite) indexes that can be used to satisfy a query without accessing the table. This eliminates the need to go to the table to retrieve the data, reducing I/O.
- Use bitmap indexes for columns with a low cardinality. An example is a column called GENDER with two possible values of "male" or "female" (the cardinality is only 2).
- To query a list of your bitmap indexes, query the USER_INDEXES view.

- Don't use bitmap indexes to avoid locking issues, where many INSERTs occur on tables, such as heavy OLTP environments; learn the restrictions associated with bitmap indexes.
- Consider using index-organized tables for tables that are always accessed using exact matches or range scans on the primary key.
- If you have a limited number of disks and large concurrent sequential loads to perform, reverse key indexes may be a viable solution.
- For function-based indexes to be used by the optimizer, you must set the QUERY_REWRITE_ENABLED initialization parameter to TRUE.
- Local prefixed indexes allow Oracle to prune unneeded partitions quickly. The partitions that do not contain any of the values appearing in the WHERE clause will not need to be accessed, thus improving the statement's performance.
- Specify the UPDATE GLOBAL INDEXES clause of the ALTER TABLE command when modifying a partitioned table. By default, you need to rebuild global indexes when altering a partitioned table.
- Use bitmap join indexes to improve the performance of joins within data warehousing environments.
- Use the REBUILD option of the ALTER INDEX statement for quickly rebuilding an index using the existing index instead of the table.
- You can use the REBUILD ONLINE option to allow DML operations on the table or partition during the index rebuild. You cannot specify REBUILD ONLINE for bitmap indexes or for indexes that enforce referential integrity constraints. This option has been improved and is faster and better in 12*c*R2.
- In 12*c*R2 you can do an online conversion of a nonpartitioned table to a partitioned table, including the indexes. You can also set partitions and subpartitions to be read-only.

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Dave Radoicic did the main update for 12*c*R2. Greg Pucka contributed a major portion of this original chapter. Kevin Loney contributed the major portion of the 10*g* update to this chapter. Rich Niemiec added 11*g* new content and Mike Messina tested queries and added BLEVEL detail for the

11*g* version.

CHAPTER 3

Pluggable Databases, Disk Implementation Methodology, and ASM (DBA)

With 12*c*, Oracle has changed the structure of a database. We now have multitenant databases with the introduction of pluggable databases (PDBs). Oracle also changed the landscape of disk access in Oracle 10*g* with the release of Automatic Storage Management (ASM). With the releases of Oracle 11*g* and 12*c*, more features have been added to ASM to make it even more robust. ASM is now the standard for Oracle databases! This chapter will focus heavily on pluggable databases and ASM in addition to the non-ASM-specific disk implementation methodology in Oracle.

In addition to its broad coverage of ASM and disk management, this chapter will start with an introduction to 12*c* multitenant databases, which include container databases (CDBs) and PDBs. Starting with 12*c*, Oracle supports a new architecture that lets you have subdatabases inside a single database. Oracle calls the subdatabases PDBs and the main database a CDB. Within the main CDB, there can be a maximum of 252 subdatabases (PDBs) in 12*c*R1 and 4096 in 12*c*R2. With this new feature, you can consolidate databases rather than having them scattered in multiple instances, which makes patching and provisioning of databases simpler.

In the last several years, disk configuration techniques seemed to be reaching the point where you couldn't do much more to improve the performance of your system without greatly complicating your life as a DBA. If your system operated with some unique qualities, or you chose to review the I/O activity on your tablespaces on a frequent basis, you might be able to achieve slightly better performance than simply mashing all your disk use into a single logical device, but for most DBAs, this just wasn't worth it. If you used raw partitions and were diligent, you could get some performance advantages from using that "technology," but again, it didn't simplify your life as a DBA. Then with the enormous leap in the capacity of single devices, even in the high-end Fibre Channel sector, things were further complicated; restricting yourself to only four or six very large disks was simple, whereas before you may have had a full array or multiple arrays of disks. In the most recent releases of the Oracle Database, you have been given a whole new toolbox. With a full X6-2 Exadata with an entire flash array of storage, you can now have 180T of flash. The Oracle FS1 flash array has almost a petabyte of flash (912T).

More features are now available for managing how the data resides on disk. And more have been released in the last 24 months with Exadata (most recently X6). To make it even better, almost anyone running an Oracle database can use these new features. Don't worry, this chapter will still talk about balancing your disk (including 12*c* sharding) and eliminating fragmentation, but it will also discuss

12*c* new features you can utilize to rid yourself of the repeated effort these activities required in the past or, very possibly, prevent you from having to do them altogether.

To keep your system running at its peak, this chapter offers the following tips:

- Exploiting 12*c* new features for pluggable databases and 12*c*R2 features
- Understanding storage hardware and its performance implications
- Understanding RAID levels
- Using the 12*c* Heat Map and 12*c* I/O performance views
- Understanding bigfile tablespaces and getting to the 8-exabyte Oracle 12*c* database
- Understanding ASM instances including the 12*c* install and 12*c* new features
- Understanding ASM disks, diskgroups, and multipathing
- Avoiding disk contention and managing large tables by using partitions
- Sizing extents properly to eliminate fragmentation, reduce chaining, and keep performance optimal
- Managing redo and rollbacks in the database for speed
- Having multiple control files on different disks and controllers
- Understanding issues to consider in the planning stages of your system

Pluggable Databases (New in Oracle 12*c*)

I'm starting the chapter with an introduction to pluggable databases since it is such a key feature in 12*c*. While the focus of the book is tuning, I do want to ensure you have an arsenal of commands to be able to work with this new feature, but please read the *Oracle Database Administrator's Guide* for complete coverage of this topic (this chapter will only get you started and exposed to PDBs).

"Pluggable" databases can be unplugged from one container database (CDB) and plugged into another CDB easily, therefore making databases portable between environments and allowing the upgrade of a database by unplugging it from one environment at one version and plugging it into a new environment at a higher version. You can also unplug a PDB from on premises and plug it into the cloud (or vice versa). This new feature also allows a single PDB to be independently recovered (you can flashback a PDB in 12*c*R2). Each PDB looks to an application like any other traditional Oracle database (called a non-CDB), so no application changes are needed to work with the PDB architecture. Non-CDBs are now deprecated. The following are some notes to keep in mind when working with a CDB and PDBs. Keep in mind that these are subject to change.

- CDB = container database (has a root database and also a seed PDB).
- PDB = pluggable database (plugged into a CDB).
- Non-CDB = traditional Oracle database instance (neither a CDB nor a PDB).
- Why PDBs? To consolidate hundreds of databases on one machine. Too many resources are

required when you add up the System Global Areas (SGAs) for each of the instances when not using PDBs. One CDB has one SGA and resources shared for multiple PDBs.

- Share PDBs (e.g., big data sources, acquisitions, partners, shared research, governments).
- Quickly create a new database (PDB) or copy an existing one (PDB).
- In 12*c*R2, can refresh a read-only PDB.
- In 12*c*R2, can flashback an individual PDB.
- Recover an individual PDB.
- Move existing PDBs to a new platform or location or clone them (snapshot).
- Patch/upgrade a PDB by plugging it into a CDB at a later version.
- Physical machine runs more PDBs the old way; easier to manage/tune.
- Back up entire CDB + any number of PDBs.
- New syntax for commands: PLUGGABLE DATABASE.

The following sections show a few commands that you can run with pluggable databases. The need to easily move data around is becoming increasingly important in many scenarios: integrating big data sources; company acquisitions; moving data to/from the cloud; sharing research among partners; and governments sharing security or other data. To give you a taste of what's possible, the following are a few nice examples of queries for the multitenant world.

Is the database a CDB or non-CDB?

```
select name, created, cdb, con_id
from   v$database;

NAME        CREATED    CDB      CON_ID
---------- --------- --- ----------
CDB1        19-FEB-12 YES            0
```

This example is a CDB, as indicated by YES in the CDB column.

You can also query the PDBs. In this example, I have three PDBs, but only PDB_SS and PDB1 were created by me. PDB$SEED was created by Oracle when I installed the database. I can clone the seed PDB to create new, empty PDBs.

```
select name, open_mode, open_time
from v$pdbs;

NAME             OPEN_MODE  OPEN_TIME
---------------- ---------- -------------------------
PDB$SEED         READ ONLY  23-FEB-13 05.29.19.861 AM
PDB1             READ WRITE 23-FEB-13 05.29.25.846 AM
PDB_SS           READ WRITE 23-FEB-13 05.29.37.587 AM
```

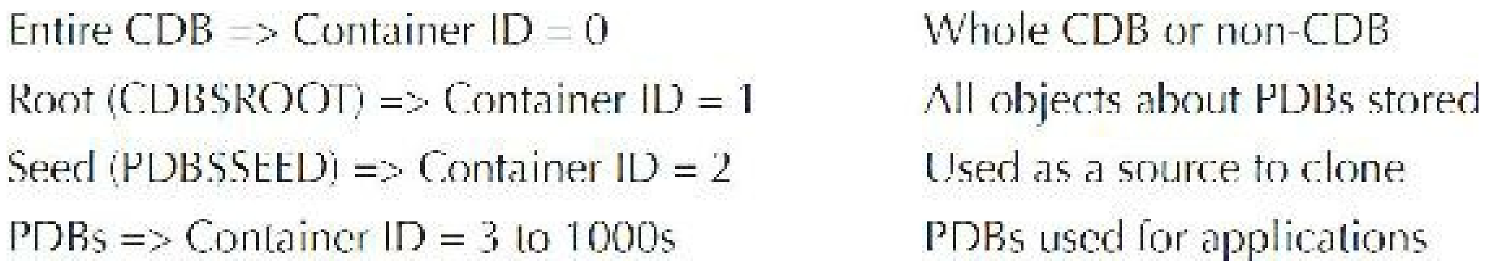
CDB or PDB Created Objects

Some items are specific to only the CDB, some are specific to only the PDB, and some are shared by both (or the DBA can choose to create separate or shared). The following list details which items are specific to the CDB, PDB, or shared by both:

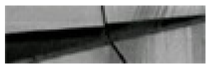
- **Background processes/SGA** Shared by root and all PDBs
- **Character set** Shared by root and all PDBs
- **Redo** Shared by root and all PDBs
- **Undo** Shared by root and all PDBs
- **Time zones** Shared or can be set for each PDB
- **Initialization parameters** Some can be set by PDB
- **Temporary tablespace** Shared by PDBs or create your own local TEMP
- **SYSTEM and SYSAUX** Separate for root and each PDB
- **Datafiles** Separate for root and each PDB (same block size)

Pluggables 0 – 254+

Oracle has the capability to support up to 252 PDBs in 12*c*R1 and 4096 PDBs in 12*c*R2. Here is what is in each container:



Entire CDB => Container ID = 0	Whole CDB or non-CDB
Root (CDB$ROOT) => Container ID = 1	All objects about PDBs stored
Seed (PDB$SEED) => Container ID = 2	Used as a source to clone
PDBs => Container ID = 3 to 1000s	PDBs used for applications



```
(While in PDB1):                         (Connect to ROOT):
                                         SQL> connect / as sysdba
SQL> SHO CON_ID                          SQL> SHO CON_ID
CON_ID                                   CON_ID
-------------------               -------------------
3                                        1

SQL> SHO CON_NAME                        SQL> SHO CON_NAME

CON_NAME                                 CON_NAME
-------------------               -------------------
PDB1                                     CDB$ROOT
```

Creating a PDB: Many Ways to Do It

There are many ways to create a PDB. Most DBAs create new PDBs by cloning the seed PDB and then going from there. For example, creating a PDB to use for a warehouse application may be accomplished by cloning from another PDB that holds OLTP data. You may also get a clone from another system, which includes the XML file (small) and datafiles (large), and create your PDB based on those files, which is fast since the data only needs to be attached, not imported. The commands for many of these options are provided in the following section, but these are the ways to create a PDB:

- Create a PDB by copying the seed PDB (common way)
- Create a PDB by cloning another PDB (very common way)
- Create a PDB by using the XML metadata files and other files and plugging them into a CDB (very common way)
- Create a PDB using a non-CDB (multiple ways):
  - Use DBMS_PDB to create an unplugged PDB (less common)
  - Create an empty PDB and use Data Pump to move data (common way)
  - Use GoldenGate replication (common for initial migration)

Great Pluggable Database Commands

This section contains many of the commands that you'll be using with multitenant (pluggable) databases. These include commands for creating pluggable databases, moving between containers (most of which are different PDBs or the main root), starting and shutting down, and finding out where the actual data in tables resides (in which PDB).

Cloning a PDB

The following three examples show how to create a PDB from another PDB. All three allow different settings for the new PDB, and the last example shows how to do it over a link.

NOTE
*The source no longer needs to be read-only in 12cR2 (**PDB hot clone** as long as the database is in ARCHIVELOG mode and local undo mode).*

```
CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
PATH_PREFIX = '/disk2/oracle/pdb2'
FILE_NAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/');

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
FILE_NAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/')  STORAGE
(MAXSIZE 2G MAX_SHARED_TEMP_SIZE 100M);

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1@pdb1_link;
```

Unplugging and Dropping PDBs

This section provides a few examples of unplugging and dropping PDBs. The first query shows the most common way to unplug a PDB so that someone else can create a PDB using it (that is, plug in the PDB). This operation completes very fast, even if the set of datafiles or the PDB is very large. It's fast because you are only creating an XML file and then copying the datafiles (instead of unloading them) to an additional location and plugging in the PDB.

```
ALTER PLUGGABLE DATABASE dwpdb UNPLUG INTO '/oracle/data/dwpdb.xml';
```

These two commands show how to drop PDBs with and without the datafiles, respectively:

```
DROP PLUGGABLE DATABASE dwpdb KEEP DATAFILES;
DROP PLUGGABLE DATABASE dwpdb INCLUDING DATAFILES;
```

How to Move Between Containers (CDB/PDB)

The following commands show how to move between containers:

```
alter session set container=PDB1;
Session altered.

alter session set container=CDB1;
Session altered.
alter session set container-CDB$ROOT;
Session altered.

alter session set container=PDB$SEED;
Session altered.

alter session set container-pdb ss; (not case sensitive)
Session altered.
```

Opening and Closing PDBs

The following examples show different ways for opening and closing PDBs:

```
alter session set container=pdb_ss; --Commands for only pdb_ss
Session altered.

alter pluggable database close immediate;
Pluggable database altered.

alter pluggable database open read write;
Pluggable database altered.

alter pluggable database close; --(shutdown)
Pluggable database altered.

alter pluggable database open upgrade; --(to migrate)
Pluggable database altered.

alter session set container=CDB$ROOT;  --Now for all PDBs
Session altered.

alter pluggable database ALL open read only; --(from CDB)
Pluggable database altered.

alter pluggable database pdb_ss, pdb1 close;
Pluggable database altered.
```

Starting Up an Individual PDB from the CDB (Root)

The following examples show how to start up an individual PDB when you are in the CDB.

```
startup pluggable database pdb1 open;(read/write)
Pluggable Database opened.
(or while in pdb1 just run STARTUP)

startup pluggable database pdb1 open read only;
Pluggable Database opened.

startup pluggable database pdb1 force; (closes/opens)
Pluggable Database opened.
(or while in pdb1 just run STARTUP FORCE)
```

Starting Up the CDB

(Note that I am *not* using In-Memory here.)

The following command shows how to start the CDB and the resulting feedback upon startup.

```
SQL> startup
ORACLE instance started.
Total System Global Area  626327552 bytes
Fixed Size                  2276008 bytes
Variable Size             524289368 bytes
Database Buffers           92274688 bytes
Redo Buffers                7487488 bytes
Database mounted.
Database opened.

select name, open_mode,  open_time
from   v$pdbs;

NAME       OPEN_MODE  OPEN_TIME
---------- ---------- -------------------------
PDB$SEED   READ ONLY  27-MAR-13 02.04.46.883 AM
PDB1       MOUNTED
PDB_SS     MOUNTED
```

Also note that in 12*c*R2, the PDBs are opened on startup if they were in an open state when the container was shut down.

Tracking PDBs to Datafiles (Where Is Everything?)

One of the tougher things to find out is where the data is for a given PDB, or what table is in which PDB. The following query shows you how to map PDBs to datafiles, and the second query shows you how to map tables to PDBs. You can do this similarly with all objects by accessing the V$ related to the object.

```
SELECT d.con_ID, p.PDB_NAME, d.FILE_ID, d.TABLESPACE_NAME,
       d.FILE_NAME
FROM   CDB_PDBS p, CDB_DATA_FILES d
WHERE  p.PDB_ID(+) = d.CON_ID
order  by d.con_id;

   CON_ID PDB        FILE_ID  TABLESPACE_NAME  FILE_NAME
--------- --------- --------  ---------------- ---------------------------------------------------
        1                  6  USERS            /u01/app/oracle/oradata/cdb1/users01.dbf
        1                  4  UNDOTBS1         /u01/app/oracle/oradata/cdb1/undotbs01.dbf
        1                  3  SYSAUX           /u01/app/oracle/oradata/cdb1/sysaux01.dbf
        1                  1  SYSTEM           /u01/app/oracle/oradata/cdb1/system01.dbf
        2 PDB$SEED         2  SYSTEM           /u01/app/oracle/oradata/cdb1/pdbseed/system01.dbf
        2 PDB$SEED         5  SYSAUX           /u01/app/oracle/oradata/cdb1/pdbseed/sysaux01.dbf
        3 PDB1             7  SYSTEM           /u01/app/oracle/oradata/cdb1/pdb1/system01.dbf
        3 PDB1             8  SYSAUX           /u01/app/oracle/oradata/cdb1/pdb1/sysaux01.dbf
        4 PDB_SS           9  SYSTEM           /u01/app/oracle/oradata/cdb1/pdb_ss/system01.dbf
        4 PDB_SS          10  SYSAUX           /u01/app/oracle/oradata/cdb1/pdb_ss/sysaux01.dbf
        4 PDB_SS          11  EXAMPLE          /u01/app/oracle/oradata/cdb1/pdb_ss/example.dbf

11 rows selected.
```

Map tables to PDBs:

```
SELECT p.PDB_ID, p.PDB_NAME, t.OWNER, t.TABLE_NAME
FROM   CDB_PDBS p, CDB_TABLES t
where  p.PDB_ID = t.CON_ID
AND    T.OWNER ='ORDDATA'
ORDER  BY t.TABLE_NAME;

    PDB_ID PDB_NAME   OWNER      TABLE_NAME
---------- ---------- ---------- ------------------------------
         2 PDB$SEED   ORDDATA    ORDDCM_ANON_ACTION_TYPES
         3 PDB1       ORDDATA    ORDDCM_ANON_ACTION_TYPES
         2 PDB$SEED   ORDDATA    ORDDCM_ANON_ATTRS
         3 PDB1       ORDDATA    ORDDCM_ANON_ATTRS
         3 PDB1       ORDDATA    ORDDCM_ANON_ATTRS_TMP
         2 PDB$SEED   ORDDATA    ORDDCM_ANON_ATTRS_TMP
         3 PDB1       ORDDATA    ORDDCM_ANON_ATTRS_WRK
         2 PDB$SEED   ORDDATA    ORDDCM_ANON_ATTRS_WRK
```

Checking PDB History (When Was It Created?)

Important information about where a PDB came from (where was it cloned from), how it was created, and when it was created is located in the CDB_PDB_HISTORY, which you can query as follows:

```
SELECT DB_NAME, CON_ID, PDB_NAME, OPERATION,
       OP_TIMESTAMP, CLONED_FROM_PDB_NAME
FROM   CDB_PDB_HISTORY
WHERE  CON_ID > 2
ORDER  BY CON_ID;


DB_NAME     CON_ID PDB_NAME        OPERATION  OP_TIMEST CLONED_FROM_PDB
---------- ------ --------------- ---------- --------- ---------------
NEWCDB          3 PDB1            CREATE     01-APR-13 PDB$SEED
NEWCDB          4 PDB_SS          CREATE     01-APR-13 PDB$SEED
NEWCDB          5 PDB2            CLONE      02-APR-13 PDB1
```

Identifying Which Services You Have

The following query enables you to find out which services you have:

```
select name, service_id, con_name, con_id
from   v$active_services
order  by 1;

NAME            SERVICE_ID CON_NAME            CON_ID
--------------- ---------- --------------- ----------
SYS$BACKGROUND           1 CDB$ROOT                 1
SYS$USERS                2 CDB$ROOT                 1
cdb1                     6 CDB$ROOT                 1
cdb1XDB                  5 CDB$ROOT                 1
pdb1                     3 PDB1                     3
pdb_ss                   3 PDB_SS                   4
```

ALTER SYSTEM While in a PDB and Other Nice Commands

The following powerful DBA commands are not only part of the root database, but can be run at an individual PDB level:

CAUTION
These are very powerful commands to run at the PDB level (you should usually not run these in production). If you FLUSH the caches or change initialization parameters, it could seriously affect the performance of other sessions.

- ALTER SYSTEM FLUSH SHARED_POOL
- ALTER SYSTEM FLUSH BUFFER_CACHE
- ALTER SYSTEM SET USE_STORED_OUTLINES
- ALTER SYSTEM CHECKPOINT
- ALTER SYSTEM KILL SESSION
- ALTER SYSTEM DISCONNECT SESSION
- ALTER SYSTEM SET *initialization_paramete*r

Modifying Initialization Parameters for a Given PDB

There are also initialization parameters that can be set even at an individual PDB level (Chapter 4 covers initialization parameters in detail), as follows:

```
select name from v$parameter
where  ispdb_modifiable = 'TRUE'
and    name like 'optim%';

NAME
----------------------------------------
optimizer_adaptive_reporting_only
optimizer_capture_sql_plan_baselines
optimizer_dynamic_sampling
optimizer_features_enable
optimizer_index_caching
optimizer_index_cost_adj
optimizer_mode
optimizer_use_invisible_indexes
optimizer_use_pending_statistics
optimizer_use_sql_plan_baselines
10 rows selected.
```

Using RMAN Commands

The RMAN commands that can be executed for a database are the same for a given PDB. A few examples are displayed here:

```
RMAN> alter pluggable database pdb1 close;
RMAN> restore pluggable database pdb1;
RMAN> recover pluggable database pdb1 until SCN 777070;
RMAN> alter pluggable database pdb1 open resetlogs;
```

Using In-Memory (IM) with Pluggable Databases

Pluggable databases can also use the In-Memory (IM) column store (which is an option you must license and is covered in Chapter 4). While you can set the INMEMORY_SIZE parameter for the entire database, you can also set the INMEMORY_SIZE for individual PDBs. You can additionally *oversubscribe* the INMEMORY_SIZE of the main database (the sum of the PDBs can be more than the main database setting). What will happen as you use up the memory? When you are out, you are out, so whoever gets it first when it is oversubscribed is how it works.

The following are some other notes on using IM with PDBs:

- All PDBs within a CDB share a single IM column store set at the CDB.
- There is an INMEMORY_SIZE initialization parameter on the CDB.
- Each PDB also sets an INMEMORY_SIZE and anything put in IM comes from total CDBs IM.
- All PDBs added together can be higher than CDBs IM (oversubscribed); used on a first-come basis, by design, to ensure this CDB IM is not wasted.
- One PDB can take up the entire CDB IM and starve other PDBs.
- Each PDB has its *own* PRIORITY list (see Chapter 4 for additional information; which PDB starts first will matter *a lot* because it will get more IM!). When you are out of space, you are out until a PDB shuts down or something is removed from the IM.

Other 12*c*R2 Features with Pluggable Databases

The following are other 12*c*R2-only features of pluggable databases:

- The source no longer needs to be read-only when cloning a PDB (point-in-time clone).
- You can do a PDB refresh of clones manually or automatically (they must be read-only).
- You can create a class of PDB (Gold/Silver/Bronze) by setting DB_PERFORMANCE_PROFILE and then using Resource Manager to set directives for each class of PDB.
- You can do a flashback of a PDB and restore points to *only* that PDB!
- You can build a subset standby (introduced next) of just one or a portion of your PDBs!
- You can now have 4096 PDBs, not just 252.

Subset Standby (New in Oracle 12*c*R2)

The new subset standby feature allows a standby database in a multitenant environment to have a standby without having to take all the PDBs into the standby. Keep in mind this impacts switchover and failover operations, so you should understand the impact that only a subset of PDBs has on switchover and failover operations.

TIP
One of the best features of 12cR1 is pluggable databases. It offers the ability to consolidate hundreds of databases into a single container database (CDB) with hundreds of pluggable databases (PDBs). Two of the best features of 12cR2 are the ability to flashback pluggable databases (PDBs) and the ability to build a subset standby with only some PDBs.

Disk Arrays

Configuring disks with RAID (Redundant Array of Independent/Inexpensive Disks) is now the norm. RAID is here to stay, and one would be hard pressed to buy even a midrange system without it. Later in this chapter, you'll see that ASM also provides levels of redundancy. Even in the personal computing area, using some hardware-based configuration of redundant disks has become more commonplace. For the DBA, this means that more than ever, care must be taken to ensure that the disk array configuration used enhances I/O while also providing appropriate protection against drive failure. Regardless of whether the RAID configuration is hardware- or software-based (hardware-based is usually faster), the configuration should be configured properly for best performance, without sacrificing protection.

Use Disk Arrays to Improve Performance and Availability

A RAID logical unit number (LUN) is created by grouping several disks in such a way that the individual disks act as one logical disk (grouped into a volume or virtual disk). Prior to the advent of the storage area network (SAN), a LUN was the address (number) for the disk drive. During normal operation, a single logical device now gets the benefit of having multiple physical devices behind it, which means faster access to data (when configured properly) and the ability to have storage volumes that are significantly greater than the physical limit of an individual device. If a disk fails and all the data on the disk is destroyed, the group of disks can be structured so the data exists in more than one place. The system never goes down because of the failure of a single disk (when the proper RAID level is employed). Users continue to operate as if nothing has happened. The system alerts the system administrator that a specific disk has failed. The administrator pulls out the disk and slides in a new disk. The hardware controller or operating system automatically writes the missing information on the new disk. The system goes on without missing a beat.

How Many Disks Do You Need?

I know the hardware vendors out there are going to love me for saying this, but it is true. A good rule of thumb on buying disks in today's market is "Don't buy disks on the basis of capacity alone." If you have a moderately sized database at 10T, where performance is very important, why would you buy 600G SAS disks instead of 2T SATA disks to run it? Speed and data distribution—that's why. SAS disks at 15,000 RPMs are much faster than SATA at 7,200 RPMs, but the infrastructure and tools surrounding SAS are also faster. With disk capacities hovering between 300G to 2T, this choice can be hard to rationalize, but too often lately I have seen people make disk purchase choices on capacity alone. This leaves them with inadequate redundancy (when they forget about mirroring costs), poor performance (using slower disks), or both. You can certainly still use the slower 2T disks for online backups, archived information, or very old information. Remember, after you configure that 2T disk properly, you may have only less than 1T of usable storage (after mirroring, etc.). Whatever you do, try to use the high-speed 15,000 RPM SAS disks for your most important databases. There are now 8T drives in a full X6-2 Exadata or an entire Flash Array of storage, but you only get 180T in the same X6-2. These are the questions that techs must ask the business so the correct choices are made.

Consider speeds of different types of hardware:

- Memory: Nanoseconds
- 10 Gigabit Ethernet (GbE) network: 50 microseconds
- Flash: 20 to 500 microseconds
- Disk: 4 to 7 milliseconds

What Are Some of the RAID Levels Available?

Almost every midrange to enterprise-class server today offers a hardware RAID solution either built into the server or as an attached storage device. Using the various available RAID levels is pretty much standard, regardless of the type of array you buy. The following list describes some of the more common options that Oracle database administrators will want to consider:

- **RAID 0 (Striped Set)** Automatic disk striping means that the Oracle datafiles are automatically spread across multiple disks. The tablespace's corresponding datafile pieces can be spread across and accessed from many disks at the same time instead of from one (a large savings in disk I/O). Just be wary; this isn't a solution for high availability or fault tolerance, as a loss of one disk in the group means all the data needs to be recovered.
- **RAID 1 (Mirrored Set)** Automatic disk mirroring is available on most systems today. It's generally used for the operating system itself but can be used with the Oracle database for higher availability. You need twice the storage compared to the amount of data that you have for RAID 1.
- **RAID 5 (Striped Set with Parity)** This level carries the parity on an extra disk, which allows

for media recovery. Heavy read applications get the maximum advantage from this disk array distribution. This solution is low-cost and generally very bad for write-intensive Oracle applications. I will discuss improvements to this more in the next section.

- **RAID 1+0 (RAID 10, a Stripe of Mirrors)** Mirrored disks that are then striped. This level is a common Oracle OLTP production RAID level, also known as "RAID 10." RAID 1+0 incorporates the advantages of the first two RAID levels by adding the disk I/O striping benefit of RAID 0 to the mirroring provided by RAID 1. For high read/write environments such as OLTP, where sporadic access to data is the norm, this RAID level is highly recommended.
- **RAID 0+1 (RAID 01, a Mirror of Stripes)** Striped disks that are then mirrored. Often confused with RAID 10 or thought not to exist, this level incorporates the advantages of the first two RAID levels by providing the disk I/O striping benefit of RAID 0 to the mirroring provided by RAID 1. For high read/write environments such as OLTP, where sporadic access to data is the norm, this RAID level is good, but it is *not* as robust as RAID 10, and it cannot tolerate two disk failures if they are from different stripes. Also, in a rebuild after failure, all the disks in the array must participate in the rebuild, which is also not as favorable as RAID 10.
- **RAID 1+0+0 (RAID 100, a Stripe of RAID 10s)** Mirrored disks that are then striped and then striped again (usually with software, the top-level stripe is a MetaLun or soft stripe). The advantages are mainly for random read performance improvement and the elimination of hotspots.

The Newer RAID 5

Many hardware vendors configure systems with a RAID 5 configuration to maximize the utilization of available space on disk and reduce the overall cost of the array. Although RAID 5 is a good choice for inexpensive redundancy, it is usually a poor choice for write-intensive performance. At the most general level, when a write request is made to a RAID 5 array, the modified block must be changed on disk; a "parity" block is read from disk; and using the modified block, a new parity block is calculated and then written to disk. This process, regardless of the size of the write request, can limit throughput because for every write operation, there are at least two more I/O operations. I recommend RAID 5 only for mostly read or read-only filesystems. Most storage vendors realize that this parity write is a penalty and have come up with various solutions to reduce the impact of this additional operation. The most common solution is to implement a memory cache on the array to speed up the write performance of all I/O on the array. For periodic or light write activity, this solution may be completely suitable for your system, but you need to remember that eventually those write operations need to make it to disk. If you overload that disk cache with heavy write activity, you may produce what is often referred to as a "serialized I/O" condition. This is where the array can't write to disk fast enough to clear the cache, essentially neutralizing the benefit of your cache. Be sure to check out other solutions that your vendor may have implemented. Don't be afraid to ask them how they handle heavy I/O. Some solutions to look for are

- **Dynamic cache management** This is the ability for the array to adjust the way that the cache is being used. Some vendors simply split the cache down the middle—if you have 1G of cache, 500M is for read and 500M is for write. Because the Oracle buffer cache is essentially already a read cache, being able to adjust the array cache so it is primarily a write cache can give you some flexibility. This ability to adjust the array cache to be primarily a write cache goes for other configurations other than just RAID 5.
- **Bundled writes** Generally, the maximum size of a write operation is larger than an Oracle block. Some vendors have implemented intelligence into their arrays that allows them to group multiple parity operations into a single I/O operation. Because this requires fewer round trips to the physical disk, it can greatly improve the performance and effectiveness of the cache when running RAID 5.

RAID 6 is another variant of RAID 5 that you may also see advertised. RAID 6 behaves just like RAID 5, except it utilizes corresponding parity blocks for every set of data block stripes. While this does carry the added benefit of more fault tolerance, because you can lose two disks, it also brings with it even lower performance.

I still prefer to see RAID 1+0 (mirroring and then striping). RAID 1+0 (aka RAID 10) is generally going to be faster or at least as fast as RAID 5 and natively more fault tolerant to multiple device failures. Because you may be in a situation where you have multiple physical enclosures for your disk, using striping and mirroring allows you to build fault tolerance between enclosures too.

Solid-State Disks

Solid-state disk (SSD) data is stored and accessed in dynamic random access memory (DRAM), which in turn improves performance by avoiding the disk I/O that is typical of magnetic disks. Magnetic disk latency includes *rotational delay*, which is the time taken for a disk platter to revolve until the desired storage address is found. Disk I/O service time influences performance on databases and applications; with SSDs, service times are very fast because SSDs do not perform the costly disk operations such as disk rotation that cause the delays incurred by magnetic disks. Oracle recommends storing REDO logs, undo datafiles, and TEMP tablespace on SSD storage media to achieve better read/write performance and reduce I/O waits. What do Google, Facebook, and Amazon all have in common? Their data centers are “racks of flash” as far as the eye can see! Do you want your company to be a leader? Get an X6-2 with all flash storage (180T) or, if you need more storage, get an FS1 (Oracle’s all flash array) with a petabyte of storage. Be the leader or be left behind!

ASM Storage Management (Striping/Mirroring)

A database created under the constructs of ASM (much of this chapter is dedicated to ASM) will be striped by default and mirrored as specified in the stripe-and-mirror-everything (SAME) methodology (i.e., the I/O load is evenly distributed and balanced across all disks within the diskgroup). The striping is done on a file-by-file basis, using a 1M stripe size, as opposed to other logical volume managers (LVMs) that perform striping and mirroring at a disk-volume level. Oracle states that an ASM 1M stripe depth has proved to be the best stripe depth for Oracle databases. This optimal stripe depth, coupled with even distribution of extents in the diskgroup, reduces the occurrence of hot spots.

ASM allocates space in units called *allocation units (AUs)*. ASM always creates one-AU extents (not the same as tablespace extents) across all of the disks in a diskgroup. For diskgroups with similarly sized disks, there should be an equal number of AU extents on every disk. A database file is broken up into file extents. There are two types of AU extent distributions: coarse and fine. For coarse distribution, each coarse-grain file extent is mapped to a single AU. With fine-grain distribution, each grain is interleaved 128K across groups of eight AUs. Fine distribution breaks up large I/O operations into multiple 128K I/O operations that can execute in parallel, benefiting sequential I/Os. Coarse- and fine-grain attributes are predefined, as part of system templates, for all system-related files.

TIP
Redo and archive log files are defined as fine-grained, whereas datafiles are coarse.

Setup and Maintenance of the Traditional Filesystem

Using RAID-configured groups of physical devices and traditional filesystems makes Oracle datafile setup and maintenance *much* easier for the DBA because manually balancing disks is not as arduous. With the large disk sizes in today's storage systems, dissecting filesystem configuration between four or six devices quickly becomes an exercise in splitting hairs. Unless you are utilizing a system where 12 or more physical disks are involved, dividing these up into more than one logical disk device provides only a small benefit. Even if you have a case where two datafiles are heavily utilized, the cache or host bus adapter (HBA) that they share on the array may be a common avenue to the disk. Finally, depending on your expected growth, the number of filesystems you end up managing could, in time, make keeping all of this in balance a frustrating exercise.

TIP
Try to avoid splitting a logical device in a disk array into more than one filesystem. Splitting may seem to give you flexibility, but it can also increase the number of datafile locations you have to manage.

What Is the Cost?

To support disk arrays that mirror data, you need more—sometimes much more—raw disk storage (for RAID 1, you need at least double the space). While this requirement can increase the price of your initial system, the benefits are usually well worth it. For these reasons, while you are deciding how to configure the new storage system you are going to buy, think about the return on investment (ROI) for keeping the system up and running and also the value of great performance.

This leads me to another class of storage system that is becoming more popular. With the rising capacity of even the most basic storage array, companies are looking to leverage that storage space with *multinode* access technologies. Whether the implementation is as a storage area network (SAN) or network-attached storage (NAS), the initial investment and added benefit of being able to "plug in" another server to your storage system is often well worth it. So when you are faced with the dilemma of having a 4-Gbit/sec Fibre Channel (Exadata has 40-Gbit/sec each direction with InfiniBand) storage array with four disks and are feeling a bit like you aren't utilizing the resource to its maximum, consider expanding that purchase into an infrastructure decision that allows your enterprise to grow and share that resource among all your important systems.

TIP

Use disk arrays to improve performance and protect your data against disk failure. Choose the proper RAID level and technology solutions that enable you to maintain the availability your organization needs. Don't go "good enough," because you will regret it at 2 a.m. when you lose a disk.

Storing Data and Index Files in Separate Locations

Tables that are joined (simultaneously accessed during a query) often could also have their data and index tablespaces separated. The following example shows a table join and one possible solution for managing the data:

```
select  COL1, COL2, ....
from    CUST_HEADER, CUST_DETAIL
where   ...;
```

Here is a data management solution:

```
Disk1: CUST_HEADER Table
Disk5: CUST_HEADER Index
Disk8: CUST_DETAIL Table
Disk12: CUST DETAIL Index
```

This solution allows the table join to be done while accessing four different disks and controllers. Separate data and index files onto different physical disk devices and controllers; consequently, when tables and indexes are accessed at the same time, they will not be accessing the same physical devices. You could expand this to involve a larger number of disks. You will see later in the chapter that table and index partitioning will help you to accomplish this more easily. Oracle's ASM does a great job of assisting with this when you set it up, but it also has ways of moving *hot* data to a different part of a disk.

TIP
Separate key Oracle datafiles in traditional filesystems to ensure that disk contention is not a bottleneck. By separating tables and indexes of often-joined tables, you can ensure that even the worst of table joins do not result in disk contention. In Enterprise Manager (Cloud Control), Oracle makes it easy to move data to a hotter or colder region of a disk.

Avoiding I/O Disk Contention

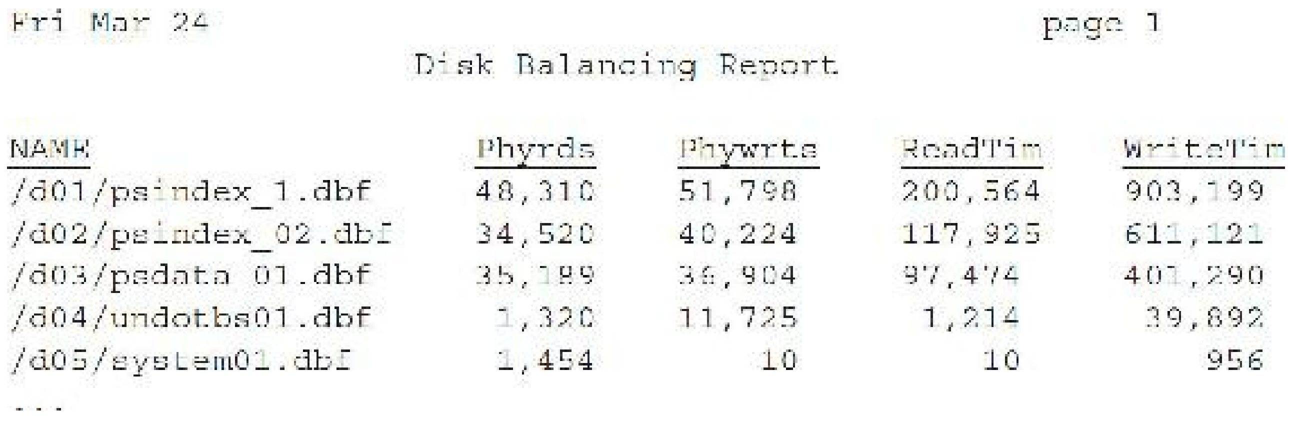
Disk contention occurs when multiple processes try to access the same physical disk simultaneously. Disk contention can be reduced, thereby increasing performance, by distributing the disk I/O more evenly over the available disks. Disk contention can also be reduced by decreasing disk I/O. To monitor disk contention, review the Database Files Metrics in Cloud Control. This Metric group contains two sets of metrics. The *Average File Read Time* and *Average File Write Time* apply to all datafiles associated with your database. If you find that one or two datafiles seem to have especially high values, you click one and then use the Compare Objects File Name link to view collected statistics between them. If they are both busy at the same time and are on the same disk, you may choose to relocate one datafile to another filesystem, if you are concerned about performance during that time.

You can also determine file I/O problems by running a query:

```
 col PHYRDS  format 999,999,999
 col PHYWRTS  format 999,999,999
 title  "Disk Balancing Report"
 col READTIM   format 999,999,999
 col WRITETIM   format 999,999,999
 col name format a40
 spool fio1.out

select  name, phyrds, phywrts, readtim, writetim
from    v$filestat a, v$datafile b
where   a.file# = b.file#
order   by readtim desc
/
spool off
```

Here is a partial query output:



```
Fri Mar 24                                              page 1
                    Disk Balancing Report

NAME                   Phyrds     Phywrts     ReadTim     WriteTim
/d01/psindex_1.dbf     48,310     51,798      200,564     903,199
/d02/psindex_02.dbf    34,520     40,224      117,925     611,121
/d03/psdata_01.dbf     35,189     36,904      97,474      401,290
/d04/undotbs01.dbf      1,320     11,725       1,214       39,892
/d05/system01.dbf       1,454         10          10          956
...
```

NOTE
You may also have SYSAUX01.DBF, USERS01.DBF, and EXAMPLE01.DBF.

A large difference in the number of physical writes and reads between disks may indicate that a disk is being overburdened. In the preceding example, filesystems 1–3 are heavily used whereas filesystems 4–5 are only lightly used. To get a better balance, you’ll want to move some of the datafiles. Splitting datafiles across multiple disks or using partitions would also help move access to a table or an index to an additional disk.

TIP
Query V$FILESTAT and V$DATAFILE to see how effectively datafiles have been balanced. Note that temporary tablespaces are monitored using V$TEMPFILE and V$TEMPSTAT.

The 12*c* Heat Map and Automatic Data Optimization (ADO)

Even with better data/index placements on disks, there can be problems with how data inside the disks is stored. If a process is constantly accessing a certain data block, and that data block is on a disk that has poor latency, performance will be degraded. If multiple SAN tiers are used, and each SAN has different I/O capabilities, then it would be advisable to move the objects that are frequently used into one of the faster SAN disks and have the less-accessed data on slower SAN disks. Prior to 12*c*, we would manually move the hot objects to faster disks. We would query the V$SEGMENT_STATISTICS view and extract objects that are frequently used and manually move them to faster disks to eliminate issues. Starting with 12*c*, the process can be automated via the Heat Map and Automatic Data Optimization (ADO).

The new Heat Map is a feature in 12*c* that tracks usage information at a row and segment level. Data modifications are tracked at the row level and aggregated to the block level. The Heat Map tracks data modifications, table full scans, and index lookups at the segment level. It provides a detailed view of how data is being accessed and how access patterns are changing over time. The Heat Map, when enabled, automatically collects segment- and row-level statistics that can be used to define compression and storage policies, which will then be automatically maintained throughout the life cycle of the data (often referred to as information lifecycle management [ILM]). The Heat Map skips internal system tasks like gathering stats and system DDLs.

To enable the Heat Map:

```
SQL> alter system set HEAT_MAP = ON;    -- By default the value of OFF
```

DBA tables (see Figure 3-1) can be queried to retrieve detailed information for any objects captured. The V$HEAT_MAP_SEGMENT view displays real-time segment access information.

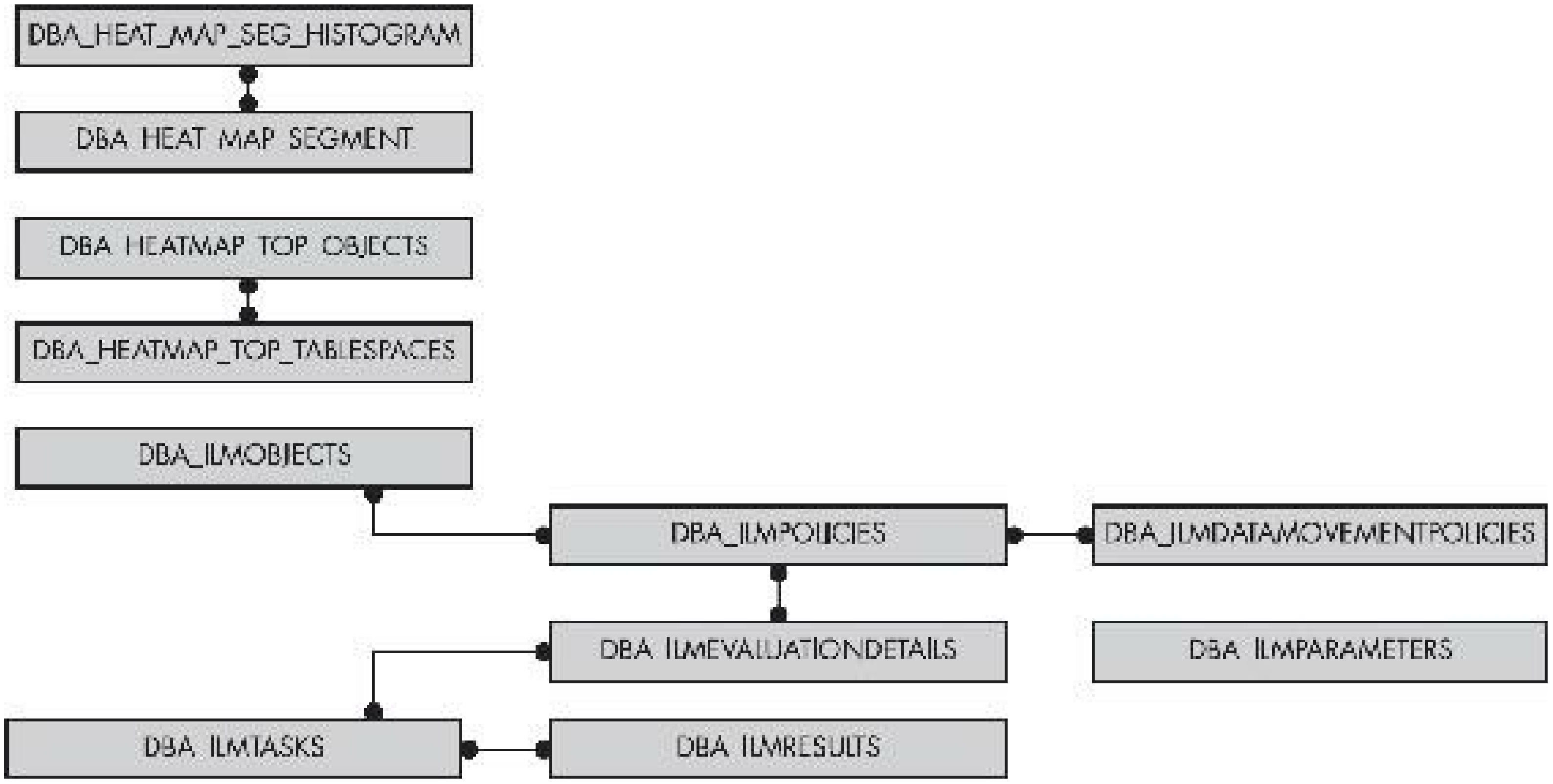


FIGURE 3-1. *Heat Map for segments*

Automatic Data Optimization allows the creation of policies for data compression and data movement. ADO works in conjunction with the Heat Map where information from the Heat Map is used in the compression policies. The Oracle database evaluates ADO policies during database maintenance windows and uses the information collected by the Heat Map to determine which operations to execute. ADO operations are executed automatically in the background with no user intervention. The policies ADO uses can be specified at the segment or row level for tables and table partitions. Policies will be executed automatically in the background when policy criteria are satisfied. Policies can also be executed manually.

This is done through the *ilm_clause* (*ilm* referring to information lifecycle management) of the CREATE TABLE and ALTER TABLE statements. The feature determines when data meets the policy standard for movement by the Heat Map, which is tracking changes to the table and table partitions. There are two types of policies, a *table_compression* or *tiering_clause*. When data meets the policy, the data is either compressed row level or segment level, or is moved to a new storage tier based on the policy criteria supplied in the AFTER clause of the policy.

Some parts of the *ilm_clause* are as follows:

- **ADD_POLICY** Specify the policy to add to the table.
- **DELETE** Delete a policy from the table.
- **ENABLE** Enable a policy for the table.
- **DISABLE** Disable a policy on the table.

The following are some parts of the AFTER clause of the policy:

- **LOW ACCESS** For policy to take effect after a period of time of low table access

- **NO ACCESS** For policy to take effect after a period of time of no table access
- **NO MODIFICATION** For policy to take effect after a period of time with no table changes
- **CREATION** For policy to take effect after a period of time after table creation

The following example shows how to compress a row after it has not been modified for seven days:

```
ALTER TABLE orders ILM ADD POLICY ROW STORE COMPRESS ADVANCED ROW AFTER 7 DAYS
OF NO MODIFICATION;
```

Even though ADO uses the Heat Map to determine which segments to move, you can also create custom conditions using PL/SQL functions to extend the flexibility of ADO (to use your own data to determine when to move or compress data). The Heat Map and ADO require purchasing the Advanced Compression option. In 12*c*R2, ADO is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics.

12*c* I/O Performance Tracking Views (Outliers)

Starting with 12*c*, Oracle provides dynamic views that give detailed analysis of I/O that takes a long time to complete (i.e., a large, slow report). The views are dynamically populated when the I/O has taken longer than 500 ms to complete. The default threshold of 500 ms can be modified by the hidden parameter _IO_OUTLIER_THRESHOLD.

- **V$IO_OUTLIER** Use this view to see if there are any occasional delays in servicing a disk I/O request by the storage subsystem.
- **V$LGWRIO_OUTLIER** Contains entries corresponding to Log Writer process that have taken longer than the default 500 ms to complete.
- **V$KERNEL_IO_OUTLIER** Use this view to see the individual kernel components of the I/O subsystem that have taken more than 500 ms to complete; *this view is specific to Solaris operating systems* and must meet conditions for it to be populated. On Solaris platforms, to have the view populated, the database should be configured to use ASM or raw devices and have the initialization parameter DISK_ASYNCH_IO=FALSE. Oracle uses Solaris DTrace functionality to populate this view.

Oracle Bigfile Tablespaces

Introduced in Oracle 10*g* was a locally managed tablespace type for extreme-size databases: *Bigfile tablespaces* allow for the creation of tablespaces with one file where the size of that datafile fully incorporates the power of 64-bit systems. When implemented with Oracle Managed Files (OMF) or ASM, bigfile tablespaces can greatly simplify the management of your storage system. Additionally, because you should have fewer datafiles, performance of database management operations such as checkpoints should improve, but be aware that recovery operation times are likely to increase in the event of datafile corruption.

Now you be may asking: “Then what is the benefit of bigfile tablespaces?” A bigfile tablespace, with a typical 8K block size, can contain a single 32T datafile. If you’re using a 32K block, it can contain a 128T datafile. This is achieved by changing the way ROWIDs are managed within the tablespace. In a traditional tablespace, three positions in the ROWID are used to identify the relative file number of the row. Because you only have one datafile in bigfile tablespaces, these three positions are instead used to lengthen the data block number for the row, thereby allowing for a much larger number of ROWIDs from traditional smallfile tablespaces.

NOTE
To have the largest Oracle 12c database possible, 8 exabytes, you must use 128T datafiles (and must also use bigfile tablespaces and a 32K block size).

To use bigfile tablespaces, you must be using locally managed tablespaces with Automatic Segment Space Management (ASSM), discussed later in the chapter. Also, you cannot use bigfile tablespaces for UNDO, TEMP, or SYSTEM. If you are thinking of using bigfile tablespaces to reduce the amount of management needed for your system, consider also using OMF and ASM (covered next). Also, if you are using traditional filesystems, make sure you are using a logical volume manager that provides the flexibility to map out your storage system appropriately so the single datafile can grow as needed.

ASM Introduction

In Oracle Database 10*g* Release 2, storage management and provisioning for the database has been greatly simplified using *Automatic Storage Management (ASM)*. ASM provides filesystem and volume manager capabilities built into the Oracle database kernel. In Oracle Database 11*g* and 12*c*, Oracle ASM as a technology is the best of all worlds, combining the benefits of using raw devices with the ease of management as seen with standard volume managers in UNIX. With this capability, ASM simplifies storage management tasks, such as creating/laying out databases and disk space management. Because ASM allows you to manage disks using familiar CREATE/ALTER/DROP SQL statements, DBAs do not need to learn a new skill set or make crucial provisioning decisions to use ASM. ASM is basically built on raw devices; therefore, it is also inherently cluster aware. The initial release of ASM was first built for a clustered database and then made available for nonclustered databases. An Enterprise Manager interface (see Chapter 5 for additional information), as well as a new command-line utility (new in Oracle Database 10*g* Release 2 and available in 11*g* and 12*c*), ASMCMD, is also available for those ASM administrators who are not familiar with SQL.

ASM is a management tool specifically built to simplify the DBA’s job. It provides a simple storage management interface across all server and storage platforms. ASM provides the DBA with flexibility to manage a dynamic database environment with increased efficiency. This feature is a key component of grid computing and database storage consolidation.

The following are some of ASM's key benefits:

- As good as raw devices from a performance perspective.
- An extremely simple, but powerful, volume manager toolkit/utility for managing the space from a database perspective.
- Spreads I/O evenly across all available disk drives to prevent hot spots and maximize performance.
- Eliminates the need for overprovisioning and maximizes storage resource utilization facilitating database consolidation.
- Inherently supports large files.
- Performs automatic online redistribution after the incremental addition or removal of storage capacity.
- Maintains redundant copies of data to provide high availability or leverage third-party RAID functionality.
- Supports Oracle Database 10*g*, 11*g*, 12*c*, and Oracle Real Application Clusters (RAC).
- The OCR and voting disk can be on the ASM diskgroup and cluster filesystem with ASM in 11*g*R2. With 12*c* password files can also be stored in the ASM diskgroup.
- Can leverage third-party multipathing technologies.
- Inherently capable of supporting async I/O as well as direct I/O.
- Fully integrated into Oracle Managed Files (OMF), thereby reducing complexity without compromising performance.
- Exadata only allows ASM!

For simplicity and easier migration to ASM, an Oracle 10*g*R2 and above database can contain ASM and non-ASM files. You can use the RMAN COPY command to move datafiles from the filesystem to an ASM diskgroup.

DBAs have much to consider before they deploy and create a database. They must consider and determine the following:

- Plan filesystem layout and device usage
- Determine application workload characteristics (random read/write for OLTP versus sequential I/O for DSS systems)
- Calculate storage capacity and sizing for the database

ASM addresses these concerns in the following ways:

- Traditionally, DBAs would create filesystems to store their database files, and then create additional filesystems as needed. Doing this can become a manageability and provisioning nightmare since DBAs also have to manage the I/O load on each filesystem. ASM presents a single storage pool (*diskgroup*), so there is no need to maintain several filesystem containers and no need to worry about the placement of the next datafile.

- One of the core benefits of ASM is the ability to expand storage to meet an application's capacity needs. Thus, the ASM diskgroup that houses the database can be expanded without worrying excessively about storage capability management.
- Using ASM and applying the defined general best practices, ASM-based databases should be able to handle any workload. Additionally, because ASM inherently uses raw devices, considerations such as async I/O and direct I/O become nonissues.

Communication Across IT Roles

Sometimes there is a disconnect among the DBA, system admin, and storage admin. The DBA asks for a 200G filesystem, the storage/system admin provides a 200G RAID 5 device or RAID 10 device that has an improper or inefficient stripe size, and performance starts to suffer. Later, the DBA finds out what was actually provisioned and isn't very happy.

DBAs and other technical IT roles will always experience some inherent level of disconnect because these groups think and operate differently. As this disconnect is mostly a communication issue, ASM doesn't necessarily fix it. However, several things come into play with ASM that have lessened this communication issue. First, Oracle published a paper called "Optimal Storage Configuration Made Easy." This paper proposed a stripe-and-mirror-everything (SAME) methodology. With this paper came a standard methodology for database deployment, which made DBA-storage admin communication much simpler because DBAs had a way to express what they needed.

NOTE
You can access "Optimal Storage Configuration Made Easy" at OTN: www.oracle.com/technetwork/database/focus-areas/performance/opt-storage-conf-130048.pdf.

ASM incorporates all the essentials of the SAME methodology. ASM also offers a streamlined approach to storage capacity management. With ASM, database storage can be expanded as business or capacity plans dictate, all with no application downtime.

ASM Instances

Starting with Oracle Database 10*g* (and continuing through 11*g*R2 and 12*c*), there are two types of instances: database and ASM instances. The ASM instance, which is generally named +ASM, is started with the INSTANCE_TYPE=ASM initialization parameter. This parameter, when set, signals the Oracle initialization routine to start an ASM instance, not a standard database instance. Unlike the standard database instance, the ASM instance contains no physical files, such as log files, control files, or datafiles, and requires only a few initialization parameters for startup.

Upon startup, an ASM instance will spawn all the basic background processes, plus some new ones that are specific to the operation of ASM. The STARTUP clauses for ASM instances are similar to those for database instances. For example, NOMOUNT starts up an ASM instance without mounting any diskgroup. The MOUNT option simply mounts all defined diskgroups. Oracle has continued to make great strides in how disks are accessed and configured using ASM. Prior to 12*c*, Oracle had tightly coupled configuration between databases and ASM instances on servers. Versions 10*g* and 11*g* required ASM and database instances to be on the same server. With new features of 12*c* ASM, this tightly coupled configuration for ASM and database instance has been loosened, and this provides for greater flexibility when managing ASM instances in a RAC environment.

Here is an example to query for the instance name that you are connected to:

```
select instance_name
from   v$instance;

INSTANCE_NAME
----------------
+ASM
```

The next example lists the various views that you can query to see the ASM configuration:

```
select name, type
from   v$fixed_table
where name like 'GV$%ASM%'
SYS@+ASM> /

NAME                           TYPE
------------------------------ -----
GV$ASM_TEMPLATE                VIEW
GV$ASM_ALIAS                   VIEW
GV$ASM_FILE                    VIEW
GV$ASM_VOLUME                  VIEW
GV$ASM_FILESYSTEM              VIEW
GV$ASM_ACFSVOLUMES             VIEW
GV$ASM_ACFSSNAPSHOTS           VIEW
GV$ASM_ACFS_SECURITY_INFO      VIEW
GV$ASM_ACFS_ENCRYPTION_INFO    VIEW
```

```
GV$ASM_VOLUME_STAT                VIEW
GV$ASM_CLIENT                     VIEW
GV$ASM_DISKGROUP                  VIEW
GV$ASM_DISKGROUP_STAT             VIEW
GV$ASM_DISK                       VIEW
GV$ASM_DISK_STAT                  VIEW
GV$ASM_DISK_IOSTAT                VIEW
GV$ASM_OPERATION                  VIEW
GV$ASM_ATTRIBUTE                  VIEW
GV$ASM_USER                       VIEW
GV$ASM_USERGROUP                  VIEW
GV$ASM_USERGROUP_MEMBER           VIEW
```

These views are also available under the database that is using ASM, sometimes with slightly different information, such as V$ASM_CLIENT.

ASM Initialization Parameters

The list that follows shows some of the basic initialization parameters required to start ASM (in 12*c*). Observe that all ASM processes begin with *asm*, as opposed to the database processes, whose names begin with *ora*.

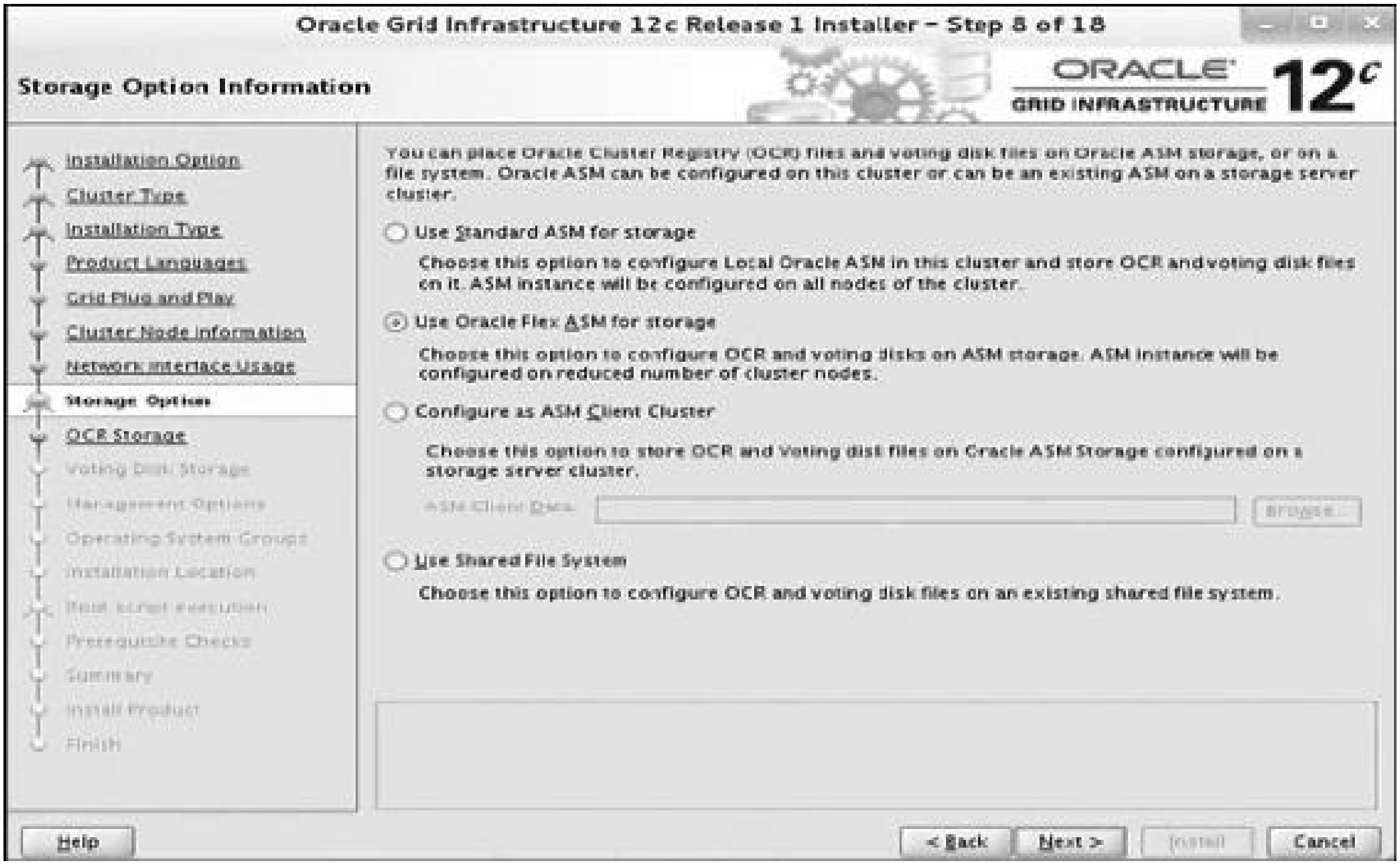
```
+ASM1.__oracle_base='/u01/app/grid_base'#ORACLE_BASE set from in memory value
+ASM2.__oracle_base='/u01/app/grid_base'#ORACLE_BASE set from in memory value
*.asm_diskgroups='DB_DISK'#Manual Mount
*.asm_diskstring='AFD:*'
*.asm_power_limit=1
*.large_pool_size=12M
*.remote_login_passwordfile='EXCLUSIVE'
```

In 11*g* and 12*c*, DBAs who use ASM tend to use AUTOMATIC MEMORY MANAGEMENT, so it uses the initialization parameters MEMORY_TARGET and MAX_MEMORY_TARGET:

```
SYS@+ASM> show parameter mem  (partial listing of key values only)
NAME                                 TYPE        VALUE
------------------------------------ ----------- ------------------------------
memory_max_target                    big integer 272M
memory_target                        big integer 272M
```

ASM Installation in 12*c*

Installation of 12*c* Grid Infrastructure (GI) is very similar to the 11*g* version except for the additional features related to Flex ASM and the option for using IPv4/IPv6, ASM private network, and Grid Infrastructure Management Repository (MGMTDB, required on 12.1.0.2, Doc ID *1568402.1*). During the GI installation, you have the option to choose the typical cluster (similar to 11*g*) or to enable Flex Cluster. If you choose the standard-cluster option and then the advanced configuration option during installation, it will provide an option for configuring Flex ASM (see Figure 3-2).



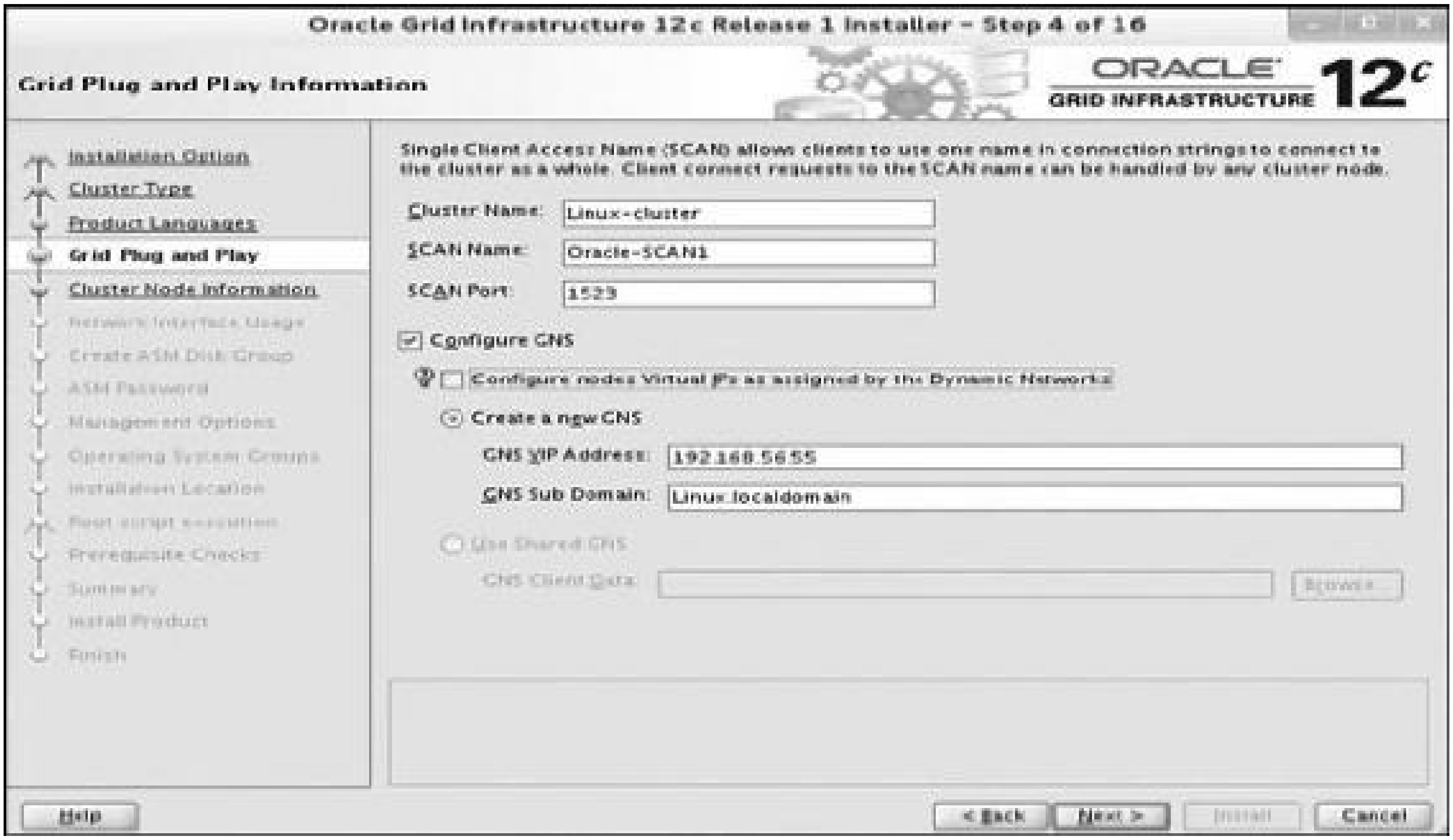
You can place Oracle Cluster Registry (OCR) files and voting disk files on Oracle ASM storage, or on a file system. Oracle ASM can be configured on this cluster or can be an existing ASM on a storage server cluster.

- ○ Use Standard ASM for storage
  Choose this option to configure Local Oracle ASM in this cluster and store OCR and voting disk files on it. ASM instance will be configured on all nodes of the cluster.
- [✓ Use Oracle Flex ASM for storage]
  Choose this option to configure OCR and voting disks on ASM storage. ASM instance will be configured on reduced number of cluster nodes.
- ○ Configure as ASM Client Cluster
  Choose this option to store OCR and Voting disk files on Oracle ASM Storage configured on a storage server cluster.
- ○ Use Shared File System
  Choose this option to configure OCR and voting disk files on an existing shared file system.

FIGURE 3-2. *ASM installation—storage options*

One of the requirements for configuring Flex ASM is Grid Naming Service (GNS). GNS simplifies client connections to servers, especially when the cluster has a large number of nodes. The GNS daemon dynamically collects cluster information and passes it to the DNS server for name resolutions. To configure GNS you must obtain a static public IP address from your network administrator. The DNS server must be configured to forward all cluster IPs to the GNS VIP. The GNS daemon and VIP will *run on a single node of the cluster*. Oracle clusterware manages the GNS services and will perform failover if GNS service fails.

Figure 3-3 must be completed if Flex ASM is to be configured; the GNS VIP is required even if you are not planning on using GNS.



Single Client Access Name (SCAN) allows clients to use one name in connection strings to connect to the cluster as a whole. Client connect requests to the SCAN name can be handled by any cluster node.

Cluster Name: Linux-cluster
SCAN Name: Oracle-SCAN1
SCAN Port: 1523

[✓] Configure GNS

[ ] Configure nodes Virtual IPs as assigned by the Dynamic Networks

(•) Create a new GNS

GNS VIP Address: 192.168.56.55
GNS Sub Domain: Linux.localdomain

( ) Use Shared GNS

GNS Client Data:

FIGURE 3-3. *ASM installation—GNS information*

How does GNS get the cluster names and the corresponding node addresses? This information is collected when cluster services start and DHCP provides cluster IPs to the clusterware during startup; the cluster IPs are then automatically registered with GNS. After installation, you can view which node is running the GNS VIP by issuing the following command:

```
[oracle@Linux71 ~]$ olsnodes -n -a
linux71 1       Hub
linux72 2       Hub

[oracle@Linux71 ~]$ srvctl status gns -node linux72
GNS is not running on node linux72.
GNS is enabled on node linux72.

[oracle@Linux71 ~]$ srvctl status gns -node linux71
GNS is running on node linux71.
GNS is enabled on node linux71.

[oracle@Linux71 ~]$ srvctl status gns
GNS is running on node linux71.
GNS is enabled on node linux71.
```

Oracle 12*c* Has Introduced Oracle Flex ASM

Flex ASM can be enabled during the initial installation of Grid Infrastructure by choosing Advanced Installation and choosing Use Oracle Flex ASM for Storage. This is relevant only when the cluster is installed and not for a single-instance configuration. Also, an existing non-Flex cluster can be converted to Flex using the "asmca" GUI tool. Once Flex ASM is configured, the process cannot be reverted to a standard ASM cluster.

To confirm Flex is enabled:

```
ASMCMD> showclustermode
ASM cluster : Flex mode enabled
ASMCMD>
ASMCMD> showclusterstate
Normal
```

Oracle Flex ASM allows database clients to connect to remote ASM instances if the local ASM instance fails. When configuring Flex ASM, a private ASM network is added during installation for communicating between ASM instances in a cluster. When an ASM instance fails, databases running on the failed ASM instance are automatically connected to surviving ASM instances on the cluster via the ASM network. It is strongly recommended to configure a separate network interface for ASM even though it is possible to use the private cluster interconnect for ASM communication. When an ASM instance fails in Flex configuration, Oracle Clusterware will start a new ASM instance on a different server to maintain the cardinality setting. ASM cardinality settings determine how many ASM instances will be available in a cluster at any time. The default value for ASM cardinality is 3, and this value can be changed using the `srvctl` command.

To view ASM cardinality value:

```
[oracle@Linux71 ~]$ srvctl config asm
ASM home: <CRS home>
Password file: +OCR_DISK/orapwASM
ASM listener: LISTENER
ASM instance count: 3
Cluster ASM listener: ASMNET1LSNR_ASM
[oracle@Linux71 ~]$
```

From the preceding output, "ASM instance count : 3" shows the default setting. This setting can be changed dynamically by `srvctl modify asm -count <`*`value`*`>`:

```
[oracle@Linux71 ~]$ srvctl modify asm -count 2
[oracle@Linux71 ~]$
[oracle@Linux71 ~]$ srvctl config asm
ASM home: <CRS home>
Password file: +OCR_DISK/orapwASM
ASM listener: LISTENER
ASM instance count: 2
Cluster ASM listener: ASMNET1LSNR_ASM
[oracle@Linux71 ~]$
```

When the ASM cardinality value is modified, the clusterware automatically adjusts the number of ASM instances on the cluster. For example, before modifying the ASM cardinality value to 2, the two-node test RAC with Flex ASM configuration showed the third ASM instance as OFFLINE, which is due to the default cardinality value (3) for enabling Flex ASM. Even though there is not a third node, clusterware will show three entries for ASM. If we set the cardinality value to 5, it will show five ASM entries with three as OFFLINE, and this is done dynamically by clusterware. This configuration allows the flexibility to scale up or down as needed.

The following example shows cardinality value 5 where only two servers exist:

```
srvctl modify asm -count 5
crsctl stat res -t
ora.asm
      1        ONLINE  ONLINE      linux71                 Started,STABLE
      2        ONLINE  ONLINE      linux72                 Started,STABLE
      3        OFFLINE OFFLINE                             STABLE
      4        OFFLINE OFFLINE                             STABLE
      5        OFFLINE OFFLINE                             STABLE
```

The minimum value for setting cardinality value is 2:

```
[oracle@Linux71 ~]$ srvctl modify asm -count 1
PRCA-1123 : The specified ASM cardinality 1 is less than the minimum
cardinality of 2.
```

Figure 3-4 shows a three-node Flex ASM configuration using cardinality 2. ASM is running on Server1 and Server3 which is consistent with the cardinality rule of two ASM instances. Server2, where ASM is not running, is the client database server. This server uses the ASM network to communicate with the Flex ASM server to retrieve ASM metadata. If the ASM instance fails on Server3, clusterware will automatically start an ASM instance on Server2 to confine to the cardinality value 2 where at least two ASM instances need to be online, and the database on Server3 will automatically connect to the surviving Flex ASM instances.

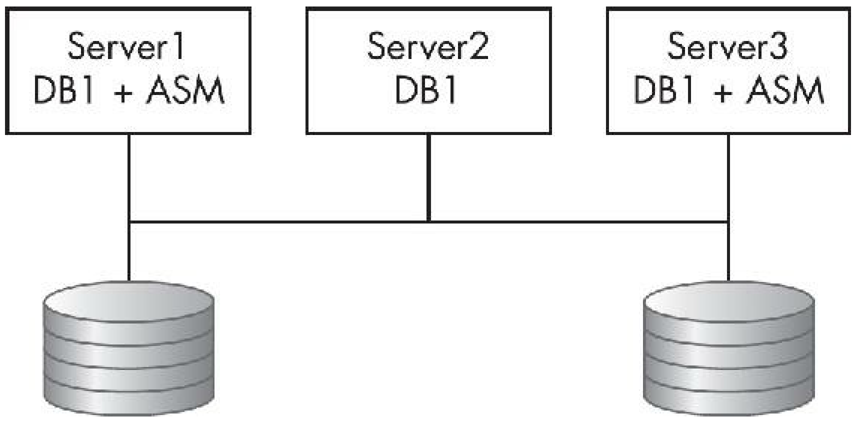


FIGURE 3-4. *Three-node Flex ASM configuration*

In a Flex ASM environment, the database instances that are connected to ASM will seamlessly connect to the surviving ASM nodes. This can be tested by forcing the ASM instance down, as shown next. If a database instance is connected to an ASM instance, then we cannot just shut down the ASM instance; otherwise it will result in an error, stating the diskgroups will need to be relocated.

```
[oracle@Linux72 ~]$ srvctl stop asm -n Linux72
PRCR-1014 : Failed to stop resource ora.asm
PRCR-1065 : Failed to stop resource ora.asm
CRS-2529: Unable to act on 'ora.asm' because that would require stopping or
relocating 'ora.DB DISK01.dg', but the force option was not specified
[oracle@Linux72 ~]$
```

As the preceding error states, it will need to be forced down by executing the command following this paragraph. It's very important to note that you should only try this when Flex ASM is enabled and the database version is 12.1 or higher. Database versions earlier than 12.1 will require an ASM instance running on the same node as the database, and if ASM is forced down on an 11*g* database, it will bring ASM and the database down. Execute this command on a Flex ASM 12*c* database to force ASM down on a node and have the database automatically connect to a surviving ASM instance:

```
srvctl stop asm -node Linux72 -stopoption abort -force
```

When the force shutdown of the Flex ASM instance completes, the database alert log will show that the database has registered with the ASM instance on the surviving Flex ASM node. The database alert log will show entries similar to these:

```
NOTE: ASMB registering with ASM instance as Flex client 0x10001
(reg:3817686277) (reconnect)
NOTE: ASMB connected to ASM instance +ASM1 osid: 14953 (Flex mode; client id
0x10001)
NOTE: ASMB rebuilding ASM server state
NOTE: ASMB rebuilt 1 (of 1) groups
NOTE: ASMB rebuilt 19 (of 19) allocated files
NOTE: fetching new locked extents from server
NOTE: 0 locks established; 0 pending writes sent to server
SUCCESS: ASMB reconnected & completed ASM server state
```

Once the database has switched over to the surviving Flex ASM instance, all ASM metadata is retrieved from the surviving ASM instance. Output of `crsctl stat res -t` would show ASM and diskgroups as "offline" where the shutdown command was executed. The view V$ASM_CLIENT will show to which ASM instance the database has connected; the view can be queried from the database or from an ASM instance:

```
select     inst_id,instance_Name,db_name,status,
            software_version,COMPATIBLE_VERSION
from        gv$asm_client;

   INST_ID INSTANCE_NAME   DB_NAME  STATUS       SOFTWARE_V COMPATIBLE
---------- --------------- -------- ------------ ---------- ----------
         2 +ASM1           oradb_cd CONNECTED    12.1.0.2.0 12.0.0.0.0
         1 +ASM1           oradb_cd CONNECTED    12.1.0.2.0 12.0.0.0.0
```

The preceding output shows a two-node RAC instance (column INST_ID 1 and 2) where +ASM1 is hosting both RAC databases (oradb_cd). Typically you would see +ASM1 for the first instance and +ASM2 for the second instance. This is because the ASM instance is down on instance 2 and Flex ASM has connected the database to the surviving ASM instance on instance 1. Even after the failed ASM instance on Node 2 is brought online, the database connection will remain on instance 1 until it's relocated back to instance 2 or a cluster bounce. To move the database back to the original ASM instance, first connect to the ASM instance that is currently hosting the database, and after confirming ASM and the diskgroup are online on the destination node, issue the RELOCATE command shown a bit later.

Before relocating the database:

```
select     inst_id,instance_Name,db_name,status,
            software_version,COMPATIBLE_VERSION
from        gv$asm_client;


   INST_ID INSTANCE_NAME   DB_NAME  STATUS       SOFTWARE_V COMPATIBLE
---------- --------------- -------- ------------ ---------- ----------
         2 +ASM1           oradb_cd CONNECTED    12.1.0.2.0 12.0.0.0.0
         1 +ASM1           oradb_cd CONNECTED    12.1.0.2.0 12.0.0.0.0
```

Start ASM on Node 2:

```
[oracle@Linux72 ~]$ srvctl start asm -n Linux72
[oracle@Linux72 ~]$
[oracle@Linux72 ~]$ ps -ef|grep smon
root      3649     1  0 13:52 ?        00:01:21 /u01/app/12.1.0/grid/bin/osys
mond.bin
oracle    9977     1  0 16:13 ?        00:00:00 asm_smon_+ASM2
```

Connect to the surviving ASM instance where the database that needs to be migrated resides and issue the RELOCATE command. We need to relocate the instance named oradbcd2 to ASM2.

```
select    inst_id,instance_Name,db_name,status,
           software_version,COMPATIBLE_VERSION
from        gv$asm_client;

  INST_ID INSTANCE_NAME   DB_NAME  STATUS       SOFTWARE_VERSIO COMPATIBLE_VERS
---------- --------------- -------- ------------ --------------- -------------
         1 oradbcd1        oradb_cd CONNECTED    12.1.0.2.0      12.1.0.2.0
         1 oradbcd2        oradb_cd CONNECTED    12.1.0.2.0      12.1.0.2.0
         1 +ASM1           +ASM     CONNECTED    12.1.0.2.0      12.1.0.2.0
         1 +ASM1           +ASM     CONNECTED    12.1.0.2.0      12.1.0.2.0
```

Connect as sysasm:

```
SQL> alter system relocate client 'oradbcd2:oradb_cdb';
System altered.
```

After issuing the RELOCATE command, you can see that the INST_ID for oradbcd2 has changed to INST_ID 2, which means ASM2 is hosting the database:

```
   INST_ID INSTANCE_NAME    DB_NAME   STATUS        SOFTWARE_VERSIO COMPATIBLE_VERS
---------- ---------------- -------- ------------ --------------- ---------------
         1 oradbcd1         oradb_cd CONNECTED    12.1.0.2.0      12.1.0.2.0
         1 +ASM1            +ASM     CONNECTED    12.1.0.2.0      12.1.0.2.0
         1 +ASM1            +ASM     CONNECTED    12.1.0.2.0      12.1.0.2.0
         2 oradbcd2         oradb_cd CONNECTED    12.1.0.2.0      12.1.0.2.0
```

You can confirm this by connecting to the oradbcd2 instance and querying V$ASM_CLIENT:

```
select     instance_Name,db_name,status,software_version,COMPATIBLE_VERSION
from         v$asm_client;

INSTANCE_NAME    DB_NAME  STATUS       SOFTWARE_VERSIO COMPATIBLE_VERSION
---------------- -------- ------------ --------------- --------------------
+ASM2            oradb_cd CONNECTED    12.1.0.2.0      12.0.0.0.0
```

Flex ASM uses the ASM network settings defined during the install. A new ASM listener is enabled with default port 1522 that connects to ASM on remote servers. Local ASM listener runs on each node where the Flex ASM instance is running. Connections are load balanced across the ASM cluster.

```
[oracle@Linux71 bin]$ lsnrctl services ASMNET1LSNR_ASM

Connecting to (DESCRIPTION=(ADDRESS=(PROTOCOL=IPC)(KEY=ASMNET1LSNR_ASM)))
Services Summary...
Service "+ASM" has 2 instance(s).
  Instance "+ASM1", status READY, has 2 handler(s) for this service...
    Handler(s):
      "DEDICATED" established:0 refused:0 state:ready
         REMOTE SERVER
         (DESCRIPTION=(ADDRESS=(PROTOCOL=TCP)(HOST=192.168.1.120)(PORT=1522)))
      "DEDICATED" established:0 refused:0 state:ready
         LOCAL SERVER
  Instance "+ASM2", status READY, has 1 handler(s) for this service...
    Handler(s):
      "DEDICATED" established:0 refused:0 state:ready
         REMOTE SERVER
         (DESCRIPTION=(ADDRESS=(PROTOCOL=TCP)(HOST=192.168.1.121)(PORT=1522)))
The command completed successfully
```

Connecting to the remote ASM instance requires an ASM password file. ASM password files are automatically created during installation. 12*c* ASM password files are kept in the ASM diskgroup, so this information is shared within the cluster. If there is a need to create the password file, the new `orapwd` utility now accepts a diskgroup for storing the password file.

To create an ASM password file:

```
orapwd file ='+OCR_DISK' asm=y
```

To create a database password file:

```
orapwd file='+OCR DISK' password=****** dbuniquename=orcl
```

To view the Flex ASM password file:

```
ASMCMD> pwd
+OCR DISK
ASMCMD> ls -l
Type      Redund  Striped  Time                Sys  Name
                                               Y    ASM/
                                               Y    Linux-cluster/
                                               Y    _MGMTDB/
PASSWORD  UNPROT  COARSE   MAR 10 11:00:00     N    orapwasm => +OCR DISK/ASM/
PASSWORD/pwdasm.256.906118657
```

Importantly, note that Oracle 12*c* requires an ASM diskgroup compatibility setting of 12.1.0.0 or higher for storing password files in ASM. The compatibility setting can be modified by using the "asmca" GUI tool or by issuing the following command:

```
alter diskgroup <diskgroup name> attribute 'compatible.asm' = '12.1';
```

If the password diskgroup compatibility setting is incorrect, then you will receive an error when creating the database.

Oracle provides an option to convert from 12*c* standard ASM to Flex ASM using asmca:

```
asmca -silent -convertToFlexASM -asmNetworks eth1/ 192.168.1.121-asmListenerPort 1522

To complete ASM conversion, run the following script as privileged user in local node.
/u01/app/12.1.0/grid/cfgtoollogs/asmca/scripts/converttoFlexASM.sh
```

Oracle 12*c* Flex Cluster

Starting with Oracle 12*c* Grid Infrastructure, Oracle has introduced a new topology for RAC and how high-availability applications and databases are managed using RAC. Oracle Flex Cluster provides a platform for both applications and databases that are managed by cluster services. The correlation between Flex ASM and Flex Cluster is that Flex ASM is required for Flex Cluster, but Flex ASM does not require Flex Cluster.

Oracle Flex Cluster contains two types of nodes, referred to as Hub Nodes and Leaf Nodes. Hub Nodes are considered similar to the standard cluster configuration where ASM and database instances run and have access to shared storage. The main difference between a Hub Node and a Leaf Node is that a Hub Node has direct access to shared storage whereas the Leaf Node does not. Leaf Nodes are different from standard Oracle grid nodes in that they don't require VIPs or direct access to shared storage. The processes which run on Leaf Nodes are the cluster services without ASM or database. The main purpose for Leaf Nodes is to host high-availability applications that are registered and managed by cluster services. Leaf Nodes are not meant to host databases, as of this release. Leaf Nodes are intended for configuring high-availability applications similar to GoldenGate and WebLogic and Apps.

Use the following command to check if Flex Cluster is enabled:

```
ASMCMD> showclustermode
ASM cluster : Flex mode enabled
```

Check the role for each node in the cluster as follows:

```
[oracle@Linux72 ~]$ olsnodes -a -n
linux71 1       Hub
linux72 2       Hub
```

Options for converting from Leaf to Hub and vice versa are provided using the `runInstaller -updateNodList` command.

Srvctl Enhancements

With version 12*c* of ASM, Oracle has made several enhancements to commands that manage database and cluster services. One such enhancement is that you can now determine the steps a command would take when executing without actually executing the command. Unlike prior versions, which have no method to evaluate the execution path of the command, this version will provide detailed steps and show the impact on the database or cluster of executing the command. The Server Control Utility, `srvctl`, has been modified to predict or evaluate a command before actually executing. Not all `srvctl` commands are enabled to take advantage of this option; only a subset of commands has this feature enabled.

The `-eval` option of `srvctl` enables you to simulate running a command without having any impact on the system. The `-eval` option provides information about what will happen if the command is executed. The following `srvctl` commands can use the `-eval` option to simulate running the command:

```
srvctl add database
srvctl add service
srvctl add srvpool
srvctl modify database
srvctl modify service
srvctl modify srvpool
srvctl relocate server
srvctl relocate service
srvctl remove srvpool
srvctl start database
srvctl start service
srvctl stop database
srvctl stop service
```

If your databases are configured using the standard admin-managed configuration, then the preceding commands might fail as shown here:

```
oracle@Linux72 ~]$ srvctl stop database -db oradb_cdb -eval -verbose
PRKO-2712 : Administrator managed database oradb_cdb is not supported with
-eval option
```

To confirm there are no server pools configured, execute the following:

```
[oracle@Linux72 ~]$ srvctl config srvpool
Server pool name: Free
Importance: 0, Min: 0, Max: -1
Category:
Candidate server names:
Server pool name: Generic
Importance: 0, Min: 0, Max: -1
Category:
Candidate server names: linux71,linux72
```

The output shows the default server pools available. There is a "Free" pool and a "Generic" pool, but there are no servers assigned to the pool. The `srvctl` command provides detailed help for each option. For example, to view the available options for starting a database using `srvctl`:

```
[oracle@Linux72 ~]$ srvctl start database -help
Starts the database.
Usage: srvctl start database -db <db_unique_name> [-startoption <start_options>]
[-startconcurrency <start_concurrency>] [-node <node>] [-eval] [-verbose]
     -db <db_unique_name>           Unique name for the database
    -startoption <start_options>   Options to startup command (e.g. OPEN,
MOUNT, or "READ ONLY")
    -startconcurrency <start_concurrency> Number of instances to be started
simultaneously (or 0 for empty start concurrency value)

    -node <node>                   Node on which to start the database (only
for RAC One Node databases)
    -eval                          Evaluates the effects of event without mak-
ing any changes to the system
     -verbose                       Verbose output
     -help                          Print usage
[oracle@Linux72 ~]$
```

The `-help` option of `srvctl` will provide details on all the command options, including `-eval`. In addition to the `-eval` commands, Oracle 12*c* ASM provides another useful command, `predict`, which predicts what will happen when a resource fails and cannot be restarted on the same node. Same as the `-eval` command, this command also does not make any modification to the system.

To view the list of `srvctl` commands that can be used with `predict`, add the `–help` option:

```
oracle@Linux72 ~]$ srvctl predict -help
```

The `srvctl predict` command evaluates the consequences of resource failure:

```
Usage: srvctl predict database -db <database_name> [-verbose]
Usage: srvctl predict service -db <database_name> -service <service_name>
[-verbose]
Usage: srvctl predict asm [-node <node_name>] [-verbose]
Usage: srvctl predict diskgroup -diskgroup <diskgroup_name> [-verbose]
Usage: srvctl predict filesystem -device <volume device> [-verbose]
Usage: srvctl predict vip -vip <vip_name> [-verbose]
Usage: srvctl predict network [-netnum <network_number>] [-verbose]
Usage: srvctl predict listener -listener <listener_name> [-verbose]
Usage: srvctl predict scan -scannumber <scan_ordinal_number> [-netnum <net-
work_number>] [-verbose]
Usage: srvctl predict scan_listener -scannumber <scan_ordinal_number> [-netnum
<network number>] [-verbose]
Usage: srvctl predict oc4j [-verbose]
```

For example, to predict the outcome if ASM fails on a two-node RAC:

```
[oracle@Linux72 ~]$ srvctl predict asm
Resource ora.asm will be stopped
Resource ora.DB_DISK01.dg will be stopped
Resource ora.OCR DISK.dg will be stopped
Resource ora.mgmtdb will be stopped
Database oradb cdb will be stopped on nodes linux71,linux72
[oracle@Linux72 ~]$
```

The preceding output from `predict` outlines the consequences if ASM is stopped. It shows that the diskgroups (DB_DISK01, OCR_DISK) will be stopped, database mgmtdb (single-node database) will be stopped, and database oradb_cdb (two-node RAC instance) will be stopped. So the `predict` command is predicting that if ASM crashes on both nodes on a two-node RAC environment, it will bring down everything. The two-node RAC test environment I'm using is configured for Flex ASM, so why is it bringing down the databases if ASM is down? The answer is that the command I issued to stop ASM was cluster wide, and not for a specific ASM instance running on a cluster server.

The following example predicts if ASM fails on a specific cluster node:

```
[oracle@Linux72 ~]$ srvctl predict asm -node linux72
Resource ora.asm will be stopped
Resource ora.DB_DISK01.dg will be stopped
Resource ora.OCR DISK.dg will be stopped
[oracle@Linux72 ~]$
```

Note the preceding example is isolating ASM failure on node linux72; the output shows diskgroups only come down and does not show any impact on the database running on this node. If this was an 11*g* RAC environment, the databases running on cluster node linux72 would crash if ASM fails. With Flex ASM enabled with 12*c*, the database will automatically connect to the surviving ASM instance on the cluster via the ASM listener.

More detailed help for each `predict` command can be seen using the `-help` option:

```
[oracle@Linux72 ~]$ srvctl predict listener -h

Predicts the consequences of listener failure.

Usage: srvctl predict listener -listener <listener_name> [-verbose]
    -listener <lsnr_name>          Listener name
    -verbose                       Verbose output
    -help                          Print usage
[oracle@Linux72 ~]$
```

In addition to the preceding changes for `srvctl`, 12*c* has deprecated single-character parameters when executing commands. Version 12.1 of `srvctl` still is backward compatible and will allow for single-character parameters, but for newer versions, the single-character parameter will be deprecated. For example, the `-d` parameter for database option would need to spelled out as follows:

```
11g:    srvctl status database -d oradb_cdb
12c:    srvctl status database -database oradb_cdb
        (or  srvctl status database -db oradb_cdb)
```

To see the improvement of 12*c*, consider the following list of new 12*c* `srvctl` commands that *did not exist* on 11*g* ASM. To understand how each command works, use the `-help` option for the command.

```
srvctl predict asm
srvctl relocate asm
srvctl predict database
srvctl update database
srvctl predict diskgroup
srvctl add exportfs
srvctl disable mgmtdb
srvctl enable mgmtdb
srvctl getenv mgmtdb
srvctl modify mgmtdb
srvctl relocate mgmtdb
srvctl remove mgmtdb
srvctl predict network
srvctl predict oc4j
srvctl add rhpclient
srvctl config rhpclient
srvctl disable rhpclient
srvctl enable rhpclient
```

srvctl config exportfs	srvctl setenv mgmtdb	srvctl modify rhpclient
srvctl disable exportfs	srvctl start mgmtdb	srvctl relocate rhpclient
srvctl enable exportfs	srvctl status mgmtdb	srvctl remove rhpclient
srvctl modify exportfs	srvctl stop mgmtdb	srvctl start rhpclient
srvctl remove exportfs	srvctl unsetenv mgmtdb	srvctl status rhpclient
srvctl start exportfs	srvctl update mgmtdb	srvctl stop rhpclient
srvctl status exportfs	srvctl add mgmtlsnr	srvctl add rhpserver
srvctl stop exportfs	srvctl config mgmtlsnr	srvctl config rhpserver
srvctl predict filesystem	srvctl disable mgmtlsnr	srvctl disable rhpserver
srvctl relocate filesystem	srvctl enable mgmtlsnr	srvctl enable rhpserver
srvctl export gns	srvctl getenv mgmtlsnr	srvctl modify rhpserver
srvctl import gns	srvctl modify mgmtlsnr	srvctl relocate rhpserver
srvctl update gns	srvctl remove mgmtlsnr	srvctl remove rhpserver
srvctl add havip	srvctl setenv mgmtlsnr	srvctl start rhpserver
srvctl config havip	srvctl start mgmtlsnr	srvctl status rhpserver
srvctl disable havip	srvctl status mgmtlsnr	srvctl stop rhpserver
srvctl enable havip	srvctl stop mgmtlsnr	srvctl predict scan
srvctl modify havip	srvctl unsetenv mgmtlsnr	srvctl predict scan_listener
srvctl relocate havip	srvctl add mountfs	srvctl update scan_listener
srvctl remove havip	srvctl config mountfs	srvctl predict service
srvctl start havip	srvctl disable mountfs	srvctl predict vip
srvctl status havip	srvctl enable mountfs	srvctl config volume
srvctl stop havip	srvctl modify mountfs	srvctl disable volume
srvctl update instance	srvctl remove mountfs	srvctl enable volume
srvctl predict listener	srvctl start mountfs	srvctl start volume
srvctl add mgmtdb	srvctl status mountfs	srvctl status volume
srvctl config mgmtdb	srvctl stop mountfs	srvctl stop volume

For `crsctl`, the only newly added command seems to be `crsctl eval`, which is similar to `srvctl -eval`. To get detailed help on `crsctl eval`, use the `-help` option.

ASM Disk Scrubbing

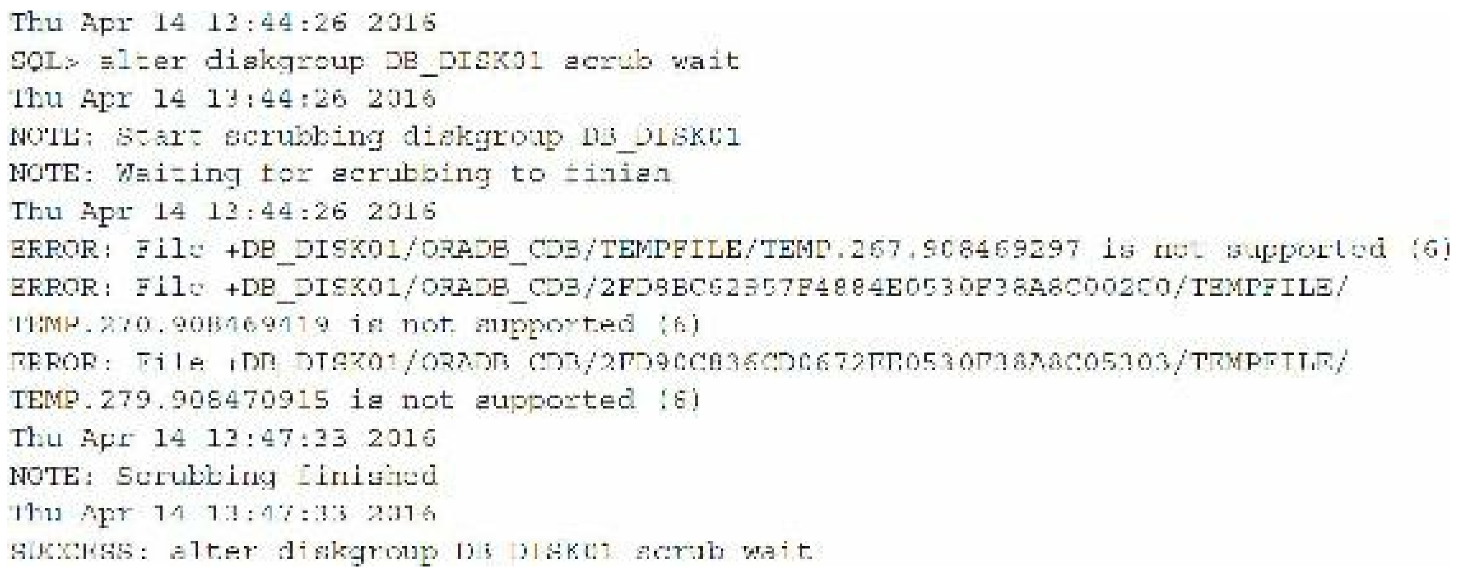
With Oracle ASM 12*c*, logical disk corruptions can be repaired by the scrubbing process. ASM disks that are configured with normal or high redundancy can take advantage of this process. Disk scrubbing works by using the mirror disks to fix logical corruptions, and the scrub operation has minimal impact to I/O. The scrub operation can be performed on a diskgroup, disks, or ASM datafile. The scrub operation provides four options for disk scrubbing:

1. **REPAIR** : `alter diskgroup DB_DISK01 scrub repair;`

   The REPAIR option automatically repairs disk corruptions. If the REPAIR option is not specified, the process only checks for logical corruption without fixing the corruption.
2. **POWER (AUTO, LOW, HIGH, MAX):** `alter diskgroup DB_DISK01 scrub POWER HIGH;`

   The POWER option controls the resources ASM will allocate for the scrub operation. If the POWER option is not specified, then the default is AUTO, where ASM would evaluate the current system load and run the scrub process with minimal impact to the system.
3. **WAIT:** `alter diskgroup DB_DISK01 scrub wait;`

   When the WAIT option is used, the scrub operation is not added to the scrubbing queue; instead the process waits for the scrubbing operation to complete. If this option is performed using SQL*Plus, the prompt won't return until the `scrub wait` completes. The alert log for ASM will show the "wait" process. For example:



```
Thu Apr 14 12:44:26 2016
SQL> alter diskgroup DB_DISK01 scrub wait
Thu Apr 14 13:44:26 2016
NOTE: Start scrubbing diskgroup DB_DISK01
NOTE: Waiting for scrubbing to finish
Thu Apr 14 12:44:26 2016
ERROR: File +DB_DISK01/ORADB_CDB/TEMPFILE/TEMP.267.908469297 is not supported (6)
ERROR: File +DB_DISK01/ORADB_CDB/2FD8BC62B57F4884E0530F38A8C002C0/TEMPFILE/
TEMP.270.908469419 is not supported (6)
ERROR: File +DB_DISK01/ORADB_CDB/2FD90C836CD0672EE0530F38A8C05303/TEMPFILE/
TEMP.279.908470915 is not supported (6)
Thu Apr 14 12:47:33 2016
NOTE: Scrubbing finished
Thu Apr 14 13:47:33 2016
SUCCESS: alter diskgroup DB_DISK01 scrub wait
```

4. **FORCE:** `alter diskgroup DB_DISK01 scrub force;`

   This option is used to force a scrub operation even if the system load is high. As previously mentioned, the scrub operation can be performed on ASM diskgroups, disks, and files:

   - **Diskgroup:** `alter diskgroup DB_DISK01` ***`scrub`*** `repair power high force;`
   - **Disks:** `alter diskgroup DB_DISK01` ***`scrub disk`*** `DB_DISK01_0000 repair power high force;`
   - **ASM file:** `alter diskgroup DB_DISK01` ***`scrub file`*** `'+DB_DISK01/ORADB_CDB/DATAFILE/users.259.908469163' repair power max force`

The exception to ASM files is the TEMP files, as shown in the previous log for WAIT:

```
ERROR: File +DB_DISK01/ORADB_CDB/TEMPFILE/TEMP.267.908469297 is not supported (6)
```

The disk scrubbing process can be combined with a diskgroup rebalancing operation to reduce I/O resources. The progress of the scrub operation can be viewed using V$ASM_OPERATION, or use ASMCMD LSOP.

ASM Rebalance Enhancements

One of the new options in 12*c* in regard to ASM disks is the choice of rebalancing ASM disks manually. Typically ASM disks are automatically rebalanced, where disk configuration changes by adding or removing disks from a diskgroup. With 12*c* ASM, Oracle provides the ability to run manual rebalance operations. The ALTER DISKGROUP REBALANCE operation uses the POWER value to allocate resources and speed up the rebalance operation. If the POWER value is not specified, the process uses the value in ASM_POWER_LIMIT specified in the ASM spfile, which by default is 1. In 12*c* ASM the POWER values range from 0 to 1024, and for setting the values larger than 11, you must set the COMPATIBLE.ASM parameter to 11.2.0.2 or higher. If the COMPATIBLE.ASM is set to less than 11.2.0.2, then the max POWER setting will be 11 even if you explicitly set the POWER limit to a higher value.

With the POWER settings of the rebalance operations, you can control the degree of parallelism and thus speed up the rebalance operation. This option also provides functionality to increase or decrease the POWER limit to accommodate for the server resource capacity. You can completely halt the rebalance operation by setting the POWER value to 0, and when you want it to resume, you can then increase the POWER setting to start the rebalance operation from where it stopped.

The EXPLAIN WORK SQL statement, which is new to 12*c* ASM, uses the V$ASM_ESTIMATE view to determine the amount of work required to add or drop disks. The EXPLAIN WORK statement populates the V$ASM_ESTIMATE view with the estimated work to complete the operation without actually executing the command. By modifying the POWER setting in the EXPLAIN WORK statement, you can view the adjustments made to the EST_WORK column of the V$ASM_ESTIMATE view. Column EST_WORK provides an estimate of the number of allocation units to be moved for the rebalance operation to complete. Oracle ASM tries to keep rebalance I/O for each unit of power. Each I/O requires Program Global Area (PGA) memory for the extent involved in the relocation, so increasing PGA might speed up the rebalance operation.

Rebalance behavior can be affected by modifying the CONTENT.CHECK and THIN_PROVISIONED diskgroup attributes. The CONTENT.CHECK attribute enables or disables content checking when performing data copy operations for rebalancing a diskgroup. The attribute value is either TRUE or FALSE (the default value). When the value is set to TRUE, logical content checking is enabled for all rebalance operations. The THIN_PROVISIONED attribute enables or disables the functionality to discard unused storage space after a diskgroup rebalance is completed; the default value is FALSE. This attribute is supported only on 12*c* with Oracle ASM Filter Driver

(ASMFD), which is described in more depth a bit later in the chapter.

To view ASM attribute settings, you can query V$ASM_ATTRIBUTE or, if connected to ASMCMD, run the following command. Oracle 12*c* ASM has added more diskgroup attributes to those available in previous releases.

```
ASMCMD> lsattr -l

Name                       Value
access_control.enabled     FALSE
access_control.umask       066
au_size                    1048576
cell.smart_scan_capable    FALSE
compatible.asm             12.1.0.0.0
compatible.rdbms           10.1.0.0.0
content.check              FALSE
content.type               data
disk_repair_time           3.6h
failgroup_repair_time      24.0h
idp.boundary               auto
idp.type                   dynamic
phys_meta_replicated       true
sector_size                512
thin_provisioned           FALSE
access_control.enabled     FALSE
access_control.umask       066
au_size                    1048576
cell.smart_scan_capable    FALSE
compatible.asm             12.1.0.0.0
compatible.rdbms           10.1.0.0.0
content.check              FALSE
content.type               data
disk_repair_time           3.6h
failgroup_repair_time      24.0h
idp.boundary               auto
idp.type                   dynamic
phys_meta_replicated       true
sector_size                512
thin_provisioned           FALSE
ASMCMD>
```

The following is an example for EXPLAIN WORK:

```
select a.name "Disk Group",b.name "Disk Name",
       b.TOTAL_MB,b.free_mb,a.COMPATIBILITY,b.disk_number
from   v$asm disk b, v$asm diskgroup a
where  a.group number = b.group number
and    a.name =  'DB DISK01'
order  by 1 ;

Disk Group           Disk Name                           TOTAL_MB    FREE_MB COMPATIBILITY   DISK_NUMBER
-------------------- ------------------------------ ---------- ---------- --------------- ----------
DB_DISK01            DB_DISK01_0000                      20479      18307 12.1.0.0.0               0

SQL> explain work for alter diskgroup DB DISK01 rebalance power 1;
Explained.

select est_work
from   v$asm estimate;

  EST_WORK
----------
       234
```

You can use EXPLAIN WORK with almost any ALTER DISKGROUP commands and query V$ASM_ESTIMATE to better estimate the amount of work needed for completion.

With 12*c* ASM, we have V$ACTIVE_SESSION_HISTORY (ASH), which gives us the ability to query ASM SQL history and check when commands were executed in ASM; this requires using the “tuning-pack” license.

```
select sample time,session type,sql id,sql opname
from   v$active_session_history
where  sql_opname is not null
order  by 1;

SAMPLE TIME                     SESSION TY SQL ID        SQL OPNAME
------------------------------- ---------- ------------- ---------------
22-APR-16 12.25.30.807 PM       FOREGROUND 2652h28tjmm7k ALTER DISK GROUP
22-APR-16 12.25.31.807 PM       FOREGROUND 2652h28tjmm7k ALTER DISK GROUP
22-APR-16 12.25.32.807 PM       FOREGROUND 2652h28tjmm7k ALTER DISK GROUP

select sql text
from   v$sqltext
where  sql_id = '2652h28tjmm7k'
order  by piece;

SQL_TEXT
----------------------------------------------------------------
ALTER DISKGROUP ALL MOUNT /* asm agent call crs *//* {0:9:3} */
```

ASM Fast Mirror Resync

Oracle ASM fast resync significantly reduces the time to resynchronize a failed disk by quickly resynchronizing the Oracle ASM disk extents. Problems that make a failure group temporarily unavailable are considered transient failures that can be recovered from by the ASM fast mirror resync feature. This feature keeps track of pending changes to extents on an offline disk during an outage. When the disk is brought back online, the extents stored on the offline disk are resynced. When a disk is taken offline, Oracle ASM by default will drop the disk in 3.6 hours. By setting the DISK_REPAIR_TIME attribute you can delay the drop operation by specifying a time interval. The DISK_REPAIR_TIME attribute can only be set on diskgroups with high or normal redundancy, and the ASM compatibility setting must be set at 11.1 or higher. The REPAIR_TIME of V$ASM_DISK shows the amount of time left, in seconds, before the offline disk is dropped. When the REPAIR_TIME is elapsed, ASM will drop the disk.

You can use the ALTER DISKGROUP command to set the DISK_REPAIR_TIME attribute to a specified hour or minute value:

```
alter diskgroup DB_DISK01 set attribute 'disk_repair_time' = '4.0h';
alter diskgroup DB_DISK01 set attribute 'disk_repair_time' = '240m';
```

During the ALTER DISKGROUP operations, you can query V$ASM_OPERATION as follows to view the state of the current operation. The PASS column of V$ASM_OPERATION shows the type of operation performed.

```
select group_number, pass, state
from   v$asm_operation;
```

Use this query of V$ASM_OPERATION to verify what might be running to slow down I/O performance, noting the type of operation performed.

ASM Filter Driver

Starting with 12*c* ASM, for stand-alone and cluster environments, Oracle provides a kernel module called ASM Filter Driver (ASMFD) for managing ASM disks. As part of the 12*c* Grid Infrastructure (GI) install, ASMFD simplifies the configuration and management of disk devices by eliminating the need to rebind disk devices when Oracle ASM is restarted. ASMFD also filters any non-Oracle I/O request that could accidently overwrite ASM disks. If ASMLIB is already configured while installing 12*c* GI, then ASMFD will not automatically override ASMLIB configuration. After installing 12*c* GI, you will need to migrate disks manually from ASMLIB to ASMFD if you decide to not use ASMLIB. Oracle 12*c* GI will work with ASMLIB and this functionally will still be supported, but if the choice is to migrate to ASMFD for better management and security for ASM disks, then after the 12*c* GI install, you will need to manually migrate to ASMFD.

One of the key benefits of migrating to ASMFD is the security it provides to the ASM disks. Once the disks are migrated to ASMFD, the ownership of the disks will be "root" and not "oracle" or "grid." By having the ownership changed to root, the disks are better secured from non-root users accidently damaging the header or contents of the disks. Oracle provides documentation on how to configure ASMFD with and without ASMLIB (Doc ID 2060259.1). Since the test environment I am using is a two-node 12*c* cluster without ASMFD, the following steps provide an example of how to convert from ASMLIB to ASMFD.

Before configuration of ASMFD, as you can see here, ASMFD is not loaded (run as root user):

```
[root@Linux71 ~]# asmcmd afd state
SMCMD-9526: The AFD state is 'NOT INSTALLED' and filtering is 'DEFAULT' on hos
```

And before configuration of ASMFD, my disks are owned by oracle:oinstall:

```
/dev/oracleasm/disks
brw-rw----. 1 oracle oinstall 8, 49 Apr 25 11:59 DB_DISK_01
brw-rw----. 1 oracle oinstall 8, 33 Apr 25 12:00 OCR_DISK
```

Now, I'll configure ASMFD (run as root user). As the Oracle GI owner, I update the Oracle ASM disk discovery string to enable ASMFD to discover devices. You can check what the current ASM disk discovery string is as follows:

```
[oracle@Linux71 ~]$ asmcmd dsget
parameter:/dev/oracleasm/disks/*
profile:/dev/oracleasm/disks/*
```

So, the output shows the ASM disk discovery string is `'/dev/oracleasm/disks/*'`. I need to update this value to have ASM automatically discover ASMFD disks also:

```
[oracle@Linux71 ~]$  asmcmd dsset '/dev/oracleasm/disks/*','AFD:*'
[oracle@Linux71 ~]$
[oracle@Linux71 ~]$ asmcmd dsget
parameter:/dev/oracleasm/disks/*, AFD:*
profile:/dev/oracleasm/disks/*,AFD:*
```

As the preceding example shows, I used the ASMCMD DSSET command to add to the ASM disk discovery string `'AFD:*'`, so the disk discovery path has both the old and new search paths for ASM disks. If you need to completely remove the old ASM disk discovery path, then issue `ASMCMD DSSET '/dev/oracleasm/disks/*'`, but for now, until I have completely configured ASMFD, I'll leave the old disk path in place.

Since my test environment is two-node RAC 12*c*, I will need to shut down the CRS stack on all nodes before configuring ASMFD. To check how RAC nodes are configured:

```
[oracle@Linux71 ~]$ olsnodes -n -a
linux71 1       Hub
linux72 2       Hub
```

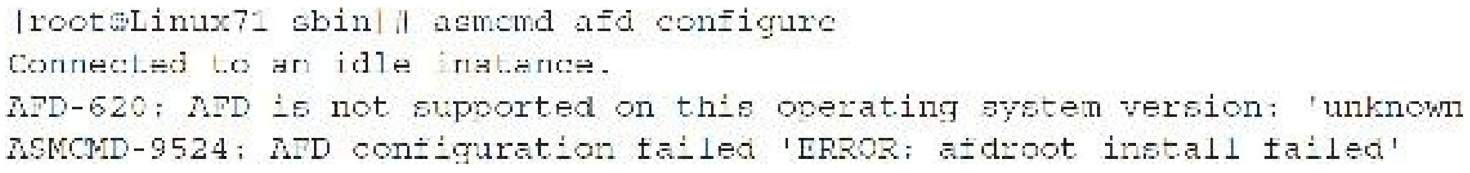
To stop CRS *on all nodes*, issue `crsctl stop has` as root for each node:

```
[root@Linux71 sbin]# crsctl stop has
CRS-2791: Starting shutdown of Oracle High Availability Services-managed re-
sources on 'linux71'
CRS-2673: Attempting to stop 'ora.crf' on 'linux71'
CRS-2673: Attempting to stop 'ora.gpnpd' on 'linux71'
CRS-2673: Attempting to stop 'ora.mdnsd' on 'linux71'
CRS-2677: Stop of 'ora.crf' on 'linux71' succeeded
CRS-2673: Attempting to stop 'ora.gipcd' on 'linux71'
CRS-2677: Stop of 'ora.gpnpd' on 'linux71' succeeded
CRS-2677: Stop of 'ora.mdnsd' on 'linux71' succeeded
CRS-2677: Stop of 'ora.gipcd' on 'linux71' succeeded
CRS-2793: Shutdown of Oracle High Availability Services-managed resources on
'linux71' has completed
CRS-4133: Oracle High Availability Services has been stopped.

[root@Linux72 ~]# crsctl stop has
CRS-2791: Starting shutdown of Oracle High Availability Services-managed re-
sources on 'linux72'
CRS-2673: Attempting to stop 'ora.crf' on 'linux72'
CRS-2673: Attempting to stop 'ora.mdnsd' on 'linux72'
CRS-2673: Attempting to stop 'ora.gpnpd' on 'linux72'
CRS-2677: Stop of 'ora.crf' on 'linux72' succeeded
CRS-2673: Attempting to stop 'ora.gipcd' on 'linux72'
CRS-2677: Stop of 'ora.gpnpd' on 'linux72' succeeded
CRS-2677: Stop of 'ora.mdnsd' on 'linux72' succeeded
CRS-2677: Stop of 'ora.gipcd' on 'linux72' succeeded

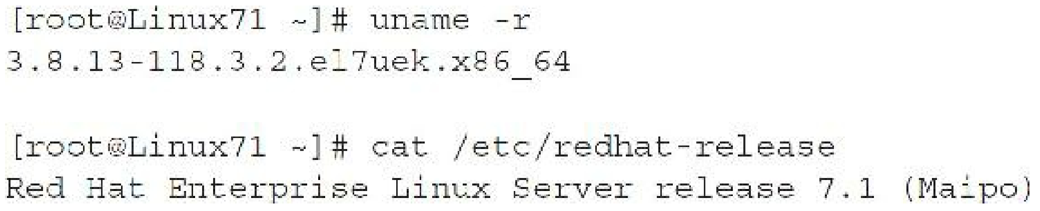
CRS-2793: Shutdown of Oracle High Availability Services-managed resources on
'linux72' has completed
CRS-4133: Oracle High Availability Services has been stopped.
```

After CRS is stopped on all nodes, I can start configuring ASMFD. As root user, I run `afd_configure`:



```
[root@Linux71 sbin]# asmcmd afd configure
Connected to an idle instance.
AFD-620: AFD is not supported on this operating system version: 'unknown
ASMCMD-9524: AFD configuration failed 'ERROR: afdroot install failed'
```

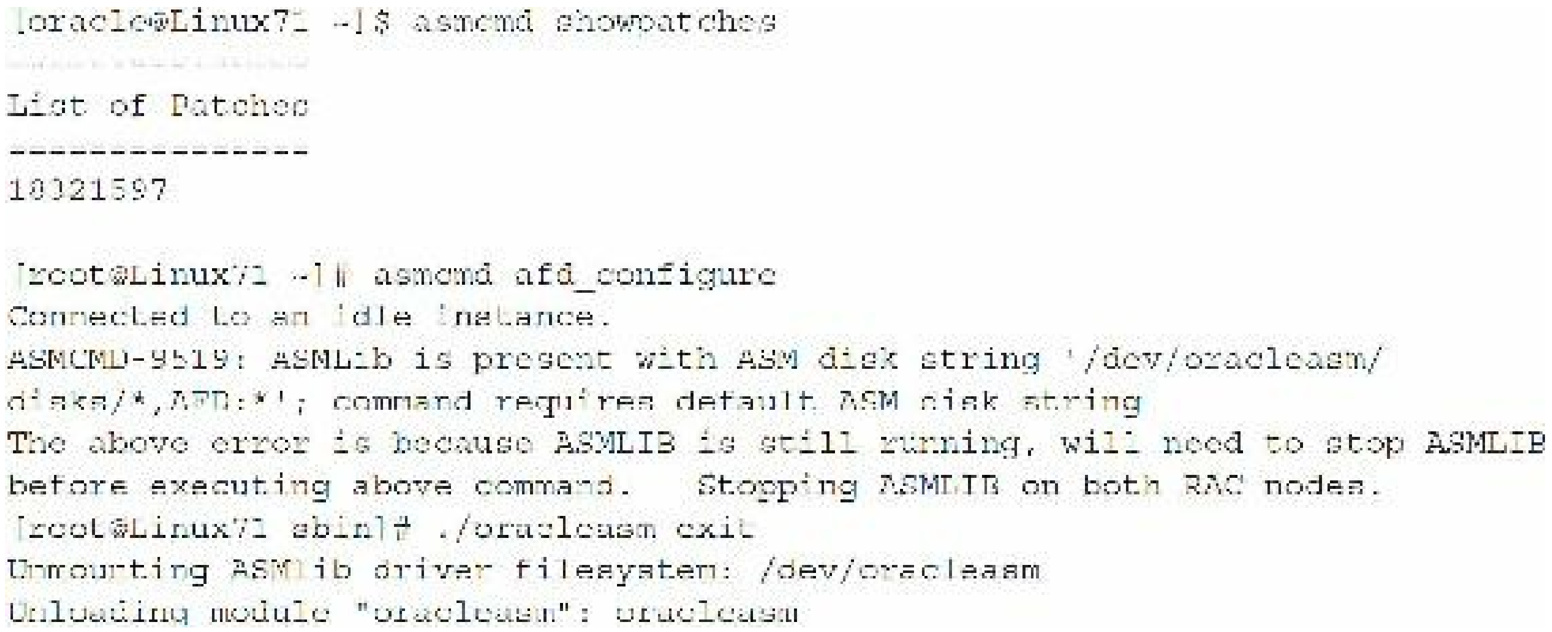
Following are the details on my test system:



```
[root@Linux71 ~]# uname -r
3.8.13-118.3.2.el7uek.x86_64

[root@Linux71 ~]# cat /etc/redhat-release
Red Hat Enterprise Linux Server release 7.1 (Maipo)
```

After applying patch 18321597, I try to configure AFD:



```
[oracle@Linux71 ~]$ asmcmd showpatches
---------------
List of Patches
---------------
18321597

[root@Linux71 ~]# asmcmd afd_configure
Connected to an idle instance.
ASMCMD-9519: ASMLib is present with ASM disk string '/dev/oracleasm/
disks/*,AFD:*'; command requires default ASM disk string
The above error is because ASMLIB is still running, will need to stop ASMLIB
before executing above command.   Stopping ASMLIB on both RAC nodes.
[root@Linux71 sbin]# ./oracleasm exit
Unmounting ASMlib driver filesystem: /dev/oracleasm
Unloading module "oracleasm": oracleasm
```

After stopping ASMLIB, I am able to successfully run the AFD_CONFIGURE command:

```
[root@Linux71 sbin]# asmcmd afd_configure
Connected to an idle instance.
AFD-627: AFD distribution files found.
AFD-636: Installing requested AFD software.
AFD-637: Loading installed AFD drivers.
AFD-9321: Creating udev for AFD.
AFD-9323: Creating module dependencies - this may take some time.
AFD-9154: Loading 'oracleafd.ko' driver.
AFD-649: Verifying AFD devices.
AFD-9156: Detecting control device '/dev/oracleafd/admin'.
AFD-638: AFD installation correctness verified.
Modifying resource dependencies - this may take some time.
```

The preceding process will add AFD devices into /etc/udev/rules.d/53-afd.rules as listed here:

```
# AFD devices
KERNEL=="oracleafd/.*", OWNER="oracle", GROUP="oinstall", MODE="0770"
KERNEL=="oracleafd/*", OWNER="oracle", GROUP="oinstall", MODE="0770"
KERNEL=="oracleafd/disks/*", OWNER="oracle", GROUP="oinstall", MODE="0660"
```

AFD_STATE reports LOADED on the first node, linux71. Since this is two-node RAC, I need to run ASMCMD AFD_CONFIGURE on the second node, also after stopping ASMLIB on the second node:

```
[root@Linux71 sbin]# asmcmd afd_state
Connected to an idle instance.
ASMCMD-9526: The AFD state is 'LOADED' and filtering is 'DEFAULT' on host
'Linux71.localdomain'
```

After running ASMCMD AFD_CONFIGURE on all nodes, I need to migrate the current ASM disks to ASMFD. Similar to ASMLIB, after configuring ASMFD it creates a directory named /dev/oracleafd on all nodes where AFD_CONFIGURE was run:

```
[oracle@Linux71 dev]$ ls -ld ora*
drwxrwx---. 3 oracle oinstall 80 Apr 26 10:54 oracleafd
drwxr-xr-x. 2 root   root     40 Apr 26 10:13 oracleasm
```

On all RAC nodes, I disable oracleasm.service, to avoid ASMLIB from automatically starting up after rebooting:

```
[root@Linux71 disks]# systemctl disable oracleasm.service
Removed symlink /etc/systemd/system/multi-user.target.wants/oracleasm.service.
```

I then confirm the AFD driver is loaded:

```
[root@Linux71 log]# asmcmd afd_state
ASMCMD-9526: The AFD state is 'LOADED' and filtering is 'DEFAULT' on host
'Linux71.localdomain'
[root@Linux71 log]#
```

Next, I migrate ASMLIB disks to AFD. Before you perform the `migrate` command, make sure you have the correct diskgroup and path; importantly, make sure you have the correct disk partition (in `sdc1`, for example, the `1` shows that it is partition one).

```
[root@Linux71 ~]# asmcmd afd_label OCR_DISK '/dev/sdc1' --migrate
Connected to an idle instance.
```

After running the preceding command, an ASCII text file is created under the /dev/oracleafd/disks/ directory, as shown next, and the content of the text file is the actual raw disk path. Also important to note is that root is the owner of the new ASCII text file.

```
root@Linux72 disks]# ls -l /dev/oracleafd/disks
total 4
-rw-r--r--. 1 root root 10 May  2 13:53 OCR_DISK


[root@Linux72 disks]# [root@Linux71 disks]# cat OCR_DISK
/dev/sdc1

root@Linux71 disks]# asmcmd afd_lsdsk
Connected to an idle instance.
--------------------------------------------------------------------------------
Label                        Filtering   Path
================================================================================
OCR_DISK                       ENABLED   /dev/sdc1
```

After executing the preceding command on all nodes, I start the cluster for each node:

```
root@Linux71 disks]# crsctl start cluster
CRS-2672: Attempting to start 'ora.crf' on 'linux71'
CRS-2672: Attempting to start 'ora.cssd' on 'linux71'
CRS-2672: Attempting to start 'ora.diskmon' on 'linux71'
CRS-2676: Start of 'ora.diskmon' on 'linux71' succeeded
CRS-2676: Start of 'ora.crf' on 'linux71' succeeded
CRS-2676: Start of 'ora.cssd' on 'linux71' succeeded
CRS-2672: Attempting to start 'ora.ctssd' on 'linux71'
CRS-2672: Attempting to start 'ora.cluster_interconnect.haip' on 'linux71'
CRS-2676: Start of 'ora.ctssd' on 'linux71' succeeded
CRS-2676: Start of 'ora.cluster_interconnect.haip' on 'linux71' succeeded
CRS-2672: Attempting to start 'ora.asm' on 'linux71'
CRS-2676: Start of 'ora.asm' on 'linux71' succeeded
CRS-2672: Attempting to start 'ora.storage' on 'linux71'
CRS-2676: Start of 'ora.storage' on 'linux71' succeeded
CRS-2672: Attempting to start 'ora.crsd' on 'linux71'
CRS-2676: Start of 'ora.crsd' on 'linux71' succeeded
```

Once the cluster is online, I connect to the ASM instance via SQL*Plus and confirm PATH is using AFD:

```
select inst_id,name,state,path
from   gv$asm_disk;

   INST_ID NAME                           STATE    PATH
---------- ------------------------------ -------- ---------------
         1 OCR_DISK_0000                  NORMAL   AFD:OCR_DISK
         2 OCR_DISK_0000                  NORMAL   AFD:OCR_DISK


SELECT SYS_CONTEXT('SYS_ASMFD_PROPERTIES', 'AFD_STATE') FROM DUAL;


SYS_CONTEXT('SYS_ASMFD_PROPERTIES','AFD_STATE')
--------------------------------------------------------------------
CONFIGURED
```

Next I modify the settings for ASM_DISKSTRING and AFD_DISKSTRING:

```
SQL> ALTER SYSTEM set asm_diskstring = 'AFD:*';
System altered.
```

```
SQL> ALTER SYSTEM AFD DISKSTRING SET 'AFD:*';
System altered.

asmcmd afd dsset '/dev/sd*'    { on all hub RAC nodes }
asmcmd afd dsget  { to view the current AFD discovery string }
```

I confirm /etc/afd.conf file settings are correct on all nodes:

```
[root@Linux72 etc]# cat /etc/afd.conf
afd_diskstring='/dev/sd*'
afd_filtering=enable
```

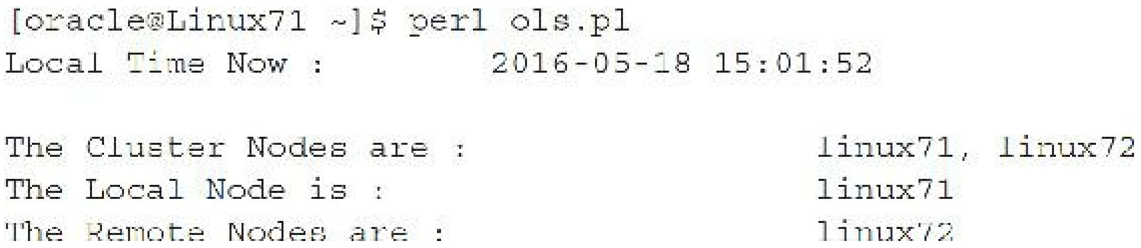
And then I confirm all cluster environments are online:

```
root@Linux72 disks]# crsctl check cluster -all
**************************************************************
linux71:
CRS-4537: Cluster Ready Services is online
CRS-4529: Cluster Synchronization Services is online
CRS-4533: Event Manager is online
**************************************************************
linux72:
CRS-4537: Cluster Ready Services is online
CRS-4529: Cluster Synchronization Services is online
CRS-4533: Event Manager is online
```

To add new disks to diskgroups, first partition the new disk using `fdisk` and then simply add the disks using `ASMCMD AFD_LABEL DB_DISK_01 '/dev/sdd1'` and then perform ASMCMD AFD_SCAN on the rest of the nodes. When creating a new diskgroup using “asmca”, make sure the discovery path is AFD during the Create Disk Group step. After adding the new disk, you should be able to list the newly added disk:

```
[root@Linux71 disks]# asmcmd afd_lsdsk
--------------------------------------------------------------------------
Label                          Filtering    Path
==========================================================================
OCR_DISK                        DISABLED    /dev/sdc1
DB DISK 01                      DISABLED    /dev/sdd1
```

Oracle has provided another new tool that displays GI/RAC cluster info (Doc ID 1568439.1). The Perl script `ols.pl` provides detailed information on the current configuration of the cluster, including Flex usage and AFD configuration and whether Hub/Leaf Nodes are configured. Sample output is shown here:



```
[oracle@Linux71 ~]$ perl ols.pl
Local Time Now :        2016-05-18 15:01:52

The Cluster Nodes are :                    linux71, linux72
The Local Node is :                        linux71
The Remote Nodes are :                     linux72
```

```
Major Clusterware Software Version is : 12.1.0.2.0
Major Clusterware Active Version is :   12.1.0.2.0
Major Clusterware Release Version is :  12.1.0.2.0

CRS_HOME is installed at :                /u01/app/12.1.0/grid
CRS_BASE is installed at :                /u01/app/grid_base
CRS_OWNER is :                            oracle
CRS_GROUP is :                            oinstall
ORACLE_HOMES[0] is installed at :         /u01/app/oracle_base/product/12.1.0/
dbhome_1 (on Local FS)
ORACLE_BASES[0] is installed at :         /u01/app/oracle_base (on Local FS)
ORACLE_OWNERS[0] is :                     oracle
ORACLE_GROUPS[0] is :                     oinstall

All databases created : orcl

DB_NAME   MANAGEMENT      DB_TYPE   DB_VERSION   DB_HOME     DG/FS USED
======    ==========      =======   ==========   ==========
orcl      administrator   RAC       12.1.0.2.0   /u01/app/oracle_base/
product/12.1.0/dbhome_1     '+DB_DISK'

NODE_NAME                 NODE_ID NODE_STATE       NODE_ROLE
=========                 ======= ==========       =========
linux71                   1       Active           Hub
linux72                   2       Active           Hub

Cluster Name :            Linux-cluster
SCAN Name :               Oracle-SCAN1
SCAN Listeners :          LISTENER_SCAN1 (Port: TCP:1523)
                          LISTENER_SCAN2 (Port: TCP:1523)
                          LISTENER_SCAN3 (Port: TCP:1523)
GNS Status :              configured and enabled
GNS Running Node :        linux71
GNS Version :             12.1.0.2.0
GNS VIP :                 192.168.56.55
GNS Subdomain :           Linux.localdomain
GNS-to-DNS  Port :        53
GNS-to-mDNS Port :        5353

Node VIP Version :        12.1.0.2.0
Local Node VIPs :         ora.linux71.vip Linux71_vip.localdomain (static)
                          ora.linux72.vip Linux72_vip.localdomain (static)

                          NIC     Subnet           Netmask          Type
                          ===     ======           =======          ====
Oracle Interfaces :       enp0s3  192.168.56.0     255.255.255.0    global  public
                          enp0s9  192.168.1.0      255.255.255.0    global
cluster_interconnect,asm
```

```
                              enp0s3             enp0s9
                              ======             ======
linux71  :
linux72  :

OCR Location :               '+OCR_DISK'
Voting Disk Location :       '+OCR_DISK'

Cluster Mode :               Flex Cluster

Hub Node                                         connects                                   Leaf
Node
========                                         ========                                   ====
linux71(1,Active)                                <---                                       None
linux72(2,Active)                                <---                                       None

MGMTDB Status :              enabled and is running on linux72
MGMTDB HOME :                <CRS home>
MGMTDB Spfile :              '+OCR_DISK/_MGMTDB/PARAMETERFILE/spfile.268.910717855'
MGMTDB Instance :            '-MGMTDB'

MGMTLSNR Status :            enabled and is running on linux72
MGMTLSNR HOME :              <CRS home>
MGMTLSNR Port :              TCP:1521
Detailed state :             169.254.160.216 192.168.1.19

                              ASMNET1LSNR_ASM
                              ===============
Subnet :                     192.168.1.0
End points :                 TCP:1522
Owner :                      oracle
Home :                       <CRS home>
Status :                     enabled

DISKGROUP         REDUNDANCY         AU        COMPATIBILITY    DB_COMPATIBILITY
SIZE_MB FREE_MB USABLE_MB            PATH
=========         ==========         ====      =============    ================
======= ======= =========            ====
DB_DISK           EXTERN             1MB       12.1.0.0.0       10.1.0.0.0
40238   25077   25077                AFD:DB_DISK_01 -> /dev/sdd1

AFD:DB_DISK_02  -> /dev/sde1
OCR_DISK          EXTERN             1MB       12.1.0.0.0       10.1.0.0.0
8119    3652    3652                 AFD:OCR_DISK -> /dev/sdc1

ASM Host                                         connects                                   Client
========                                         ========                                   ======
Linux71.localdomain(+ASM1)                       <---
'+ASM1(linux71)'
```

```
Linux71.localdomain(+ASM1)                   <---
'orcl1(linux71)'

Linux72.localdomain(+ASM2)                   <---
'+ASM2(linux72)'
Linux72.localdomain(+ASM2)                   <---
'-MGMTDB(linux72)'
Linux72.localdomain(+ASM2)                   <---
'orcl2(linux72)'

CSS Master :              linux71
OCR/CRSD Master :         linux71
CRSD PE Master :          linux71
CRSD PE Standby :         linux72
CTSS Master :             linux71
UI Master :               linux71
ONS Master :              linux72
ONSNET Master :           linux71
CHM Master :              linux71
CHM Replica :             REPLICA has been deprecated from 12c

OCR Local/Writer                             connects                          ASM
Instance
================                             ========                          ===
linux71(Hub,OCR Writer)                      --->
linux71(+ASM1)
linux72(Hub,OCR Local)                       --->
linux71(+ASM1)
```

More detailed output can be obtained by passing the parameter `ols.pl -f -v`; the script can also be run on 11*g* cluster environments.

Table 3-1 lists some of the ASM background processes and briefly describes each process.

Acronym	Description	Required for Basic DB Operation	Started by Default	New in This Release
ACFS	Tracks the cluster membership in CSS and informs the filesystem driver of membership changes.	No	No	No
ARB 0..A	Rebalances data extents across the ASM filesystems.	No	No	No
ARSn	The ASM RBAL background process coordinates and spawns one or more of these slave processes to recover aborted ASM transactional operations. These processes run only in the Oracle ASM instance.	No	No	Yes
ASMB	Communicates with the ASM instance, managing storage and providing statistics.	No	No	No
B00 0..4	Performs maintenance actions on ASM diskgroups.	No	No	No
Bnnn	Performs maintenance actions on Oracle ASM diskgroups. Bnnn performs actions that require waiting for resources on behalf of GMON. GMON must be highly available and cannot wait.	No	No	Yes
FENC	Processes fence requests for RDBMS instances that are using Oracle ASM IOServer instances.	No	No	Yes
GMON	Maintains disk membership in ASM diskgroups.	No	No	No
MARK	Marks ASM Allocation Units as stale following a missed write to an offline disk.	No	No	No
OCFn	Maintains a connection to the ASM instance for metadata operations.	No	No	No
Onnn	Maintains a connection to the ASM instance for metadata operations.	No	No	No

RBAL	In an Oracle ASM instance, RBAL coordinates rebalance activity for diskgroups. In a database instance, it manages Oracle ASM diskgroups.	No	No	No
RMON	Manages the rolling migration procedure for an Oracle ASM cluster. The RMON process is spawned on demand to run the protocol for transitioning an ASM cluster in and out of rolling migration mode.	Yes	No	Yes
Rnnn	A database instance reading from an Oracle ASM diskgroup can encounter an error during a read. If possible, Oracle ASM asynchronously schedules an Rnnn slave process to remap this bad block from a mirror copy.	No	No	No
SCCn	Acts as a slave process for SCRB and performs the checking operations.	No	No	Yes
SCRB	Runs in an Oracle ASM instance and coordinates Oracle ASM disk scrubbing operations.	No	No	Yes
SCRn	Acts as a slave process for SCRB and performs the repairing operations.	No	No	Yes
SCVN	Performs Oracle ASM disk scrubbing verify operation. SCVn acts as a slave process for SCRB and performs the verifying operations. The possible processes are SCV0–SCV9.	No	No	Yes
TEMn	Emulates I/O errors on ASM disks through named events.	No	No	No
VBGn	Communicates between the ASM instance and the operating system volume driver.	No	No	No

VDBG	Forwards ASM requests to perform various volume-related tasks.	No	No	No
VMBO	Maintains cluster membership on behalf of the ASM volume drivers.	No	No	No
VUBG	Relays messages between Oracle ASM instance and Oracle ASM Proxy instance that is used by ADVM (for ACFS).	No	No	Yes
Xnnn	Performs Oracle ASM post-rebalance activities. This process expels dropped disks at the end of an Oracle ASM rebalance.	No	No	Yes

TABLE 3-1. *ASM Background Processes*

ASM and Privileges

Access to the ASM instance is comparable to access to a standard instance, requiring a privilege level similar to that of SYSDBA and SYSOPER. Note, however, that since there is no data dictionary, authentication is done from an operating system level and/or an Oracle password file. Typically, the SYSDBA privilege is granted through the use of an operating system group. On Unix, this is typically the *dba* group, also referred to as the OSDBA group. With Oracle 10*g*, members of the *dba* group have SYSDBA privileges on all instances on the node, including the ASM instance. Users who connect to the ASM instance with the SYSDBA privilege have complete administrative access to all diskgroups in the system.

In 11*g* and 12*c*, Oracle has modified this concept and introduced the concept of ASMDBA, as well as the role of SYSASM. This role is tied to the OS-level group, logically called OSASM. This continues support for the separation-of-duties concept between system administrators and DBAs. The SYSDBA role can still be used when connecting to an ASM instance, but this role is not the all-powerful user. It has access capabilities to all the V$ views but does not have administrative privileges on ASM instances. The various roles are outlined here:

OS-Level Logical Group	DBA Privilege Level
OSOPER	SYSOPER
OSDBA	SYSDBA
OSASM	SYSASM

Three additional administrative users are introduced in 12*c*: SYSBACKUP, SYSDG, and SYSKM.

```
SQL> desc v$pwfile_users;
 Name                                          Null?    Type
 --------------------------------------------- -------- ---------------------------
 USERNAME                                               VARCHAR2(30)
 SYSDBA                                                 VARCHAR2(5)
 SYSOPER                                                VARCHAR2(5)
 SYSASM                                                 VARCHAR2(5)
 SYSBACKUP                                              VARCHAR2(5)
 SYSDG                                                  VARCHAR2(5)
 SYSKM                                                  VARCHAR2(5)
 CON_ID                                                 NUMBER
```

The following query lists who has been granted SYSDBA, SYSOPER, SYSASM, SYSBACKUP, SYSDG, or SYSKM as derived from the password file:

```
select *
from   v$pwfile_users;

USERNAME                       SYSDB SYSOP SYSAS SYSBA SYSDG SYSKM     CON_ID
------------------------------ ----- ----- ----- ----- ----- ----- ----------
SYS                            TRUE  TRUE  TRUE  FALSE FALSE FALSE          0
CRSUSER__ASM_001               TRUE  FALSE TRUE  FALSE FALSE FALSE          0
ASMSNMP                        TRUE  FALSE FALSE FALSE FALSE FALSE          0
```

The SYSOPER privilege is supported in ASM instances and limits the set of allowable SQL commands to the minimum required for basic operation of an already-configured system.

The SYSASM privileges permit mounting and dismounting diskgroups and other storage administration tasks. SYSASM privileges provide no access privileges on an RDBMS instance. The following commands are available to SYSASM users:

- STARTUP/SHUTDOWN
- ALTER DISKGROUP MOUNT/DISMOUNT
- ALTER DISKGROUP ONLINE/OFFLINE DISK
- ALTER DISKGROUP REBALANCE
- ALTER DISKGROUP CHECK
- Access to all V$ASM_* views

All other commands, such as CREATE DISKGROUP, ADD/DROP/RESIZE DISK, and so on, require the SYSDBA privilege and are not allowed with the SYSOPER privilege:

- SYSBACKUP is used to perform all backup and recovery operations (new to 12*c*).
- SYSDG is used for Data Guard activities (new to 12*c*).
- SYSKM is used for key management–related operations (new to 12*c*).

ASM and Multipathing

An I/O path generally consists of an initiator port, a fabric port, a target port, and a LUN. Each permutation of this I/O path is considered an independent path. Dynamic multipathing/failover tools aggregate these independent paths into a single logical path. This path abstraction provides I/O load balancing across the host bus adapters (HBAs), as well as nondisruptive failovers on I/O path failures. Multipathing (MP) software requires all the required disks to be visible on each available and eligible HBA. An MP driver detects multipaths by performing a SCSI `inquiry` command. Multipathing software also provides multipath software drivers. To support multipathing, a physical HBA driver must comply with the multipathing services provided by this driver. Please ensure that the configuration that you are considering is certified by the vendor. A multipathing tool provides the following benefits:

- Provides a single block device interface for a multipathed LUN
- Detects any component failures in the I/O path, for example, fabric port, channel adapter, or HBA
- When a loss of path occurs, ensures that I/Os are rerouted to the available paths with no process disruption
- Reconfigures the multipaths automatically when events occur
- Ensures that failed paths get revalidated as soon as possible and provides auto-failback capabilities
- Configures the multipaths to maximize performance using various load-balancing methods, for example, round robin, least I/Os queued, or least service time

TIP
Although ASM does not provide multipathing capabilities, it does leverage multipathing tools, as long as the path or device produced by the multipathing tool returns a successful return code from an FSTAT system call. My Oracle Support Note 294869.1 provides more details on ASM and multipathing.

Bigfile and ASM

The bigfile feature (as stated earlier in this chapter) is a perfect fit for VLDBs (very large databases) and ASM. Instead of managing several hundred datafiles, using bigfiles reduces the number of datafiles significantly. This improves checkpointing, and the time to open the database become significantly faster, as fewer file opens have to be performed. Using bigfiles reduces the internal overhead needed to manage a large number of datafiles. With ASM, bigfiles can be 32T for external redundancy and 12T for normal/high redundancy. This is based on an 8K block size. When using bigfiles, you have to review your backup and recovery strategy carefully. Obviously, you can't do full datafile backup for a 36T datafile, so things like RMAN incremental and cumulative backups become an integral part of bigfile management.

Avoiding Disk Contention by Using Partitions

Partitioning is probably the single best option available for increasing the performance related to large tables. *Partitioning* is a way to increase efficiency by accessing smaller pieces of a table or index instead of accessing the full table or index. This can be particularly useful when one or more users are accessing multiple parts of the same table. If these partitions (pieces) of the table reside on different devices, the throughput is greatly increased. Partitions can also be backed up and recovered independently of each other (even while they are in use), eliminating potential disk I/O issues during backup times. Only when partitions are properly implemented are Oracle's best performance-enhancing features realized. In 12*c*R2, Oracle also allows read-only partitions and subpartitions. The best way to understand partitioning is to look at an example. Consider the following simple example, where you partition the DEPT table into three partitions (pieces) using the DEPTNO column.

The TABLE DEPT is created with three range partitions:

```
create table dept
 (deptno       number(2),
  dept_name    varchar2(30))
  partition    by range(deptno)
 (partition d1 values less than (10) tablespace dept1,

partition d2 values less than (20) tablespace dept2,
partition d3 values less than (maxvalue) tablespace dept3);
```

This example builds three distinct partitions on the DEPT table. The key to getting better throughput is to ensure that each partition is placed on a different physical disk so that all three partitions can be accessed simultaneously if you are not using ASM. The tablespaces DEPT1, DEPT2, and DEPT3 must have physical files that are located on different physical disks. Remember that the tablespace is the logical holder of information where the datafile is the physical disk. You can have one tablespace that includes multiple datafiles, but a datafile can only relate to a single tablespace. The key to partitioning to improve disk I/O is to ensure that the partitions that will be accessed simultaneously either are located on different physical disks or use ASM.

Data is then entered into all three table partitions:

```
insert into dept values (1, 'ADMIN');
insert into dept values (7, 'MGMT');
insert into dept values (10, 'MANUF');
insert into dept values (15, 'ACCT');
insert into dept values (22, 'SALES');
```

The DEPT table still looks like a single table when you select from it:

```
select  *
from    dept;

DEPTNO   DEPT_NAME
------------------
1         ADMIN
7         MGMT
10        MANUF
15        ACCT
22        SALES
```

Here you selected all records from all of the partitions in the preceding example. In the next three examples, you select individually from each partition.

In this instance, you select from a single partition and access only a *single* partition:

```
select  *
from    dept partition (d1);

DEPTNO   DEPT_NAME
------------------
1         ADMIN
7         MGMT

select  *
from    dept partition (d2);

DEPTNO   DEPT_NAME
------------------
10        MANUF
15        ACCT
```

```
select   *
from     dept partition (d3);

DEPTNO    DEPT_NAME
--------------------
22         SALES

select   *
from     dept
where    deptno = 22;

DEPTNO    DEPT_NAME
--------------------
22         SALES
```

Note that in the final example, you eliminate the need to access the first or second partition (partition elimination). Partitioning indexes and using the parallel option along with partitions make partitioning even more powerful.

TIP
To minimize disk I/O on a single large table, you can break the table into multiple partitions that reside in tablespaces on different physical disks.

With *interval partitioning* (as of 11*g*), you no longer need to specify MAXVALUE in the upper partition. If you set it to 30 instead, and insert values above that, an additional partition will be built by Oracle:

```
create table dept
 (deptno      number(2),
  dept_name   varchar2(30))
------------------------------------------------------------
  partition   by range(deptno)
 (partition d1 values less than (10) tablespace dept1,
  partition d2 values less than (20) tablespace dept2,
  partition d3 values less than (30) tablespace dept3);
insert into dept values (70, 'SALES');
```

A new partition will be created automatically (SYS_P41 in my case), which now holds the value of 70 in it. There are now four partitions in this table. Also, interval partitions in 12*c*R2 can be part of a subpartition (values can be inserted that are not in the range of the original table).

Getting More Information About Partitions

You can retrieve the information regarding partitions by accessing USER_TABLES, DBA_PART_TABLES, and USER_SEGMENTS. Example queries to these three tables are displayed next with corresponding output for the examples in the preceding section.

```
select   table_name, partitioned
from     dba_tables
where    table_name in ('DEPT','EMP');
----------------------------------------
TABLE_NAME    PAR
DEPT          YES
EMP           NO
```

In the preceding example, the PAR (partitioned) column indicates whether a table is partitioned.

```
select   owner, table_name, partition_count
from     dba_part_tables
where    table_name = 'DEPT';
---------------

OWNER    TABLE_NAME     PARTITION_COUNT
KEVIN    DEPT           3
```

In the preceding and following examples, there are three partitions on the DEPT table:

```
select   segment_name, partition_name, segment_type, tablespace_name
from     user_segments;

SEGMENT_NAME  PARTITION_NAME  SEGMENT_TYPE         TABLESPACE_NAME
EMP                           TABLE                USER_DATA
DEPT          D1              TABLE PARTITION      DEPT1
DEPT          D2              TABLE PARTITION      DEPT2
DEPT          D3              TABLE PARTITION      DEPT3
```

TIP
Tables can be easily partitioned for individual pieces to be accessed and/or manipulated; you can still access the entire table of a partitioned table. Accessing the tables DBA_TABLES,

DBA_PART_TABLE, and DBA_SEGMENTS provides additional information concerning tables that have been partitioned. See Chapter 2 for more information on index partitioning.

Other Types of Partitioning

There are several types of partitioning. The main types are range, hash, composite, and list partitioning. There are also multiple index types associated with partitions. I covered range partitioning in the preceding section, but another partitioning option is multicolumn range partitioning.

Multicolumn Range Partitioning

Multicolumn range partitioning is the same as range partitioning except when using multiple columns to define the ranges. In the following example, the data is segmented into quarters so you can eliminate the quarters that are not needed when a single quarter is accessed, but also so the data can be archived one quarter at a time without interfering with another quarter. The data can also be segmented into multiple tablespaces so better I/O is achieved.

```
create table cust_sales
(acct_no      number(5),
 cust_name    char(30),
 item_id      number(9),

 sale_day     integer not null,
 sale_mth     integer not null,
 sale_yr      integer not null)
partition by range (sale_yr, sale_mth, sale_day)
(partition cust_sales_q1 values less than (2011, 04, 01) tablespace users,
 partition cust_sales_q2 values less than (2011, 07, 01) tablespace users2,
 partition cust_sales_q3 values less than (2011, 10, 01) tablespace users,
 partition cust_sales_q4 values less than (2012, 01, 01) tablespace users2,
 partition cust_sales_qx values less than (maxvalue, maxvalue, maxvalue)
 tablespace users2);
```

TIP

You can also partition tables using multiple columns as the criteria. You must specify MAXVALUE for all columns that are part of the partition key except for interval partitioning as of 11g. With interval partitioning, you no longer need to set MAXVALUE, and Oracle will create new partitions for you.

Hash Partitioning

Hash partitioning is generally used when you are unsure where to put the breakpoints as you would in range partitioning. Hash partitioning breaks up data into the number of partitions specified based on the hash of the partition key specified. To get an even distribution, you should always specify a power of 2 (2*n*) as the number of hash partitions. Hash partitioning only supports local indexes and range- or hash-partitioned global indexes. You can specify the names of the index and table partition, and you can later add or reduce the number of partitions if you find you have too many or too few. The following example shows a table with four hash partitions that is built on the partitioning key ACCT_NO and distributed across four tablespaces:

```
create table cust_sales_hash (
acct_no   number(5),
cust_name char(30),
sale_day  integer not null,
sale_mth  integer not null,
sale_yr   integer not null)
partition by hash (acct_no)
partitions 4
store in (users1, users2, users3, users4);
```

TIP
When you don't know how to break up a table, but you know that it needs to be partitioned and spread out, use hash partitioning.

Composite Partitioning

Sometimes a table is so large and accessed so frequently that you need a much better way to "slice and dice it." *Composite partitioning* combines range and hash partitioning. You use range partitioning to allow partition elimination and then hash the partitions further to distribute I/O. Composite partitioning supports local indexes and range- or hash-partitioned global indexes. The following is an example of composite partitioning that could lead to incredible job security due to its nonintuitive complexity:

```
create table orders(
ordid      number,
acct_no    number(5),
cust_name char(30),
orderdate date,
productid number)
 partition by range(orderdate)
 subpartition by hash(productid) subpartitions 8
   (partition q1 values less than  (to_date('01-APR-2011', 'dd-mon-yyyy')),
    partition q2 values less than  (to_date('01-JUL-2011', 'dd-mon-yyyy')),
    partition q3 values less than  (to_date('01-OCT-2011', 'dd-mon-yyyy')),
    partition q4 values less than(maxvalue));
```

This example build partitions based on the range of values listed for the ORDERDATE column and puts them into partitions Q1, Q2, Q3, and Q4. It then subpartitions each of these range partitions into eight subpartitions based on a hash of the PRODUCTID column.

Here is an example of a hash-partitioned global index created on this table:

```
CREATE INDEX orders_acct_global_ix
ON orders (acct_no, ordid)
GLOBAL PARTITION BY HASH (acct_no)
partitions 4;
```

In 12*c*R2, composite partitioning may use interval partitioning as a subpartitioning strategy. In other words, MAXVALUE is not needed because the future subpartitions will automatically be built as data is added that is outside the current ranges.

List Partitioning

Oracle added *list partitioning* for the DBA or developer who really knows his or her data well. List partitioning allows you to assign the individual column values associated with each of the partitions. Several restrictions on list partitioning are displayed after the following code listing.

```
create table dept_part
(deptno    number(2),
 dname     varchar2(14),
 loc       varchar2(13))
partition by list (dname)
(partition d1_east  values ('BOSTON', 'NEW YORK', 'KANSAS CITY'),
 partition d2_west  values ('SAN FRANCISCO', 'LOS ANGELES'),
 partition d3_south values ('ATLANTA', 'DALLAS'),
 partition d4_north values ('CHICAGO', 'DETROIT'));
```

Restrictions on list partitioning are as follows:

- You can specify only one partitioning key in the column list, and it cannot be a LOB column. If the partitioning key is an object-type column, you can partition on only one attribute of the column type.
- Each partition value in the VALUES clause must be unique among all partitions of the table.
- If you specify the literal NULL for a partition value in the VALUES clause, then to access data in that partition in subsequent queries, you must use an IS NULL condition in the WHERE clause, rather than a comparison condition.
- You cannot list partition an index-organized table.
- The string comprising the list of values for each partition can be up to 4K.
- The total number of partition values for all partitions cannot exceed 64K–1.

TIP
In 12cR2, you can also have the database automatically create a separate partition for each distinct partition key value (auto-list partitioning).

Partitioned Indexes (Local)

Different types of partitioned indexes are covered in Chapter 2. The most common type is a local partitioned index, which is where the index is partitioned on the same columns, same number of partitions and bounds as the corresponding table:

```
create table dept
 (deptno       number(2),
  dept_name    varchar2(30))
  partition    by range(deptno)
 (partition d1 values less than (10) tablespace dept1,
  partition d2 values less than (20) tablespace dept2,
  partition d3 values less than (maxvalue) tablespace dept3);

create index dept_idx on dept(deptno) local;
```

Partial Indexes

Although partitioned tables have been providing management and performance improvements for quite some time, partitioned tables typically are very large tables and therefore have very large indexes as well. In Oracle 12*c*, the introduction of partial indexes enables you to create an index and apply it to only specific partitions of the table, reducing the size of the index and only indexing partitions that get frequent use. The partial index can apply to both local and global indexes. To utilize this capability, we specify with the partition of a table if the partitioned is to be indexed using the INDEXING clause (INDEXING ON/INDEXING OFF). For example:

```
CREATE TABLE orders_partial_idx (
order_id NUMBER(12),
order_date DATE CONSTRAINT order_date_nn NOT NULL,
order_mode VARCHAR2(8),
customer_id NUMBER(6) CONSTRAINT order_customer_id_nn NOT NULL,
order_status NUMBER(2),
order_total NUMBER(8,2),
sales_rep_id NUMBER(6),

promotion_id NUMBER(6),
CONSTRAINT order_mode_lov CHECK (order_mode in ('direct','online')),
CONSTRAINT order_total_min CHECK (order_total >= 0))
INDEXING OFF
PARTITION BY RANGE (ORDER_DATE)
(PARTITION ord_p1 VALUES LESS THAN (TO_DATE('01-MAR-1999','DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p2 VALUES LESS THAN (TO_DATE('01-JUL-1999','DD-MON-YYYY'))
INDEXING OFF,
PARTITION ord_p3 VALUES LESS THAN (TO_DATE('01-OCT-1999','DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p4 VALUES LESS THAN (TO_DATE('01-MAR-2000','DD-MON-YYYY')),
PARTITION ord_p5 VALUES LESS THAN (TO_DATE('01-MAR-2010','DD-MON-YYYY')));
```

Then, we create the index and indicate if it is a partial index with the PARTIAL INDEX clause. For example, on a global index:

```
CREATE INDEX ORDERS_GI1 ON orders_partial_idx (PROMOTION_ID) GLOBAL INDEXING
PARTIAL;
```

And here’s an example on a local index:

```
CREATE INDEX ORDERS_GI1 ON orders_partial_idx (PROMOTION_ID) GLOBAL INDEXING
PARTIAL;
```

Other partitioning new features in 12*c*R2 include the capability to split and merge partitions online; convert nonpartitioned tables to partitioned tables online; create multiple-column list partitions; use list partitioning as a subpartitioning strategy for composite partitioned tables; and create read-only partitions.

Reference Partitioning

As of 11*g*R2, Oracle has added reference partitioning where a child table derives its partitioning information from the parent table, and the relationship is defined based on existing primary key (PK)/foreign key (FK) relationships between the parent and child. The partitioning key is resolved through an existing parent-child relationship, enforced by enabled and active primary key and foreign key constraints. Tables with a parent-child relationship can be logically equipartitioned by inheriting the partitioning key from the parent table without duplicating the key columns. The logical dependency also automatically cascades partition maintenance operations, thus making application development easier and less error-prone.

For example, consider the simple case of the ORDERS (parent) and LINEITEMS (child) tables, which are joined based on the PK/FK relationship on the ORDER_ID column in both tables. The ORDERS table also has an ORDER_DATE column, which is used to partition and prune the ORDERS table (there is range partitioning on the ORDER_DATE). The LINEITEMS table does not have any such column (so it's not duplicated), and, therefore, there's not an easy way to partition this table, and it can't take advantage of partition pruning or partition-wide joins based on the ORDER_DATE column.

With reference partitioning, however, the ORDERS table is range-partitioned on ORDER_DATE, for a month at a time, and the LINEITEMS table also now automatically has one partition for each partition of the parent table (given that a reference partition is created using the PARTITION BY REFERENCE clause). The partitioning key is *inherited* through the PK/FK relationship. Please see the *Oracle VLDB (Very Large Database) and Partitioning Guide* for more information.

TIP
Reference partitioning is tailor-made for the partitioning of OLTP systems and those systems that tend to be far more normalized than the rest.

Partition-wise Joins

Oracle also allows a query against two partitioned tables to join on only the needed partitions. Instead of joining many rows to many rows, you can now perform partition elimination on each table and then join the results. To join on partitions, the tables must be equipartitioned tables, which means

- Tables are partitioned using the same partition key.
- Tables must be partitioned with the same partition breakpoints.

System Partitions

System partitions are used to break data into many smaller partitions, but not grouped into any particular groupings other than whatever you decide. System partitions are great to use when you are inserting large amounts of data and want to break it into smaller pieces, but using the same table. You decide exactly what data goes where. Yes, this is as powerful and as dangerous as it sounds; things go exactly where you want them! You can't forget to specify the partition or you will get an "ORA-14701: Partition-extended name or bind variable must be used for DMLs on tables partitioned by System method."

System partitions have the following restrictions:

- Can*not* be used with index-organized tables
- Can*not* play a part in composite partitioning
- Can*not* split
- Can*not* be used with CREATE TABLE AS SELECT…
- Can*not* be used with INSERT INTO *table* AS...

The basic syntax is

```
CREATE TABLE …PARTITION BY SYSTEM PARTITIONS n
```

where *n* is 1 to 1024K–1.

The following is an example:

```
CREATE TABLE DEPT
  (DEPTNO    NUMBER(2),
   DEPT_NAME VARCHAR2(30))
  PARTITION BY SYSTEM
  (PARTITION D1,
   PARTITION D2,
   PARTITION D3);

INSERT INTO DEPT  PARTITION (D1) VALUES (1, 'DEPT 1');
INSERT INTO DEPT  PARTITION (D1) VALUES (22, 'DEPT 22');
INSERT INTO DEPT  PARTITION (D1) VALUES (10, 'DEPT 10');
INSERT INTO DEPT  PARTITION (D2) VALUES (15, 'DEPT 15');
INSERT INTO DEPT  PARTITION (D3) VALUES (7, 'DEPT 7');
```

The PARTITION clause is optional for UPDATEs and DELETEs, but more efficient if you can use it (*be very careful* to ensure that what you are doing is what you want to do).

Global Index Maintenance: Drop and Truncate

Partition Operations

- With Database 12*c*, when you drop or truncate a partition, the global indexes are no longer invalid and managed automatically.
- Table partitions can be moved online:

```
alter table dept move partition d1 tablespace data2 online;
```

- MERGE/SPLIT partitions are now online operations (12*c*R2).
- Nonpartitioned tables can be changed to partitioned tables online (12*c*R2).
- In 12*c*R2, Automatic Data Optimization (ADO, covered in the discussion of the Heat Map earlier in this chapter) is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics.

Other Partitioning Options

This section covers some of the many options that you can use when managing partitions. You will see that many of these options that are available for operations on tables are also available for partitions:

- **MODIFY PARTITION** *partition_name* Modifies the real physical attributes of a table partition. You can specify any of the following as new physical attributes for the partition: LOGGING, PCTFREE, PCTUSED, INITRANS, and STORAGE (note MAXTRANS is deprecated and defaults to 255 concurrent update transactions for a given data block, if there is enough available space in the block).
- **RENAME PARTITION** *partition_name TO new_partition_name* Renames table partition PARTITION_NAME to NEW_PARTITION_NAME.
- **MOVE PARTITION** *partition_name* Moves a table partition to another segment. You can move partition data to another tablespace, recluster data to reduce fragmentation, or change a create-time physical attribute:

```
alter table dept move partition d3 tablespace dept4 nologging;
```

In this example, the D3 partition with all corresponding data is moved from the DEPT3 tablespace, where it originally resided, to the DEPT4 tablespace; NOLOGGING disables redo generation during the MOVE operation and is not the same as the LOGGING or NOLOGGING attribute of the partition or table.

TIP
When moving a partition, use the NOLOGGING option (if possible) for speed.

- **ADD PARTITION** *new_partition_name* **VALUES LESS THAN (***value_list***)** Adds a new partition to the "high" end of a partitioned table. You can specify any of the following as new physical attributes for the partition: LOGGING, PCTFREE, PCTUSED, INITRANS, and STORAGE. The VALUES clause specifies the upper bound for the new partition. The VALUE_LIST is a comma-separated, ordered list of literal values corresponding to partition key values. The VALUE_LIST must contain values that are greater than the partition bound for the highest existing partition in the table.
- **EXCHANGE PARTITION** This powerful option allows you to convert a partition or subpartition into a nonpartitioned table or convert a nonpartitioned table into a partition. This option is very useful if you are archiving old range partitions and want to export them as stand-alone tables before you drop them. Also, it can be useful for quickly loading incremental data into an already-existing partitioned table.
- **DROP PARTITION** *partition_name* Removes a partition and the data in that partition from a partitioned table:

```
alter table dept drop partition d3;
```

TIP

Dropping a table partition causes its local index (but not the other local partition indexes) to be dropped and a global index (one that exists on the entire table) to be unavailable (unless you're willing to rebuild the indexes afterward). Don't use global indexes if you plan to drop table partitions.

- **TRUNCATE PARTITION** *partition_name* Removes all rows from a partition in a table. The example that follows shows the truncation of the D1 partition. For each partition or subpartition truncated, Oracle Database also truncates corresponding local index partitions and subpartitions. If those index partitions or subpartitions are marked UNUSABLE, then the database truncates them and resets the UNUSABLE marker to VALID.

```
alter table dept truncate partition d1;
```

- **SPLIT PARTITION** *partition_name_old* Creates two new partitions, each with a new segment, new physical attributes, and new initial extents. The segment associated with the old partition is discarded. The example that follows shows *splitting* the D1 partition into a D1A partition and D1B partition at DEPTNO=5. Note that you must also rebuild the indexes after this operation.

```
Alter table dept split partition d1 at (5) into
  (partition d1a tablespace dept1,
   partition d1b tablespace dept2);

SEGMENT_NAME PARTITION_NAME SEGMENT_TYPE
------------ -------------- -----------------
DEPT         D1A            TABLE PARTITION
DEPT         D1B            TABLE PARTITION
DEPT         D2             TABLE PARTITION

Alter index dept_idx rebuild partition d1a;
Alter index dept_idx rebuild partition d1b;
```

- **MERGE PARTITIONS** *partition_list* **INTO PARTITION** *new_name* Takes two partitions and combines them into one partition. The next example shows *merging* the D1A and D1B partition back into the partition named D1. Note that you must also rebuild the indexes after this operation.

```
Alter table dept merge partitions d1a, d1b
into partition d1;

SEGMENT_NAME PARTITION_NAME SEGMENT_TYPE
------------ -------------- -----------------
DEPT         D1             TABLE PARTITION
DEPT         D2             TABLE PARTITION

Alter index dept_idx rebuild partition d1;
```

The following bullet points are no longer commands, but options you can use with the partition maintenance commands (ALTER TABLE PARTITION *name* MODIFY or the ALTER INDEX):

- **UNUSABLE LOCAL INDEXES** Marks all the local index partitions associated with the specified partition as unusable.
- **REBUILD UNUSABLE LOCAL INDEXES** Rebuilds the unusable local index partitions associated with the named partition.
- **ALTER INDEX .. MODIFY PARTITION .. UNUSABLE** Marks the index or index partition(s) as unusable. An unusable index must be rebuilt or dropped and re-created before it can be used. While one partition is marked unusable, the other partitions of the index are still valid, and you can execute statements that require the index if the statements do not access the unusable partition. You can also split or rename the unusable partition before rebuilding it.
- **ALTER INDEX .. REBUILD PARTITION** Rebuilds one partition of an index. You can also use this option to move an index partition to another tablespace or to change a create-time physical attribute.

Index Partitioning

Partitioned indexes have the same advantages as partitioned tables. Accessing smaller pieces instead of one index on the entire table increases performance when properly executed. There are local and global indexes, and prefixed or nonprefixed indexes. A *local index* has been partitioned; each piece is a local index. A *global index* is just a regular nonpartitioned index. A *prefixed index* is when the leftmost part of the index is the partition key, whereas a *nonprefixed index* can be costly to access because the partition key is not indexed. If a partition of a table with a global index is dropped, then the corresponding global index is invalidated. If a partition of a table with a local prefixed index is dropped, then the local index is also dropped.

The initialization parameter SKIP_UNUSABLE_INDEXES allows the user to disable error reporting of indexes and index partitions marked unusable. If you do not want the database to choose a new execution plan to avoid using unusable segments, you should set this parameter to FALSE (the default value is TRUE).

The following is an example of a local prefixed partitioned index (the most common type). The index name is DEPT_INDEX, and the index is on the DEPTNO column of the DEPT table. The index is split into three pieces (D1, D2, and D3) that are located in three tablespaces (DEPT1, DEPT2, and DEPT3) that are striped differently from the location of the corresponding table data. This ensures that accessing information from a table partition and its corresponding index partition will result in accessing two physical disk drives instead of one—given that DEPT1–DEPT3 are tablespaces that correspond to datafiles on different physical disks.

```
create index dept_index on dept (deptno)
  local
 (partition d1 tablespace dept2,
  partition d2 tablespace dept3,
  partition d3 tablespace dept1);

Index Created.
```

You can get the information regarding partitioned indexes by accessing DBA_INDEXES:

```
select    index_name, partition_name, tablespace_name
from      dba_ind_partitions
where     index_name = 'DEPT_INDEX'
order by  partition_name;

INDEX_NAME   PARTITION_NAME   TABLESPACE_NAME
DEPT_INDEX               D1             DEPT2
DEPT_INDEX               D2             DEPT3
DEPT_INDEX               D3             DEPT1
```

TIP
Indexes that are partitioned (local indexes) should also be prefixed, meaning the partitioning key is the leading edge of the index.

Exporting Partitions

Partitions can be effortlessly exported. If the data in your table is segmented carefully, it is possible to keep all new information in a single partition to export. This is only true for certain datasets that use some sort of increasing column value for the partition key. For example, if you partition by date, all new data goes into the latest partition. However, if your data is partitioned by username, or some other generic identifier, then this is not always true. By using a partition key of increasing values, you could potentially eliminate the need to export data from partitions that have not changed and have been previously exported. By using the EXPORT command and giving the *owner.table.partition_name* for the table to be exported, only the partition is exported:

```
expdp user/pass file=tab.dmp tables=(owner.table:partition name)
```

Here's a simple example using the DEPT table:

```
expdp scott/tiger file=dept d1.dmp tables=(dept:d1) directory=dpump dir
```

TIP
If you are archiving old data, consider exchanging the partition for a table name that is more verbose before exporting it. This way, you could import just that table back for reference later and potentially avoid even having to return it to the partitioned table.

Eliminating Fragmentation (Only If Needed—Careful!)

Fragmentation can hamper space management operations in the database, but it is a long-enduring myth that overall the number of extents in a segment *always* impacts performance against the database. It is an equally long-enduring myth that the number of extents *never* impacts performance. Bitmap indexes with many noncontiguous extents spanning multiple datafiles can cause a big performance problem. Generally, locally managed tablespaces can minimize most extent-related issues. The need for repeated reorganizations should be a thing of the past for most (but not all) DBAs, if you have set up your storage properly. Fortunately, if you do still need to deal with the occasional reorganization, you now have several ways to perform this activity while minimizing downtime.

To avoid performance issues with extent management, you can do the following:

- Use locally managed uniform-extent tablespaces when you know how big a segment will grow or the rate at which it will grow.
- Use extent sizes that are multiples of the database block size.
- Move tables to tablespaces with an appropriate extent size when they grow too large.
- Avoid row chaining by using Automatic Segment Space Management (ASSM, discussed a bit later).

I recommend that you regularly monitor your database to find segments that are growing to extreme numbers of extents (over a thousand) and then manage those segments appropriately:

```
select    segment_name, segment_type, extents, bytes
from      dba segments a, dba tablespaces b
where     a.extents > 1000;

SEGMENT NAME    SEGMENT TYPE   EXTENTS          BYTES
ORDER           TABLE          2200         220000000
ORDER_IDX1      INDEX          1200         120000000
CUSTOMER        TABLE          7000          70000000
```

TIP

Query DBA_SEGMENTS on a regular basis to ensure that objects are not building up too many extents (when not using ASM). Catching problems early is the key to avoiding performance issues later (there are times when it's better just to leave things as they are, particularly when there isn't an issue). The goal is to place objects correctly in tablespaces with uniform extent sizes that are appropriate for the expected growth of the objects.

Using the Correct Extent Size

When data is read from a table, it is either accessed by a ROWID operation via an index or by a full table scan (except for index-organized tables). In most cases, access by ROWID is the preferred method. The ROWID method allows the database to determine the exact block that a record resides in and, therefore, bypasses any extent allocation information in the segment. The short answer is that ROWID operations do not care how many extents are in the segment. Database block sizes generally range from 4K to 32K. So, regardless of the number of extents in a segment, a full table scan always performs the same number of reads as long as the extent size is a multiple of the database block size.

Do you still need to worry about extent counts if you are using extents that are multiples of the block size? Yes you do, but you aren't as driven by it as you used to be. Think of it this way, the more extents you have, the more you have to manage, even if it is managed via faster methods. Therefore, my rule of thumb is if you have a segment growing over 4096 extents (assuming you are using locally managed tablespaces), consider moving it to a tablespace where the extent size is more appropriate for the size of the segment. If you have a 15G table, using a 200M extent size is probably more efficient than using a 1M extent size. For the purposes of loading data alone, you will save backend processing time because the database does not have to allocate as many extents during the load process.

Avoiding Chaining by Setting PCTFREE Correctly

When a row is created in a table, the data is written to a block and is given a ROWID. The ROWID identifies the data's location on disk. If a row is updated, the changes are written to the same location on disk. The ROWID for the row does not change. Row chaining can occur when there isn't enough room in the data blocks to store a single row or the most recent changes made to a row. A chained row is one that exists in multiple blocks instead of a single block. Accessing multiple blocks for the same row can be costly in terms of performance. To see if you have chaining problems, run the utlchain.sql script that Oracle provides to create the CHAINED_ROWS table. The utlchain.sql file comes with Oracle and is in the /rdbms/admin subdirectory of your ORACLE_HOME. You can also use Enterprise Manager or look for "Fetch By Continued Row" in STATSPACK or AWR Report to detect chained rows. You should check for chaining on a weekly basis and fix any problems immediately. To analyze the amount of chaining in a table (CUSTOMER in this example), run the following query:

```
ANALYZE TABLE CUSTOMER
LIST CHAINED ROWS;
```

Then, run the following query accessing the CHAINED_ROWS table to check the CUSTOMER table for chaining:

```
select   HEAD_ROWID
from     CHAINED_ROWS
where    TABLE_NAME = 'CUSTOMER';
```

If no rows are returned, then you don't have a chaining problem. If there is a chaining problem, then the query will return the HEAD_ROWID for all chained rows. You can also use SELECT COUNT(*) against the CHAINED_ROWS table to find the number of chained rows. In V$SYSSTAT, "*table fetch continued row*" is an indicator of chained rows as well.

To avoid row chaining, set PCTFREE (the amount of space reserved in a block for updates) correctly (don't set this when using ASSM, discussed next). This parameter is set when the table is created. The default value is set to 10 (10 percent free for updates), but this needs to be much higher in a table where there is a large frequency of update activity to rows in the table.

Incidentally, if you have a table where update activity will be very low to nonexistent, you can set the PCTFREE to a slightly lower value to ensure more rows will fit into the block and, therefore, conserve space in your table.

TIP
Find chaining problems by accessing the CHAINED_ROWS table. Avoid chaining problems by correctly setting PCTFREE or choosing the correct size for your database.

Using Automatic Segment Space Management (ASSM)

Automatic Segment Space Management in locally managed tablespaces is an alternative to using free lists. This system of managing free space in segments utilizes bitmaps to track the amount of free space in blocks that is available for inserting rows. Because free lists are no longer used when ASSM is enabled, the overall time and resources needed by the database are greatly minimized.

In the latest version of the database, Oracle has further expanded the feature set of ASSM and provided a new clause to the ALTER TABLE and ALTER INDEXES statements. The SHRINK SPACE clause essentially coalesces the free space in the segment, releasing unused space so the segment can be smaller. This improves the performance of queries on this segment, and it is much easier to implement than to reduce a segment size through EXPORT/IMPORT or MOVE/RENAME operations. Refer to the documentation on this feature for restrictions and limitations.

ASSM should improve overall performance of block management within segments, but there is a circumstance where the architecture of using a free space bitmap for the block usage can slow performance. Full table scans of small tables (< 1000 rows) in an ASSM-enabled tablespace will actually require more buffer gets than a non-ASSM tablespace. Therefore, if you have your tablespaces organized by segment size, ASSM should probably be used only on those tablespaces with medium to large segments.

ASSM has the potential to make a dramatic improvement to block management performance, but do your research, as there are several bugs scattered across different versions of the database that can affect you in specific situations. Before implementing ASSM on your system, be sure to research the types of segments you will have in your tablespace and check for issues related to operations against those types of segments for your version of the database. Most of these bugs have patches that can be applied to resolve the issues.

TIP
Improve performance and segment management by using ASSM, or use separate tablespaces for smaller segments.

Increasing the Log File Size and LOG_CHECKPOINT_INTERVAL for Speed

If you want to speed up large numbers of INSERTs, UPDATEs, and DELETEs, increase the sizes of your log files and make sure they are on the fastest disk. Previously, you could also increase the LOG_CHECKPOINT_INTERVAL if it was set such that it would checkpoint prior to a log switch, and this currently defaults to zero (which means switching based on the redo log being full). The LOG_CHECKPOINT_INTERVAL determines the length of time between checkpoints. Therefore, any recovery that involves applying the online redo logs is affected—meaning complete database recovery or instance recovery. Increasing the size of your log files can increase the time needed for media recovery.

Oracle relies on online redo log files to record transactions. Each time a transaction takes place in the database, an entry is added to the online redo log file. If you increase the size allocated for the redo log files, you can increase performance by decreasing the overall number of required log switches and checkpoints. Uncommitted transactions generate redo entries, too, because they generate undo records and these undo records are also written to the redo logs. You can watch the logs spin during a large batch transaction. But keep the following characteristics in mind when you make modifications to the size of your log files:

- A log file must be online and available while the database is up or the database will halt (one of the few things that stops the database immediately).
- Online redo log files are recycled and offline redo log files are written to archived log files automatically (if archiving is activated).
- Minimum is two online redo log files. Online redo log file multiplexing (additional copies) is recommended to provide redundancy in case an online redo log file is lost.
- The number of initial log files and their sizes are determined automatically when the database is created.
- Archive logging can be turned on and off by restarting the database in MOUNT mode and then using the ALTER DATABASE command.
- Checkpoints occur when committed transactions in redo logs get written to the database. Checkpoints also update the datafile headers to set the checkpoint SCN, which is used during the rolling back phase of recovery. If the current SCN for the database at the time of failure was 234578, and the datafiles have a checkpoint SCN of 234500, then only the changes in the redo logs from 234500 to 234578 need to be rolled back. Checkpoints are basically consistency markers for the database—a way of saying everything is in sync at this point.

Determining If Redo Log File Size Is a Problem

Two potential problems are possible that should be addressed. The first concerns batch jobs that do not have enough total redo space to complete or are so fast that the online redo logs wrap (cycle through all the logs and start writing to the first one again) before they are archived to the offline redo logs. Because an online redo log cannot be overwritten until it is archived (when archiving is enabled), DML and DDL activity has to wait until an online log becomes available. By listing the online redo logs with their last update date and time at the operating system level, you can determine how often they are switching. You can also query V$LOG_HISTORY for the last 100 log switches. If you increase the size of the online redo logs, it may provide the space for large batch jobs doing large INSERT, UPDATE, and DELETE transactions. A better solution may be to increase the number of online redo logs so the additional space is provided while also having a frequent log switch (smaller but more online redo logs).

The second potential problem concerns long-running jobs that are spending a large amount of time switching online redo logs. Long-running jobs are often much faster when the entire job fits into a single online redo log. For the online transaction processing (OLTP) type of environment, smaller online redo logs are usually better. My rule of thumb is for online redo logs to switch every half hour (not counting the long-running batch jobs that shorten this time). By monitoring the date and time of the online redo logs at the operating system level (or querying V$LOG_HISTORY), you can determine whether to increase the size or number of online redo logs to reach an optimum switching interval.

Here is a query that shows you the time between log switches. It can be handy in determining if you have a problem:

```
select b.recid,
       to_char(b.first_time,'dd-mon-yy hh:mi:ss') start_time, a.recid,
       to_char(a.first_time,'dd-mon-yy hh:mi:ss') end_time,
       round(((a.first_time-b.first_time)*25)*60,2) minutes
from   v$log_history a, v$log_history b
where  a.recid = b.recid+1
order  by a.first_time asc
/
```

Determining the Size of Your Log Files and Checkpoint Interval

You can determine the size of your online redo log files by checking the size at the operating system level or querying the V$LOG and V$LOGFILE views. Displaying information about redo logs is shown in the query listed here:

```
select   a.member, b.*
from     v$logfile a, v$log b
where    a.group# = b.group#;

MEMBER                 CRP#   THRD#   BYTES       MEMBERS    STATUS
/disk1/log1a.ora       1      1       2048000     2          INACTIVE
/disk1/log2a.ora       2      1       2048000     2          CURRENT
/disk2/log1b.ora       1      1       2048000     2          INACTIVE
/disk2/log2b.ora       2      1       2048000     2          CURRENT
(partial columns listed only...)
```

The query output shows two groups of redo logs. Each group has two redo log files in it (one primary file and one multiplexed file). The data in /disk1/log1a.ora and in /disk2/log1b.ora is exactly the same (multiplexing redo log files is for availability and recoverability purposes).

TIP
Increase the size of your log files to increase the rate at which large INSERTs, DELETEs, and UPDATEs (DMLs) are processed.

Other Helpful Redo Log Commands

You can add additional redo logs by using the ALTER DATABASE ADD LOGFILE command to create larger redo logs and then to drop the smaller ones.

To multiplex online redo log files (creating a mirrored copy), use this command to add a log file to an existing group:

```
alter database add logfile member '/disk2/log1b.ora' to group 1;
alter database add logfile member '/disk2/log2b.ora' to group 2;
```

To drop an online redo log member, use this command:

```
alter database drop logfile member '/disk2/log2b.ora';
```

To add a new online redo log group, use this command:

```
alter database add logfile group 3 ('/disk1/log3a.ora') size 10M;
```

To drop an entire online redo log group (all copies), use this command:

```
alter database drop logfile group 1;
```

NOTE
You cannot drop a redo log file group if doing so would cause the redo thread to contain less than two redo log file groups. You cannot also drop the redo log file group if it contains the current online redo log (ORA-01623). In this case, you need to switch log groups first and then you can drop the redo log group.

To switch log files (change current redo log group to next redo log group):

```
alter system switch logfile;
```

TIP
Put the redo logs on the fastest disk (or SSD or flash) if you plan to write a lot of information. Try to use the outer edge of the disk (the fastest part on many disk types) for the redo logs. Better yet, there is an ASM feature that does this: The Intelligent Data Placement feature enables you to specify disk regions on Oracle ASM disks to ensure that frequently accessed data is placed on the outermost (hot) tracks, which provide higher performance.

Additional Redo Log Instance Parameters

These further instance parameters can have an effect on the performance of your online redo log files:

- **LOG_ARCHIVE_DUPLEX_DEST** Directory location with archive prefix (arch). This is a location to write an additional copy of archive logs (as redo logs are filled and are archived in ARCHIVELOG mode only). If you have the space, this safety net can save you if archiving errors occur. For Oracle Enterprise Edition (EE) databases, this parameter is deprecated in favor of the LOG_ARCHIVE_DEST_*n* parameters. If Oracle EE is not installed or it is installed but you have not specified any LOG_ARCHIVE_DEST_*n* parameters, this parameter is valid.
- **LOG_ARCHIVE_MIN_SUCCEED_DEST** Can be set to 1 to 10 if you are using LOG_ARCHIVE_DEST_*n*, or to values of 1 or 2 if you are using LOG_ARCHIVE_DEST and LOG_ARCHIVE_DUPLEX_DEST. This is the minimum number of successful archives

written for a redo log. If you set it to 2, then you have two mandatory archiving destinations, similar to setting LOG_ARCHIVE_DEST1 and LOG_ARCHIVE_DEST2 and mandatory archive sites. If you set any LOG_ARCHIVE_DEST_*n* parameter where *n* > 3, then those sites are treated as optional archive sites. If you set LOG_ARCHIVE_MIN_SUCCEED_DEST to 1, then the LOG_ARCHIVE_DUPLEX_DEST or LOG_ARCHIVE_DEST_*n* (*n* > 1) sites are optional best-effort archive sites, not mandatory sites.

- **DB_WRITER_PROCESSES** This is the number of database writers to write data from the SGA to disk when one database writer isn't enough.
- **DBWR_IO_SLAVES** If you can't use multiple processes (or if you don't have asynchronous I/O and want to emulate it), then you can use DBWR_IO_SLAVES to distribute the load of the ARCH and LGWR processes over multiple I/O slaves. This can't be used if DB_WRITER_PROCESSES > 1.

Storing Multiple Control Files on Different Disks and Controllers

Control files store information regarding startup, shutdown, and archiving. Because your system is useless without at least one good control file, you should store three copies of the control files on separate disks and controllers (if possible). If you do happen to remove *all* the control files while the database is open, you can use the ALTER DATABASE BACKUP CONTROLFILE command to generate a new one. If the database is closed and the control file is missing, you can use the CREATE CONTROLFILE statement to re-create the control file. However, re-creating the control file from scratch is a lot of work and prone to error. And lots of valuable, possibly critical, information is lost (for example, the most recent backup information for RMAN backups).

To view current control files, run the following query:

```
select   name, value
from     v$parameter
where    name = 'control_files';

NAME             VALUE
control_files    /disk1/ora10/ctl1.ora, /disk2/ora10/ctl2.ora,
                 /disk3/ora10/ctl3.ora
```

Another suggestion is to create a text copy of the control file at regular intervals, or at least after any database architectural change (at the file or tablespace level). This helps if you lose all copies and have to re-create the control file from scratch.

Other Disk I/O Precautions and Tips

Here are a few further miscellaneous notes pertaining to disk I/O:

- If you can afford it and you need the speed, put everything on SSD (flash) or Exadata. At a minimum, try to put redo logs on SSD and, if possible, UNDO and TEMP.
- Heavy batch processing may need much larger UNDO, REDO, and TEMP tablespace sizes.
- Heavy DML (INSERT, UPDATE, and DELETE) processing may need much larger UNDO, REDO, and TEMP tablespace sizes.
- Heavy user access to large tables will usually require more CPU and memory.
- Poorly tuned systems will require more CPU and memory and larger temporary tablespace sizes.
- A greater number of well-balanced disks and controllers will always increase performance (by reducing I/O contention).
- If you increase disk capacity, you can speed backup and recovery time by keeping a copy of the backup on disk instead of tape.
- If you can afford it, Exadata, EMC, and/or solid state or flash disk solutions are some of the absolute best ways to improve Oracle I/O performance.
- Versions 10*g* and 11*g* required ASM and database instances to be on the same server. With new features of 12*c* ASM, this tightly coupled configuration for ASM and database instance has been loosened, and this provides for greater flexibility in managing ASM instances in RAC environments and remote ASM. Oracle also provides the new 12*c* Flex Clusters for RAC, the ability to rebalance hot spots, and fast sync and repairs.

Issues to Consider in the Planning Stages

If you're planning a new system or an upgrade, here are some things you'll want to consider:

- What is the maximum possible disk capacity for the hardware?
- What disk sizes are available?
- What will be the initial size of the database?
- What will be the future size of the database and what is the rate of growth?
- Will there be a RAID (striping) level for database files or the OS? Can I use ASM?
- What recovery methods will be employed?
- What archiving methods will be used to store historical information?
- How often will report output be kept on the system?
- What development space will be needed?
- What software will be installed, and how much space will it need to function efficiently?
- What system utilities will be installed, and how much space will they need to function efficiently?

- What data transfer methods are going to be employed?
- Is ASM installed? Learn and plan for it if it is.
- What are the batch processing requirements, and will there be ad hoc user queries?
- How will the data be accessed that may cause potential hot spots?

Finally, it's worth mentioning the product Oracle Orion here. Oracle Orion is a tool for predicting the performance of an Oracle database without having to install Oracle or create a database. Unlike other I/O calibration tools, Oracle Orion is expressly designed for simulating Oracle database I/O workloads using the same I/O software stack as Oracle. Orion can also simulate the effect of striping performed by Oracle Automatic Storage Management

TIP
When you are in the system planning stage, ensure that you find out all of the information related to the current and future use of the system. Don't just think about the Oracle database needs—investigate the other software and applications that affect the performance of your Oracle database.

Tips Review

- One of the best features of 12*c* is pluggable databases. It offers the ability to consolidate hundreds of databases into a single container database (CDB) with hundreds of pluggable databases (PDBs).
- Two of the best features of 12*c*R2 are the ability to flashback pluggable databases (PDBs) and the ability to build a subset standby with only some PDBs. In 12*c*R2, you can also set partitions and subpartitions to be read-only.
- Redo and archive log files are defined as fine-grained, whereas datafiles are coarse.
- Try to avoid splitting a logical device in a disk array into more than one filesystem. Splitting may seem to give you flexibility, but it can also increase the number of datafile locations you have to manage.
- Use disk arrays to improve performance and protect your data against disk failure. Choose the proper RAID level and technology solutions that enable you to maintain the availability your organization needs. Don't just go "good enough," because you will regret it at 2 a.m. when you lose a disk. ASM is a great option with striping and mirroring capabilities.
- Separate key Oracle datafiles in *traditional* filesystems to ensure that disk contention is not a bottleneck. By separating tables and indexes of often-joined tables, you can ensure that even the worst of table joins do not result in disk contention. In Enterprise Manager (Cloud Control), Oracle makes it easy to move data to a hotter or colder region of a disk.

- Query V$FILESTAT and V$DATAFILE to see how effectively datafiles have been balanced. Note that temporary tablespaces are monitored using V$TEMPFILE and V$TEMPSTAT.
- To have the largest Oracle 12*c* database possible, 8 exabytes, you must use 128T datafiles (and must also use bigfile tablespaces and a 32K block size).
- Although ASM does not provide multipathing capabilities, it does leverage multipathing tools, as long as the path or device produced by the multipathing tool returns a successful return code from an FSTAT system call. My Oracle Support Note 294869.1 provides more details on ASM and multipathing.
- To ensure that ASM is using the multipath device names and not the regular device, set the ASM_DISKSTRING parameter to look for the multipath device names. For example, if you are using EMC PowerPath, set the disk string to '/dev/emcpower*'. The only exception is when you are using Linux and the disk string is set to 'ORCL:*'. In such cases, you would configure ASMLIB to give preference to saved multipath devices.
- To minimize disk I/O on a single large table, you can break the table into multiple partitions that reside in tablespaces on different physical disks.
- Tables can be easily partitioned for individual pieces to be accessed and/or manipulated; you can still access the entire table of a partitioned table. Accessing the tables DBA_TABLES, DBA_PART_TABLE, and DBA_SEGMENTS provides additional information concerning tables that have been partitioned.
- You can also partition tables using multiple columns as the criteria. You must specify MAXVALUE for all columns that are part of the partition key except for interval partitioning as of 11*g*. In 12*c*R2, you can have interval partitions as part of composite partitions using the intervals as a subpartitioning strategy.
- When you don't know how to break up a table, but you know that it needs to be partitioned and spread out, use hash partitioning.
- In 12*c*R2, you can have multiple columns for list partitioning.
- In 12*c*R2, you can also have the database automatically create a separate partition for each distinct partition key value (auto-list partitioning).
- Reference partitioning is tailor-made for the partitioning of OLTP systems and those systems that tend to be far more normalized than the rest.
- Use the NOLOGGING option when rebuilding a problem table to avoid generating large amounts of redo.

CAUTION
When you create a table or index as NOLOGGING, the database does not generate redo log records for the operation. Thus, you cannot recover objects created with NOLOGGING, even if you are running in ARCHIVELOG mode. If you cannot afford to lose tables or indexes created with

NOLOGGING, then make a backup after the unrecoverable table or index is created. But, in 12cR2, on Oracle Data Guard for Data Warehouses, we now have NOLOGGING operations on the primary that can be tracked. Originally, blocks on the standby would be marked unrecoverable when NOLOGGING was used on the primary. With the new tracking, Data Guard can track the blocks for loads with NOLOGGING and, using RMAN, recover the blocks using the new RMAN command RECOVER DATABASE NOLOGGING.

- Dropping a table partition causes its local index (but not the other local partition indexes) to be dropped and a global index (one that exists on the entire table) to be unavailable (unless you're willing to rebuild the indexes afterward). Don't use global indexes if you plan to drop table partitions.
- Indexes that are partitioned (local indexes) should also be prefixed, meaning the partitioning key is the leading edge of the index.
- If you are archiving old data, consider exchanging the partition for a table name that is more verbose before exporting it. This way, you could import just that table back for reference later and potentially avoid even having to return it to the partitioned table.
- Query DBA_SEGMENTS on a regular basis to ensure that objects are not building up too many extents (when not using ASM). Catching problems early is the key to avoiding performance issues later (there are times when it's better just to leave things as they are, particularly when there isn't an issue). The goal is to place objects correctly in tablespaces with uniform extent sizes that are appropriate for the expected growth of the objects.
- Find chaining problems by accessing the CHAINED_ROWS table. Avoid chaining problems by correctly setting PCTFREE or choosing the correct size for your database.
- Improve performance and segment management by using ASSM, or use separate tablespaces for smaller segments.
- Increase the size of your log files to increase the rate at which large INSERTs, DELETEs, and UPDATEs (DMLs) are processed.
- Put the redo logs on the fastest disks (SSD or flash) if you plan to write a lot of information. Try to use the outer edge of the disk (the fastest part on many disk types) for the redo logs. Better yet, there is an ASM feature that does this: The Intelligent Data Placement feature enables you to specify disk regions on Oracle ASM disks to ensure that frequently accessed data is placed on the outermost (hot) tracks, which provide higher performance.
- Increase the size of online redo logs if log switches are occurring less than every half hour during normal business conditions (excluding infrequent large batch jobs). Increase the number of online redo logs if you are wrapping during large batch jobs.
- When you are in the system planning stage, ensure that you find out all of the information related to the current and future use of the system. Don't just think about the Oracle database needs—investigate the other software and applications that impact performance of your Oracle database.

References

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Many thanks to Joe Matthew, who did the 12*c* update to this chapter. Also, thanks to Sri Avantsa, who did most of the updates for the 11*g* version, and to Bill Callahan, who did the previous update of this chapter. Thanks to Nitin Vengurlekar, who contributed a large amount of ASM knowledge to this chapter originally for 11*g*.

CHAPTER 4

Tuning the Database with Initialization Parameters (DBA)

The Oracle initialization files (SPFILE or a PFILE such as initSID.ora) determine many Oracle operating system environment attributes, such as memory allocated for data, memory allocated for statements, resources allocated for I/O, and other crucial performance-related parameters. Each version of Oracle has added to the total number of initialization parameters, and Oracle 12*c* is no exception, having added many new parameters, especially related to the In-Memory Database. Oracle 12*c* Release 2 now has 4649 initialization parameters (412 documented and 4237 hidden). Note that these numbers will vary slightly on different patch releases and different operating systems.

As you might expect, an entire book could be written on how to set and tune each parameter; this book focuses on the key parameters that affect database performance. Consider reading or referencing Appendix A after this chapter, as it contains a list of all documented initialization parameters, obsolete and deprecated parameters, my Top 25 (many covered in this chapter), my Top 20 not-to-forget parameters (things like AUDIT_TRAIL for auditing and CELL_OFFLOAD_PROCESSING for smart scans in Exadata), my Top 13 undocumented parameters (many for recovery and corruption), my bonus Top 10 undocumented new parameters (such as the Exadata parameter _KCFIS_STORAGEIDX_DISABLED to turn off storage indexes for tuning/testing), and lastly, a section containing recommendations from the Oracle Applications Development team for 12*c*.

The key to an optimized Oracle database is often the architecture of the system and the parameters that set the environment for the database. Setting key initialization parameters (MEMORY_TARGET, MEMORY_MAX_TARGET, SGA_MAX_SIZE, PGA_AGGREGATE_TARGET, **PGA_AGGREGATE_LIMIT**, DB_CACHE_SIZE, SHARED_POOL_SIZE, and **INMEMORY_SIZE**) can be the difference between subsecond queries and queries that take several minutes (new 12*c* parameters are bolded). The MEMORY_TARGET parameter can replace some of the key parameters that are covered in this chapter (although you often need to still set minimums for some parameters to ensure Oracle allocates enough memory for them, especially DB_CACHE_SIZE and SHARED_POOL_SIZE). This chapter focuses on the crucial initialization parameters, but also lists the Top 25 initialization parameters near the end of the chapter. The chapter concludes with a look at the *always growing* typical server configurations for various database sizes.

This chapter contains the following tips and techniques designed to achieve the greatest performance gain with the least effort by focusing on the parameters that yield the biggest impact:

- When upgrading to 12*c*
- Using SEC_CASE_SENSITIVE_LOGON and case-sensitive passwords
- Crucial memory initialization parameters for performance
- Setting the pluggable database (PDB) level using resource plan directives: MEMORY_LIMIT and MEMORY_MINIMUM (12*c*R2)
- Using Database 12*c* (12.1.0.2 and above) In-Memory Database
- Modifying the initialization parameter file without a restart
- Working with the SPFILE and creating a readable PFILE (init.ora)
- Viewing the initialization parameters via Enterprise Manager Cloud Control
- Tuning the DB_CACHE_SIZE
- Tuning the SHARED_POOL_SIZE
- Checking library cache and dictionary cache
- Querying the X$KSMSP table to get another picture of SHARED_POOL_SIZE
- Using multiple buffer pools
- Tuning the PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT (12*c*)
- User, session, and system memory use
- Working with the OPTIMIZER_MODE parameter
- Two important Exadata initialization parameters
- The top 25 performance-related initialization parameters to consider
- Typical server setups with different size databases
- Oracle Applications recommendations (more in Appendix A)

When Upgrading to Oracle Database 12*c*

When upgrading to Oracle Database 12*c*, you need to consider many parameters that will apply to your unique system. Please check Appendix A for any parameters that are obsolete (i.e., removed) or deprecated (i.e., may be removed in the future and use is discouraged, although still okay to use for backward compatibility). We will cover a few parameters that are both important and common for most systems. The Database Upgrade Assistant (DBUA) is extremely helpful and shows that Oracle truly wants to assist you in the upgrade process. The DBUA uses pre-upgrade scripts that check the following before the upgrade:

- Invalid user accounts or roles
- Invalid data types or invalid objects
- Desupported character sets

- Statistics gathering (recommended, but not checked by DBUA)
- Adequate resources (UNDO/ROLLBACK segments, tablespaces, and free disk space)
- Missing SQL scripts needed for the upgrade
- Listener running (if Oracle Enterprise Manager Cloud Control upgrade or configuration is requested)
- Oracle Database software linked with the Database Vault option (if Database Vault is enabled, disable it before upgrade)

Next, consider some key parameters related to the In-Memory (IM) Database, which include: INMEMORY_SIZE, INMEMORY_QUERY, INMEMORY_MAX_POPULATE_SERVERS, INMEMORY_FORCE, INMEMORY_CLAUSE_DEFAULT, INMEMORY_VIRTUAL_COLUMNS, and INMEMORY_TRICKLE_REPOPULATE_SERVERS_PERCENT. To turn on the In-Memory Database (In-Memory column store), set the following:

```
INMEMORY_SIZE=1520M
INMEMORY_QUERY_ENABLED=TRUE
SGA_TARGET =25G
```

The INMEMORY_SIZE enables the In-Memory Database when it is set to any value (so ensure you are licensed before you do this). Also note that SGA_TARGET and MEMORY_TARGET will probably need to be increased by the amount of INMEMORY_SIZE since the value of INMEMORY_SIZE is included in the amount you set for the SGA_TARGET and therefore the MEMORY_SIZE. The “In-Memory Database (INMEMORY_SIZE)” section of this chapter covers this subject in detail.

There are also new parameters related to Adaptive Query Optimization (covered in detail in Chapter 8). The main parameters new in 12*c* are OPTIMIZER_ADAPTIVE_FEATURES and OPTIMIZER_ADAPTIVE_REPORTING_ONLY. All the parameters that can change the behavior of Adaptive Query Optimization are listed here (and a couple of extra ones below that; the defaults are listed):

```
OPTIMIZER_ADAPTIVE_FEATURES =TRUE
OPTIMIZER_ADAPTIVE_REPORTING_ONLY=FALSE
OPTIMIZER_DYNAMIC_SAMPLING=2
OPTIMIZER_MODE=ALL_ROWS
OPTIMIZER_FEATURES_ENABLE=12.2.0.1

OPTIMIZER_INMEMORY_AWARE=TRUE
OPTIMIZER_USE_INVISIBLE_INDEXES=FALSE
```

By default, the OPTIMIZER_ADAPTIVE_FEATURES parameter is set to TRUE to enable adaptive plans, automatic re-optimization, SQL plan directives, and adaptive distribution. Adaptive plans are those that allow execution plans to automatically alter things like the join method (I've seen this work well) or the parallel query distribution on the first run. The OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter can be set to TRUE (FALSE is the default) to first test which queries are going to adapt before the optimizer actually uses the adapted plan. This might be helpful when first upgrading from an earlier version of Oracle, to avoid any unexpected behavior.

Using SEC_CASE_SENSITIVE_LOGON

Be aware that passwords are case sensitive. This is controlled by an initialization parameter introduced in 11*g*, SEC_CASE_SENSITIVE_LOGON. The default is TRUE, which makes passwords case sensitive by default. Set this to FALSE to disable this feature. You can also lock an account if a user fails to enter the correct password a specified number of times, using the SEC_MAX_FAILED_LOGIN_ATTEMPTS parameter (the default is 10). Based on your security needs, you may consider changing this value.

Once locked, the DBA must issue the following command to unlock an account:

```
SQL> ALTER USER username ACCOUNT UNLOCK;
```

Crucial Memory Initialization Parameters for Performance

Although tuning specific queries individually can lead to performance gains, the system will still be slow if the parameters for the initialization file are not set correctly, because the initialization file plays such an integral role in the overall performance of an Oracle database. While you can spend time setting all the initialization parameters, there are a few main parameters that need to be set correctly to realize significant performance gains:

- MEMORY_TARGET
- MEMORY_MAX_TARGET
- SGA_TARGET
- SGA_MAX_SIZE
- PGA_AGGREGATE_TARGET
- PGA_AGGREGATE_LIMIT
- DB_CACHE_SIZE
- SHARED_POOL_SIZE
- INMEMORY_SIZE

The MEMORY_TARGET parameter and optionally the parameter MEMORY_MAX_TARGET will enable Automatic Memory Management (AMM) for all shared memory, including the Program Global Area (PGA), shared pool, and database buffer cache. This will set a defined amount of memory and allow Oracle to control the memory automatically and adjust the defined memory pool between the areas based on system needs (AMM is described in more detail in My Oracle Support Note 443746.1 as well as later in this chapter). In 10*g*, SGA_TARGET and SGA_MAX_SIZE were introduced as Automatic Shared Memory Management (ASMM) (My Oracle Support Note 295626.1 describes this in detail), which is essentially Automatic Memory Management minus the automatic management of the PGA included. The Oracle Applications Development team recommends using SGA_TARGET and SGA_MAX_SIZE for both 10*g* and 11*g* in 11*i* Apps (My Oracle Support Note 216205.1) and for 11*g* in Release 12 Apps (My Oracle Support Note 396009.1). I've included the Oracle Applications Development team's recommendations at the end of this chapter.

The MEMORY_TARGET parameter enables you to set memory allocated to Oracle with *one* easy parameter (although you'll shortly see that setting some minimums for other values is recommended). MEMORY_TARGET is used by Automatic Memory Management to set other memory settings, such as the memory allocated to both the PGA and SGA (System Global Area) combined. Setting this parameter enables Automatic Memory Management, but you can also set minimum values for key parameters. MEMORY_TARGET is used for everything that SGA_TARGET covers (including the INMEMORY_SIZE if used), but also now includes the PGA (especially important since this covers PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT, an important area). Key parameters such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, LARGE_POOL_SIZE, and JAVA_POOL_SIZE are all set automatically when MEMORY_TARGET is set. Setting minimum values for important initialization parameters in your system is also a *very* good idea. The MEMORY_MAX_TARGET parameter is optional and is the maximum memory allocated for Oracle and the maximum value allowed for MEMORY_TARGET.

In Oracle9*i*, you saw the beginning of Oracle's Automated Memory Management with the SGA_MAX_SIZE (no more setting buffers, just DB_CACHE_SIZE and granule size: _KSMG_GRANULE_SIZE).

In Oracle 10*g*, the SGA_TARGET parameter was introduced (still recommended by Oracle Applications even in 11*g*). In the 10*g* edition of this book, however, it was recommended that you still set minimums for the key memory areas such as the Database Cache (DB_CACHE_SIZE) and shared pool (SHARED_POOL_SIZE). MEMORY_TARGET now combines the SGA and PGA into one setting, making life easy, especially for smaller, less complex systems, and it is still recommended when using automatic memory management of any kind to set minimums for each of the memory areas as described in this chapter. Some parameters are automatically sized (this chapter details the use of many of these parameters in the coming pages). Also note that MEMORY_TARGET (Automatic Memory Management) manages and includes SGA_TARGET and PGA_AGGREGATE_LIMIT, so it should be as big as the sum of the two of these. It is one level above Automatic Shared Memory Management (SGA_TARGET) and Automatic PGA Memory Management (PGA_AGGREGATE_TARGET). This manages many of the memory settings for the SGA that all used to be set individually (and still can be, and in some environments still should be). Setting this individual parameter is covered in later sections in this chapter.

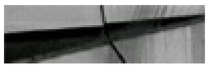
These parameters are automatically sized when you use MEMORY_TARGET or SGA_TARGET (unless you set minimums), but setting minimums for each of the memory areas separately (as described in this chapter) is still recommended when using AMM of any kind:

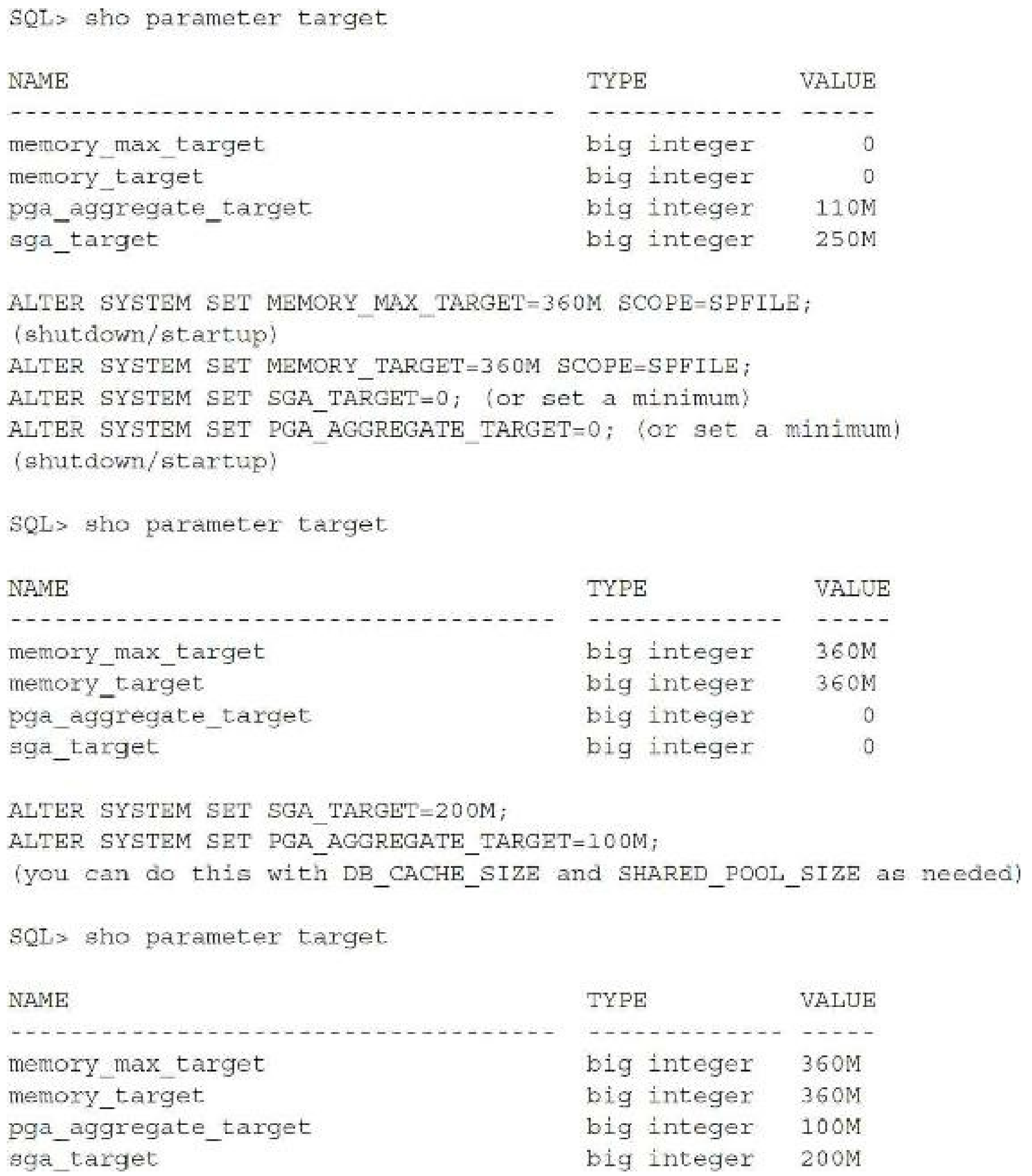
Component	Initialization Parameter
Buffer cache	DB_CACHE_SIZE (usually set minimum value also)
Shared pool	SHARED_POOL_SIZE (usually set minimum value)
Large pool	LARGE_POOL_SIZE (usually set minimum value)
Java pool	JAVA_POOL_SIZE (usually set minimum value)
Streams pool	STREAMS_POOL_SIZE

These are manually sized SGA components that also use MEMORY_TARGET:

Component	Initialization Parameter(s)
Log buffer	LOG_BUFFER
Keep pool	DB_KEEP_CACHE_SIZE (major benchmarks use this cache too)
Recycle pool	DB_RECYCLE_CACHE_SIZE (major benchmarks use this cache too)
Block caches	DB_nK_CACHE_SIZE (major benchmarks use these caches too)
In-Memory	INMEMORY_SIZE (used for the In-Memory column store)
PGA	PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT

As stated earlier, the PGA is now managed by MEMORY_TARGET as well. This includes the PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT parameters. You should also set a minimum for PGA_AGGREGATE_TARGET, and a maximum, as of 12*c*, for PGA_AGGREGATE_LIMIT. To move from the SGA_TARGET to MEMORY_TARGET, set the MEMORY_TARGET and MEMORY_MAX_TARGET. To determine what value to use, run the following query and ensure that you add the values for SGA_TARGET and PGA_AGGREGATE_TARGET to estimate MEMORY_TARGET (the following outputs are limited to key values):





```
SQL> sho parameter target

NAME                                 TYPE          VALUE
------------------------------------ ------------- -----
memory_max_target                    big integer       0
memory_target                        big integer       0
pga_aggregate_target                 big integer    110M
sga_target                           big integer    250M

ALTER SYSTEM SET MEMORY_MAX_TARGET=360M SCOPE=SPFILE;
(shutdown/startup)
ALTER SYSTEM SET MEMORY_TARGET=360M SCOPE=SPFILE;
ALTER SYSTEM SET SGA_TARGET=0; (or set a minimum)
ALTER SYSTEM SET PGA_AGGREGATE_TARGET=0; (or set a minimum)
(shutdown/startup)

SQL> sho parameter target

NAME                                 TYPE           VALUE
------------------------------------ -------------  -----
memory_max_target                    big integer     360M
memory_target                        big integer     360M
pga_aggregate_target                 big integer        0
sga_target                           big integer        0

ALTER SYSTEM SET SGA_TARGET=200M;
ALTER SYSTEM SET PGA_AGGREGATE_TARGET=100M;
(you can do this with DB_CACHE_SIZE and SHARED_POOL_SIZE as needed)

SQL> sho parameter target

NAME                                 TYPE          VALUE
------------------------------------ ------------- -----
memory_max_target                    big integer   360M
memory_target                        big integer   360M
pga_aggregate_target                 big integer   100M
sga_target                           big integer   200M
```

The following query can be used to find the current settings of the key initialization parameters on your database (if SGA_TARGET is set to a non-zero value, then some of these parameters are set to zero, which means Oracle sets it). For this example, I manually set the shared pool:

```
Col name for a25
Col value for a50
```

```
select   name, value
from     v$parameter
where    name in ('sga_max_size', 'pga_aggregate_target',
                  'db_cache_size', 'shared_pool_size');

NAME                     VALUE
--------------------- --------------------
shared_pool_size       1073741824
sga_max_size           6878658560
db_cache_size          0
pga aggregate target   0
```

The MEMORY_TARGET approach and move to simplicity, especially for beginners and those who manage *many* databases, is excellent and should simplify and minimize management going forward for many environments.

PDB Level: MEMORY_LIMIT and MEMORY_MINIMUM

In addition to the new MEMORY_TARGET initialization parameter to set all of memory for the Oracle SGA and PGA, there are PDB-specific parameters to ensure a minimum amount and a maximum setting. Those parameters set at the PDB level using resource plan directions are

- **MEMORY_LIMIT** Limits the PDB to this percentage of PGA+SGA
- **MEMORY_MINIMUM** Guarantees the PDB this percentage of PGA + SGA

You'll also see in the next section that there is both an INMEMORY_SIZE that you can set at the CDB level and then also INMEMORY_SIZE that you can set at the PDB level as well.

In-Memory Database (INMEMORY_SIZE)

Introduced in Oracle Database version 12.1.0.2, the In-Memory Database is by far the best new feature for improving database performance (especially data warehouse performance). This capability is perfect for some types of workloads and helpful for others, but best of all, it does not require any application changes to make use of it.

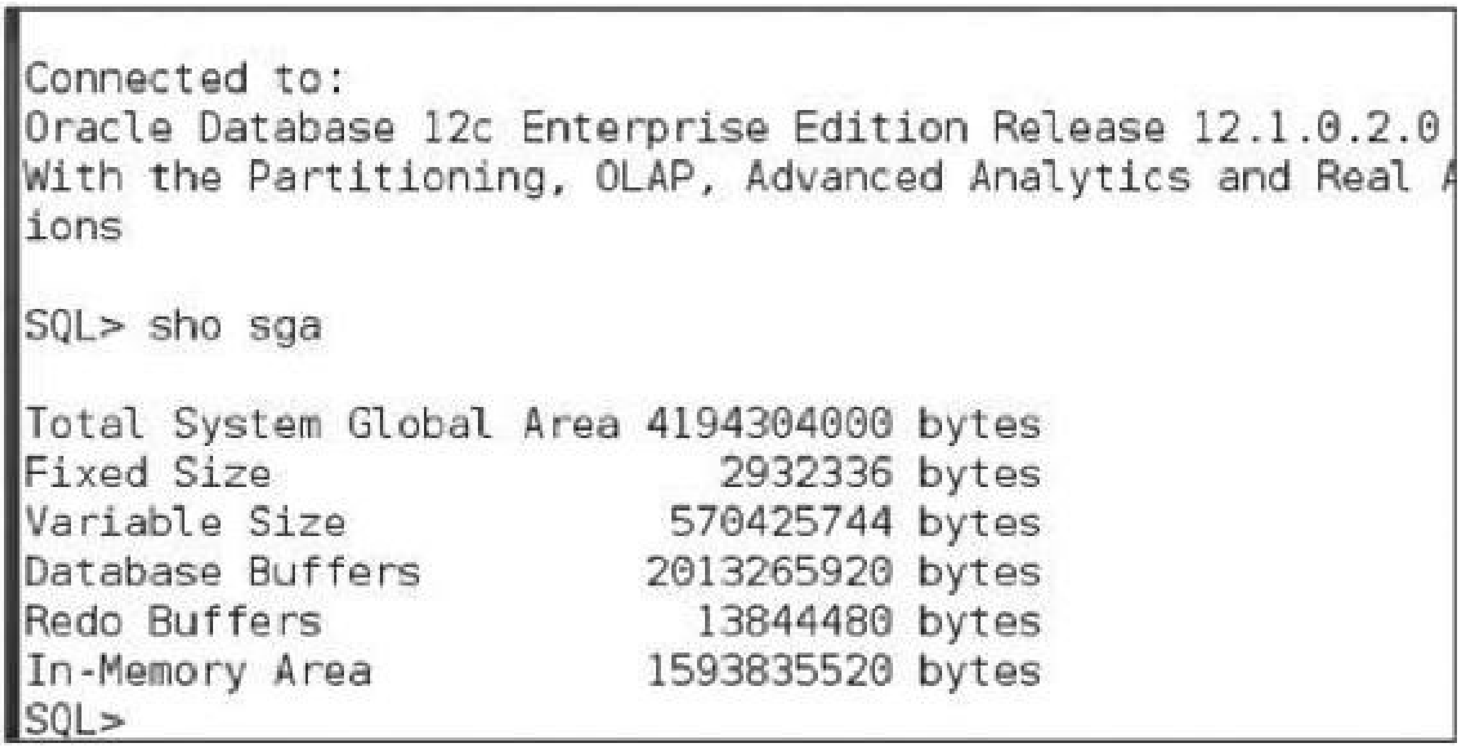
Online transaction processing (OLTP) and data warehouse applications are common in most enterprises, and many systems dramatically blur the lines between what is OLTP and what is data warehousing—increasingly more OLTP systems are including reporting and data warehouse components. The Oracle Database now has a buffer cache for OLTP and all the DML activity you might do, while also having the in-memory cache to improve performance in data warehousing operations that stays consistent even with the other OLTP cache changes (similar to how tables/indexes stay consistent with each other). This is the typical mixed workload that is becoming more common, and the In-Memory Database just made the mixed workload performance skyrocket.

The In-Memory feature is made possible through a unique dual format that maintains an Oracle row-based format for OLTP and a pure in-memory columnar format for query and analytical processing. This feature maintains both the row and columnar formats at the same time without any awareness from the application, therefore maintaining full compatibility back to the applications and allowing use of this feature without having to change a single line of code in your applications. It is also fully compatible with all existing Oracle Database features and options and therefore can be used with all features such as Real Application Clusters (RAC), partitioning, compression, pluggable databases, etc.

The In-Memory Database option is an In-Memory column store that is an addition to the database SGA called the in-memory area. Don't be concerned, though, because this does not "double" memory requirements for the database; in fact, it is estimated that only 20 percent overhead is expected to make full use of this feature with a huge impact. This feature maintains the buffer cache as it normally would in a row-format-based store, which is most efficient for DML activity. At the same time, it will maintain an additional memory area for the columnar-based format, which is most effective for query and analytical activities (storing specified columns of compressed data for quick sums, averages, etc.). Not all tables should be part of the in-memory area, and it should be populated only with the columns of tables that are most critical to overall analytics performance. When you combine the in-memory area with the buffer cache in memory (the SGA), and then you add flash for everything else (what Google, Facebook, and Amazon do), you realize huge performance improvements.

The In-Memory Database option is turned on by setting the INMEMORY_SIZE to a non-zero value (must be set to at least 100M). Keep in mind this is a fixed memory size and is not managed automatically by an LRU (least recently used) algorithm. Once you are out of space, you are out until you remove something. Also remember that this memory comes out of the SGA settings, therefore, you will probably want to increase your SGA to accommodate it by increasing SGA_TARGET and MEMORY_TARGET by the amount of INMEMORY_SIZE depending on which your database is using. Also, the use of the In-Memory column store is controlled by the INMEMORY_QUERY parameter, which is enabled by default, meaning that the optimizer will use the IM for queries. If INMEMORY_QUERY is disabled at the system or session level, then the optimizer will not direct queries to use the IM. The in-memory use can be turned off dynamically by setting the IN_MEMORY_QUERY to DISABLED; for example:

```
ALTER SESSION SET INMEMORY QUERY-DISABLE;   (stop using IM)
```



```
Connected to:
Oracle Database 12c Enterprise Edition Release 12.1.0.2.0
With the Partitioning, OLAP, Advanced Analytics and Real A
ions

SQL> sho sga

Total System Global Area 4194304000 bytes
Fixed Size                   2932336 bytes
Variable Size              570425744 bytes
Database Buffers          2013265920 bytes
Redo Buffers                13844480 bytes
In-Memory Area            1593835520 bytes
SQL>
```

FIGURE 4-1. *Screenshot of SGA listing showing the in-memory area*

The following example shows how to turn on the In-Memory Database (in-memory store):

```
inmemory_size=1520M
inmemory_query-enabled
sga_target=25G
```

Other key initialization parameter for setting up the In-Memory Database are

- **INMEMORY_MAX_POPULATE_SERVERS** Number of workers used to populate the IM Column Store. The default is 0.5xCPU_COUNT. Lowering it slows down repopulation.
- **INMEMORY_FORCE** If set to OFF, the IM will not be populated no matter what the object settings are. The default is DEFAULT, which allows normal population.
- **INMEMORY_CLAUSE_DEFAULT** Set defaults to be different. For example, to change the default compression:

  ```
  ALTER SYSTEM SET INMEMORY_CLAUSE INMEMORY PRIORITY HIGH;
  ```

- **INMEMORY_TRICKLE_REPOPULATE_SERVERS_PERCENT** The maximum percentage of time a worker (process) can participate in trickle repopulation (wakes up every 2 minutes). The default is 1 percent. It can also be set to 0 to disable trickle repopulation. *Trickle repopulation* refers to repopulating the In-Memory column store with change blocks from the SGA. Note that when a query is run against a given column in the In-Memory column store, any changed blocks from the SGA are moved at that time (your data is always “up to date” when queried).

In 12*c*R2, you can now dynamically resize the INMEMORY_SIZE while the system is running, provided you have the memory available in SGA_TARGET (and MEMORY_TARGET). In-memory is also supported with pluggable databases, but there are some things to keep in mind. All PDBs use and share a single memory area defined in the container database (CDB) level. You can define the INMEMORY_SIZE in each PDB, but it comes out of the INMEMORY_SIZE defined in the CDB; therefore, the sum of all PDBs' *used area* cannot exceed the INMEMORY_SIZE defined at the container level. That said, you can oversubscribe the amount in the CDB. For instance, if you had three PDBs, each with an INMEMORY_SIZE=3M, and the CDB had an INMEMORY_SIZE=8M (which is allowed), the total that can fit is only 8M even though the sum of the PDBs is 9M. The first 8M will get the space, with each PDB having a maximum of 3M (one PDB may only get 2M). This provides some flexibility.

The In-Memory column store for RAC is defined on a per-instance basis. In a RAC environment, each instance has its own INMEMORY_SIZE defined for that instance. This means that each RAC instance can have a different INMEMORY_SIZE defined. However, it is recommended that the INMEMORY_SIZE remain consistent across all nodes—after all, the objects that will be placed are database level, not instance level. Different data can exist in the IM for each of the instances and large tables can span different instances across nodes in the cluster, and this is done by default (essentially it's like having the combined memory of all the instances for the in-memory store). The distribution can be changed and you can set DUPLICATE across the cluster so that even the IM is fault tolerant. In Exadata only, you can set DUPLICATE ALL so that each in-memory store is an exact duplicate on each node in the cluster, which provides complete fault tolerance and continuous performance if a failure occurs in the In-Memory column store.

The following listings show how to duplicate:

```
ALTER TABLE emp INMEMORY DISTRIBUTE BY PARTITION;
ALTER TABLE emp INMEMORY DUPLICATE;
```

(Duplicate to second node in-memory)

```
ALTER TABLE emp INMEMORY DUPLICATE ALL;
```

** Duplicate copies on all nodes (ignored if not engineered systems; i.e., Exadata)

Why have an IM columnar store? Because transactions run faster in row format and analytics run faster in columnar format. For analytics, the columnar In-Memory is better and faster because it only accesses the column data needed (and in compressed format—smaller/faster). In the buffer cache, typically you only see 10 to 20 percent of the table or table partition data, whereas in the IM, 100 percent of the table column(s) or table partition(s) is in memory.

To place an object in the new In-Memory column store, the INMEMORY attribute is set. Setting the attribute can happen as a default, at the tablespace level, or for a whole table. You can also set it for a single column(s) of a table or even for partition(s) of a table. There are so many options that I will simply give you some examples:

- **Tablespace** `alter tablespace users default INMEMORY;`
- **Table** `alter table mytable INMEMORY;`
- **Column** `alter table mytable INMEMORY NO INMEMORY (prod_id);`
- **Partition** `alter table mytable modify partition mytable_part1 NO INMEMORY;`

Once we place a table object into memory, we can see when our queries use in-memory by looking at the execution/ EXPLAIN PLAN, as shown in this example:

```
select empno
from   emp
order  by empno;

EMPNO
-----
  7389
  7390
  ...

--------------------------------------------------------------------------
| Id   Operation                                                  |Name  |
|                                                                 |      |
--------------------------------------------------------------------------
|   0   SELECT STATEMENT                                          |      |
|   1    SORT AGGREGATE                                           |      |
|   2     PARTITION RANGE ALL                                     |      |
|*  3      TABLE ACCESS INMEMORY FULL                             | EMP  |
```

The IM has hints that you can use in your SQL as well to force the optimizer to utilize the In-Memory column store:

- **/*+ INMEMORY(*table*) */** Put a table into the IM area
- **/*+ NO_INMEMORY(*table*) */** Take a table out of the IM area
- **/*+ INMEMORY_PRUNING(*table*) */** Control the use of the IM storage index
- **/*+ NO_INMEMORY_PRUNING(*table*) */** Control the use of the IM storage index
- **/*+ PX_JOIN_FILTER(*table*) */** Force the use of a Bloom filter for a join if the optimizer doesn’t
- **/*+ NO_PX_JOIN_FILTER(*table*) */** Force the *non*-use of a Bloom filter for a join if the optimizer doesn’t

The IM has the option for objects to be populated immediately on database startup or when the object is first read/queried. This is controlled by the PRIORITY keyword. This allows you to immediately populate the in-memory area on database startup for some objects and help save the performance hit on first-time read. It also allows you to assign the importance level of the objects that get into the in-memory store. This is all controlled via priority levels. There are five priority levels that control the loading of objects into the in-memory area:

- **CRITICAL** Object is populated immediately after the database is opened
- **HIGH** Object is populated after all CRITICAL objects have been populated, if space remains available in the IM column store
- **MEDIUM** Object is populated after all CRITICAL and HIGH objects have been populated, if space remains available in the IM column store
- **LOW** Object is populated after all CRITICAL, HIGH, and MEDIUM objects have been populated, if space remains available in the IM column store
- **NONE** Objects only populated after they are scanned for the first time (default), if space is available in the IM column store

Setting the priority determines how and when/if the objects are loaded into the IM store and in which order. For example, to set *mytable* into the IM store at database startup and have it be one of the first loaded, I would set the priority to CRITICAL:

```
alter table mytable INMEMORY PRIORITY CRITICAL ;
```

The in-memory area also has compression, which is critical because it allows more data to be stored in-memory and uses less physical memory doing it. In 12*c* Release 2, Automatic Data Optimization (ADO, covered in Chapter 3) is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics. There are several in-memory compression options:

- **NO MEMCOMPRESS** Data is populated without any compression
- **MEMCOMPRESS FOR DML** Minimal compression optimized for DML performance
- **MEMCOMPRESS FOR QUERY LOW** Optimized for query performance (default)
- **MEMCOMPRESS FOR QUERY HIGH** Optimized for query performance as well as space saving
- **MEMCOMPRESS FOR CAPACITY LOW** Balanced with a greater bias toward space saving
- **MEMCOMPRESS FOR CAPACITY HIGH** Optimized for space saving

To see the table:

```
select table_name, inmemory, inmemory_priority,
       inmemory_compression
from   user_tables
where  table_name = 'MYTABLE'

TABLE NAME            INMEMORY INMEMORY P  INMEMORY COMPRESS
--------------------- -------- ----------  -----------------
MYTABLE               ENABLED  NONE        FOR QUERY LOW
```

By default, in-memory compression is FOR QUERY LOW, which provides the best performance while still getting some benefits from compression to improve the in-memory area utilization. The amount of compression experienced can vary anywhere from 2x–20x and is based on data type, compression type, and the data within the table.

The following example shows how we can apply different compression levels and in-memory all in the same table. This example specifies to not use in-memory for a large LOB column (c4), but to compress the table for in-memory at QUERY HIGH and to use CAPACITY HIGH for column c2:

```
CREATE TABLE mytable
( c1 NUMBER,
  c2 NUMBER,
  c3 VARCHAR2(10),
  c4 CLOB )
INMEMORY MEMCOMPRESS FOR QUERY HIGH
NO INMEMORY(c4)
INMEMORY MEMCOMPRESS FOR CAPACITY HIGH(c2);
```

Performance benefits for in-memory do not just stop at the In-Memory column store memory area; they also extend to In-Memory storage indexes created and maintained by Oracle. These are created for columns in the In-Memory column store, which allows data pruning from the SQL WHERE clause directly upon reading, saving rows returned to the optimizer for filtering. Oracle leverages SIMD speed developed in the gaming industry (think Volibear and *League of Legends*, the game that is played online by over 27M people *daily*). The SIMD (single instruction, multiple data) vector processing allows a single CPU instruction to evaluate multiple data points using a vector register and vector comparing all values in one CPU cycle (over 100× faster). Also, in-memory joins take advantage of Bloom filters to transform a join and improve the overall performance during the scan of larger tables. In 12*c*R2, the join group (column joined between two tables) is also compressed so that decompression is not needed when tables are joined (a very important advantage of R2). Also in R12*c*R2 is the ability to have In-Memory virtual columns, and Active Data Guard can now use the In-Memory column store while open in read-only mode. You can use In-Memory Expressions with the DBMS_INMEMORY_ADMIN package to capture *hot* expressions in the IM using the DBMS_INMEMORY_ADMIN.IME_CAPTURE_EXPRESSION. You can also use this package using the DBMS_INMEMORY_ADMIN.FASTSTART_ENABLE procedure to save data in the IM to a FastStart area (the specified tablespace, also see V$INMEMORY_FASTSTART_AREA) which can be used to repopulate the IM on database restarts (in the original priority order). See the *Oracle Database In-Memory Guide* for additional information. Lastly, updates to internal dictionary objects have been made to accommodate the In-Memory Database capability:

- V$IM_SEGMENTS, V$IM_USER_SEGMENTS, V$IM_COLUMN_LEVEL, USER_TABLES, and V$KEY_VECTOR
- USER_TABLES (inmemory, inmemory_priority, inmemory_compression, inmemory_distribute, inmemory_duplicate)

TIP
Setting INMEMORY_SIZE can lead to unbelievably fast analytics, but only set this parameter when properly licensed for this option.

Changing the Initialization Parameters Without a Restart

With each version of Oracle, you can alter more and more parameters without needing to restart the database, greatly reducing the need for scheduled downtime to implement system tuning changes.

As an example, this command changes the SHARED_POOL_SIZE to 128M while the database is running:

```
SQL> ALTER SYSTEM SET SHARED_POOL_SIZE = 128M;
```

In addition to being able to change parameters dynamically, you can now use a server parameter file (SPFILE) to store dynamic changes persistently to the instance parameters. Prior to Oracle9*i*, any dynamic changes were lost when the database was restarted unless the parameters were added to the initialization parameter file manually. As of Oracle9*i*, and continuing through Oracle 12*c* Release 2, dynamic changes can be stored in an SPFILE. The default order of precedence when an instance is started is to read parameter files in the following order:

1. spfile<SID>.ora
2. spfile.ora
3. init<SID>.ora

Parameters can be dynamically modified at a system-wide or session-specific scope. In addition, parameters can be changed in memory only or persistently across restarts via an SPFILE. In the first example, I change the SHARED_POOL_SIZE and also write it to the SPFILE. Note that you can use K (kilobytes), M (megabytes), and G (gigabytes), but not T (terabytes), P (petabytes), or E (exabytes) yet (even though in 64-bit, an Oracle database can be 8E and you can directly address 16E of memory). Also, note that 1G = 1024*1024*1024 = 1,073,741,824 bytes.

```
SQL> ALTER SYSTEM SET SHARED_POOL_SIZE = 128M SCOPE=SPFILE;
```

In the second example, I write SHARED_POOL_SIZE to both the SPFILE (for future restarts) and the MEMORY (for the current SGA):

```
SQL> ALTER SYSTEM SET SHARED_POOL_SIZE = 1G SCOPE=BOTH;
SQL> SHOW PARAMETER SHARED_POOL_SIZE

NAME                                 TYPE        VALUE
------------------------------------ ----------- ------------------
shared_pool_size                     big integer 1G
```

I can also create a PFILE from the SPFILE (since the SPFILE is nonreadable):

```
SQL> CREATE PFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\INITORCL.ORA'
FROM SPFILE;
```

Or, as shown here, it checks the default location and writes it to the default location:

```
SQL> CREATE PFILE FROM SPFILE;
```

If my SPFILE is deleted for some reason (don't ever do this), I can also re-create the SPFILE from the PFILE (if I've created one), as shown here, or from MEMORY:

```
SQL> CREATE SPFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\SPFILEORCL.
ORA'
     FROM PFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\INITORCL.ORA';

SQL> CREATE SPFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\SPFILEORCL.
ORA' FROM MEMORY;
```

When you look at PFILE's output, other than the parameters I've physically set, it has limited information. It also has all of the settings for key memory parameters that have been set for me since I only set MEMORY_TARGET. Consider what happens if I run this:

```
SQL> CREATE PFILE='C:\APP\USER\INITORCL.ORA' FROM SPFILE;
```

TIP
If you use the ALTER SYSTEM commands to write to the SPFILE only, and then on startup realize you have set them incorrectly, the database will not start, and you cannot use an ALTER SYSTEM command to fix the problem. You can, however, create a PFILE from the SPFILE, modify the PFILE, and then use that to start the database. Afterward you need to create the SPFILE again and restart the database with the SPFILE.

Here is a listing of the INITORCL.ORA file (note that my MEMORY_TARGET was 6.56G and INMEMORY_SIZE=0):

```
orcl.__data_transfer_cache_size=0
orcl.__db_cache_size=2315255808
orcl.__inmemory_ext_roarea=0
orcl.__inmemory_ext_rwarea=0

orcl.__java_pool_size=16777216
orcl.__large_pool_size=33554432
orcl.  pga aggregate target=2399141888
orcl.__sga_target-4479516672
orcl.__shared_io_pool_size=973078528
orcl.__shared_pool_size=1073741824
orcl.__streams_pool_size=16777216
*.compatible='12.2.0.0.0'
*.db_block_size=8192
*.db_domain=''
*.db_name-'orcl'
*.log_buffer-4931584#  log buffer update
*.max_dump_file_size='UNLIMITED'
*.memory_max_target=6871318528
*.memory target=6871318528
*.optimizer_dynamic_sampling=2
*.optimizer_mode='ALL_ROWS'
*.shared_pool_size=1073741824
*.undo_tablespace-'UNDOTBS1'
… (rows deleted for size before and after this point) …
```

You can get a better listing by dumping the MEMORY to a PFILE so you can see everything set:

```
SQL> CREATE PFILE='/home/oracle/init memory1.ora' FROM MEMORY;
```

This shows every parameter set for the database instance (whether you set them or Oracle did):

```
# Oracle init.ora parameter file generated by instance orcl on 06/18/2016
16:07:34
__data_transfer_cache_size=0
__db_cache_size=2208M
__inmemory_ext_roarea=0
__inmemory_ext_rwarea=0
__java_pool_size=16M
__large_pool_size=32M
__oracle_base='/u01/app/oracle' # ORACLE_BASE set from environment
__pga_aggregate_target=2288M
__sga_target=4272M
__shared_io_pool_size=928M
__shared_pool_size=1G
__streams_pool_size=16M
_adaptive_window_consolidator_enabled=TRUE
_aggregation_optimization_settings=0
_always_anti_join='CHOOSE'
_always_semi_join='CHOOSE'
_and_pruning_enabled=TRUE
_b_tree_bitmap_plans=TRUE
_bloom_filter_enabled=TRUE
_bloom_filter_ratio=35
_bloom_folding_enabled=TRUE
```

```
_bloom_pruning_enabled=TRUE
_bloom_serial_filter='ON'
_complex_view_merging=TRUE
_compression_compatibility='12.2.0.0.0'
… (rows deleted for size before and after this point) …
compatible='12.2.0.0.0'
db_block_size=8192
db_name='orcl'
instance name='orcl'
log_buffer=16785408 # log buffer update
max_dump_file_size='UNLIMITED'
memory_max_target=6560M
memory_target=6560M
open_cursors=300
optimizer_dynamic_sampling=2
optimizer_mode='ALL_ROWS'
plsql_warnings='DISABLE:ALL' # PL/SQL warnings at init.ora
processes=300
query_rewrite_enabled='TRUE'
remote_login_passwordfile='EXCLUSIVE'
result_cache_max_size=16800K
shared_pool_size=1G
skip_unusable_indexes=TRUE
… (rows deleted for size before and after this point) …
```

TIP
If you can't figure out why your system isn't using the value in your init.ora file, an SPFILE is probably overriding it. And, don't forget, you can also use a hint to override parameters at the query level.

Finally, in a Real Application Clusters (RAC/Grid) environment, parameters can be changed for a single instance or for all clustered database instances in a cluster.

There are two key fields in the V$PARAMETER view (which shows the parameter in effect for the session; V$SYSTEM_PARAMETER shows the parameters in effect for the entire instance):

- **ISSES_MODIFIABLE** Indicates if a user with the ALTER SESSION privilege can modify this initialization parameter for his or her session.
- **ISSYS_MODIFIABLE** Indicates if someone with ALTER SYSTEM privilege can modify this particular parameter.

The following query illustrates a list of initialization parameters that can be set without shutting down and restarting the database. This query displays the initialization parameters that can be modified with an ALTER SYSTEM or ALTER SESSION command (partial result displayed):

```
select    name, value, isdefault, isses_modifiable, issys_modifiable
from      v$parameter
where     issys_modifiable <> 'FALSE'
or        isses_modifiable <> 'FALSE'
order by  name;
```

The result of the query (partial listing only) is all of the initialization parameters that may be modified:

```
NAME                      VALUE                          ISDEFAULT ISSES ISSYS_MOD
------------------------- ------------------------------ --------- ----- ---------
aq_tm_processes           0                              TRUE      FALSE IMMEDIATE
archive_lag_target        0                              TRUE      FALSE IMMEDIATE
asm_diskgroups                                           TRUE      FALSE IMMEDIATE
asm_diskstring                                           TRUE      FALSE IMMEDIATE
asm_power_limit           1                              TRUE      TRUE  IMMEDIATE
asm_preferred_read_failure_groups                        TRUE      FALSE IMMEDIATE
audit_file_dest           C:\APP\USER\ADMIN\ORCL\ADUMP   FALSE     FALSE DEFERRED
background_dump_dest      c:\app\user\diag\rdbms\orcl\
                          orcl\trace                     TRUE      FALSE IMMEDIATE
backup_tape_io_slaves     FALSE                          TRUE      FALSE DEFERRED
```

Be careful granting the ALTER SESSION privilege to users, as knowledgeable developers can set individual parameters that positively affect their session at the expense of others on the system. A user could run the following command with the ALTER SESSION privilege:

```
SQL> ALTER SESSION SET SORT_AREA_SIZE=100000000;
```

TIP

Changing initialization parameters dynamically is a powerful feature for both developers and DBAs. Consequently, a user with the ALTER SESSION privilege is capable of irresponsibly allocating 100M+ for the SORT_AREA_SIZE for a given session, if it is not restricted.

Modifying an Initialization Parameter at the PDB Level

You can gain some insight into which initialization parameters are modifiable at the pluggable database (PDB) level (or just the CDB level) by using the following query (PDBs are covered in detail in Chapter 3):

```
SELECT NAME FROM V$PARAMETER
WHERE  ISPDB_MODIFIABLE = 'TRUE'
AND    NAME LIKE 'optim%';

(without condition - can set 150 parameters out of 412 in R12.2)
   (There were 341 total parameters in 11gR2)

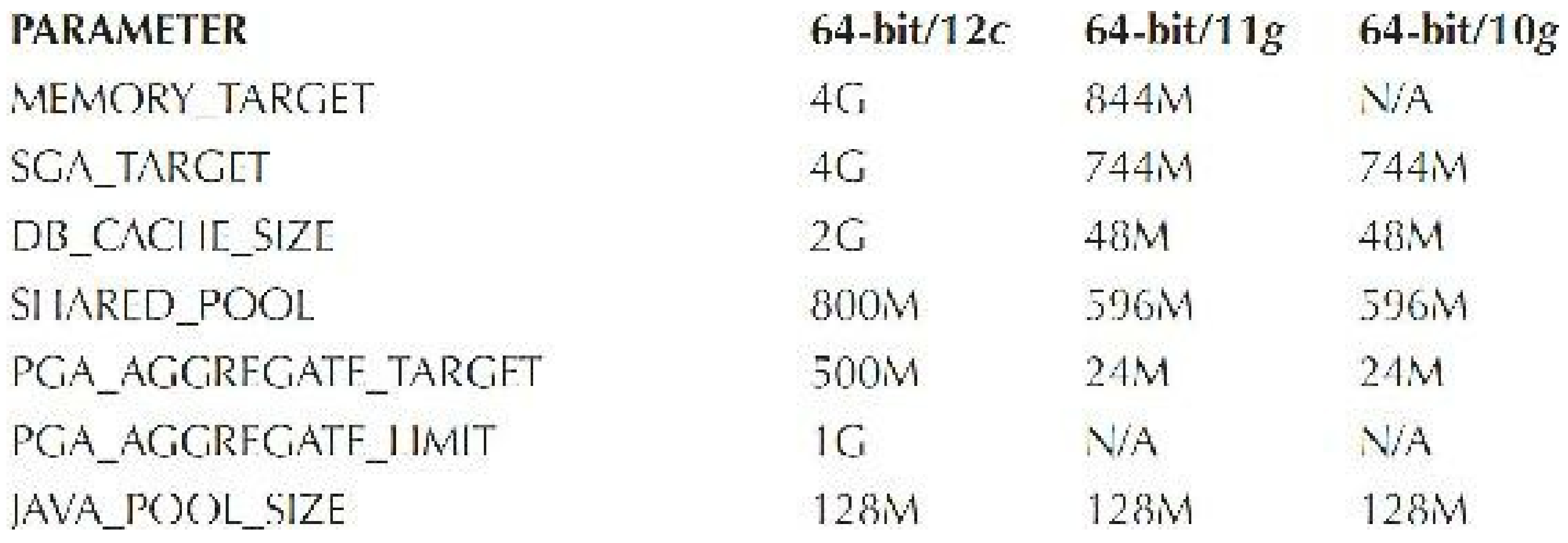
NAME                                    VALUE
--------------------------------------- ------------------
optimizer_adaptive_features             TRUE
optimizer_adaptive_reporting_only       FALSE
optimizer_capture_sql_plan_baselines    FALSE
optimizer dynamic sampling              2

optimizer_features_enable               12.2.0.1
optimizer_index_caching                 0
optimizer_index_cost_adj                100
optimizer_inmemory_aware                TRUE
optimizer_mode                          ALL_ROWS
optimizer_secure_view_merging           TRUE
optimizer_use_invisible_indexes         MANUAL
optimizer_use_pending_statistics        FALSE
optimizer_use_sql_plan_baselines        TRUE
13 rows selected.
```

Among the 150 initialization parameters that are modifiable in 12*c*R2, keys ones include CURSOR_SHARING, OPEN_CURSORS, RESULT_CACHE_MODE, SORT_AREA_SIZE, DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, and INMEMORY_SIZE. One of the key initialization parameters that is *not* modifiable is MEMORY_TARGET.

Insight into the Initialization Parameters from Oracle Utilities

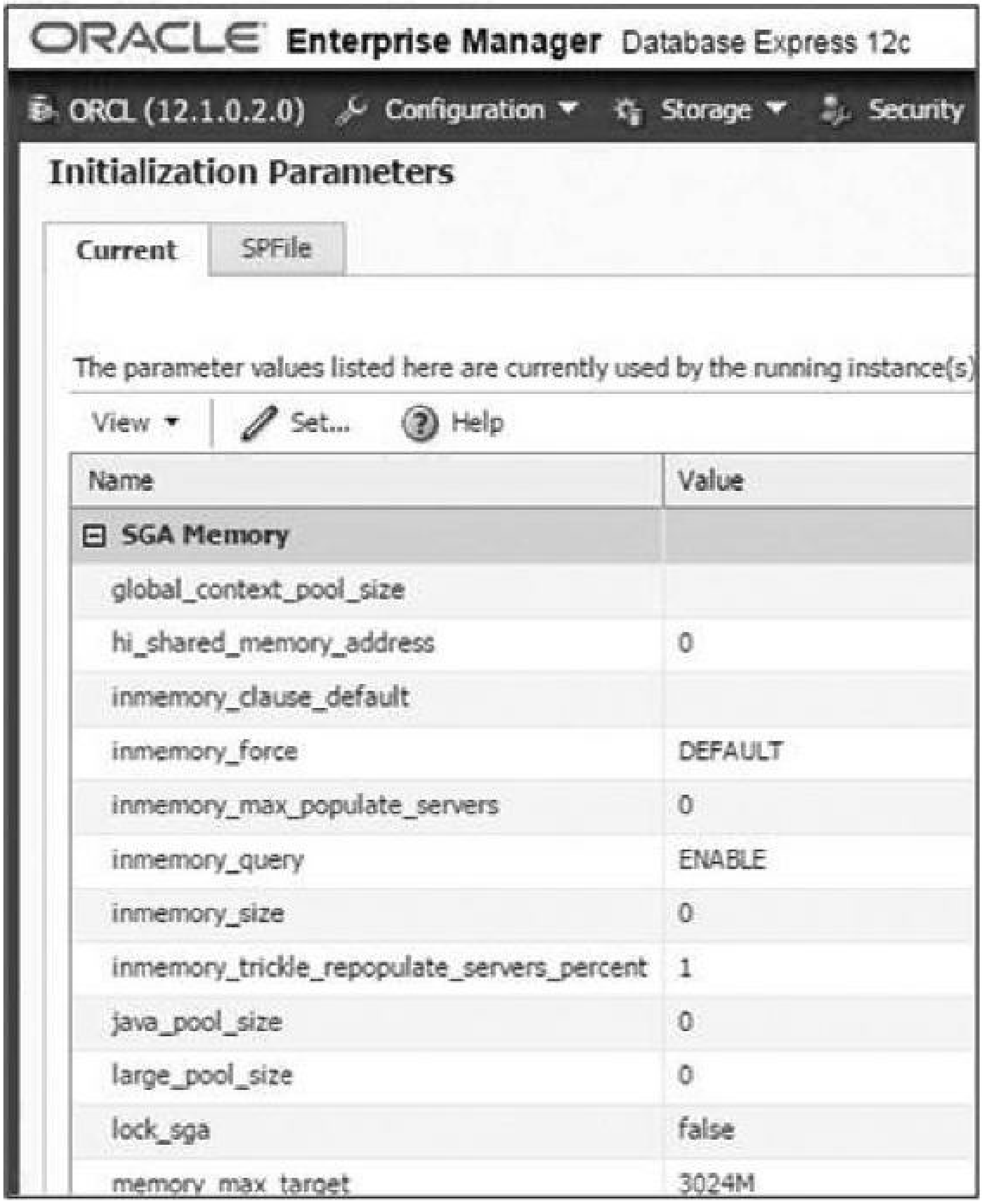
You can gain some insight into how Oracle balances some of these SGA parameters by crawling through the utility upgrade information and other scripts Oracle has published as guidelines. An interesting find is listed here, showing various size caches for different versions of Oracle, as well as 32- vs. 64-bit that Oracle (I added 12*c* based on the EBS notes later in this chapter) included in the scripts as minimum values (given you have the memory). These guidelines can be nice, but I think the DB_CACHE_SIZE is a bit too low for all of these. There are some great examples at the end of this chapter as well.



PARAMETER	64-bit/12*c*	64-bit/11*g*	64-bit/10*g*
MEMORY_TARGET	4G	844M	N/A
SGA_TARGET	4G	744M	744M
DB_CACHE_SIZE	2G	48M	48M
SHARED_POOL	800M	596M	596M
PGA_AGGREGATE_TARGET	500M	24M	24M
PGA_AGGREGATE_LIMIT	1G	N/A	N/A
JAVA_POOL_SIZE	128M	128M	128M

Viewing the Initialization Parameters with Enterprise Manager

You can also use Enterprise Manager to view the initialization parameter settings by going to the Database home page, selecting the server, and then selecting Initialization Parameters under the Database Configuration heading. The section of Enterprise Manager displayed in Figure 4-2 shows the initialization parameters. It shows the current settings for the parameters and also shows if the parameters can be modified (dynamic=•) without shutting down the database. Oracle Enterprise Manager is covered in detail in Chapter 5.



ORACLE Enterprise Manager Database Express 12c

ORCL (12.1.0.2.0) Configuration Storage Security

Initialization Parameters

Current SPFile

The parameter values listed here are currently used by the running instance(s)

View Set... Help

Name	Value
⊟ SGA Memory	
global_context_pool_size	
hi_shared_memory_address	0
inmemory_clause_default	
inmemory_force	DEFAULT
inmemory_max_populate_servers	0
inmemory_query	ENABLE
inmemory_size	0
inmemory_trickle_repopulate_servers_percent	1
java_pool_size	0
large_pool_size	0
lock_sga	false
memory_max_target	3024M

FIGURE 4-2. *Enterprise Manager—initialization parameters in the SPFILE*

Increasing Performance by Tuning the DB_CACHE_SIZE

Long-time users of Oracle and readers of prior editions of this book will notice that some familiar parameters have not been mentioned. In 10*g*, parameters such as DB_BLOCK_BUFFERS were deprecated (a parameter _DB_BLOCK_BUFFERS was set behind the scenes for backward compatibility). In later Oracle versions, DB_BLOCK_BUFFERS is back, but set to 0 (default), which means it's not used unless you set it (use DB_CACHE_SIZE instead). While many of the familiar parameters from prior versions of Oracle are still valid, using them may disable many features, including Automatic Memory Management (AMM).

The DB_CACHE_SIZE is the initial memory allocated to the main data cache or the memory used for the data itself. This parameter doesn't need to be set if you set MEMORY_TARGET or SGA_TARGET, but it is a good idea to set a value for this as a minimum setting. Your goal should always be getting toward a memory-resident database or at least getting all data that will be queried in memory. After MEMORY_TARGET (or SGA_TARGET) and MEMORY_MAX_TARGET, DB_CACHE_SIZE is the first parameter to look at in the initialization parameter file because it's the most crucial parameter in Oracle for retrieving data. If the DB_CACHE_SIZE is set too low, Oracle won't have enough memory to operate efficiently and the system may run poorly, no matter what else you do to it. If DB_CACHE_SIZE is too high, your system may begin to swap and may come to a halt. DB_CACHE_SIZE makes up the area of the SGA that is used for storing and processing data in memory initially and for subsequent queries to access. (If the In-Memory columnar store is used, some of the DB_CACHE_SIZE may be used less, as described earlier in this chapter.) As users request information, data is put into memory. If the DB_CACHE_SIZE parameter is set too low, then the least recently used (LRU) data is flushed from memory. If the flushed data is recalled with a query, it must be reread from disk (consuming I/O and CPU resources).

Retrieving data from memory can be over 10,000 times faster than retrieving it from disk (depending on the speed of memory, flash used, and disk device speed, which may or may not have memory caching on the disk). Even if you take into consideration disk caching (memory on disk) and Oracle inefficiencies, retrieving data from memory is still about 100 times faster than reading data from the fastest disks or flash. Therefore, the higher the frequency that records are found in memory (without being retrieved from disk), the faster the overall system performance (usually at least 100+ times faster for well-tuned queries). Having enough memory allocated to store data in memory depends on the value used for DB_CACHE_SIZE.

TIP

Retrieving data from physical memory is generally substantially faster than retrieving it from disk, so make sure the SGA and PGA are large enough. One Oracle study showed Oracle memory access as averaging about 100 times faster than disk access. However, this takes into account disk-caching advances and flash, which you may or may not have on your system. The same study also showed an individual case where Oracle memory access was well over 10,000 times faster than disk (which was hard for me to believe), but it shows how important it is to measure this on your own unique system.

MEMORY_TARGET, SGA_TARGET (if used), and DB_CACHE_SIZE (if a minimum is set) are the key parameters to use when tuning the data cache hit ratio. The *data cache hit ratio* is the percentage of the data block accesses that occur without requiring a physical read from disk. While several situations can artificially inflate or deflate the data cache hit ratio, this ratio is a key indicator of system efficiency.

You can use the following query to view the data cache hit ratio (the first output is one with a lot of full table scans, the second a simple index scan):

```
column phys             format 999,999,999    heading 'Physical Reads'
column gets             format 999,999,999    heading ' DB Block Gets'
column con_gets         format 999,999,999    heading 'Consistent Gets'
column hitratio format 999.99 heading ' Hit Ratio '
 select    sum(decode(name,'physical reads',value,0)) phys,

           sum(decode(name,'db block gets',value,0)) gets,
           sum(decode(name,'consistent gets', value,0)) con_gets,
          (1 - (sum(decode(name,'physical reads',value,0)) /
          (sum(decode(name,'db block gets',value,0)) +
           sum(decode(name,'consistent gets',value,0))))) * 100 hitratio
from       v$sysstat;

Physical Reads  DB Block Gets Consistent Gets  Hit Ratio
-------------- -------------- --------------- -----------
    32,895,507     23,959,814      59,387,065       60.53

Physical Reads  DB Block Gets Consistent Gets  Hit Ratio
-------------- -------------- --------------- -----------
         1,671         39,561          71,142       98.49
```

While every application has exceptions, a data cache hit ratio of 95 percent or greater should be achievable for a well-tuned transactional application with the appropriate amount of memory. Because there is such a performance difference between some disk devices and memory access, improving the data cache hit ratio from 90 to 95 percent can nearly double system performance when reading disk devices that are extremely slow. Improving the cache hit ratio from 90 to 98 percent could yield nearly a 500 percent improvement where disks are extremely slow and under the right (or should I say wrong) architectural setup. However, with the advent of more flash cache on storage servers, this continues to be something you have to look at in depth to understand what is appropriate for your particular hardware and application *load profile* (what's running through the system on a regular basis). If the load profile stays the same, but the hit ratio radically changes, you should investigate why it happened immediately (don't wait for system users to complain). In the first output just shown, I was aware of many full table scans that were not an issue, so the low hit ratio was not an issue.

Poor joins and poor indexing can also yield very high hit ratios due to reading many index blocks, so make sure your hit ratio isn't high for a reason other than a well-tuned system. An unusually high hit ratio may indicate the introduction of code that is poorly indexed or includes join issues. If the hit ratio goes much higher (bad query that might have over-indexing or poor use of indexes in joins) or much lower than normal (someone may have dropped an index or altered it to be invisible), you should investigate why it happened immediately (don't wait for system users to complain).

TIP

Hit ratios are useful to experienced DBAs but can be misleading or of little use to inexperienced DBAs. The best use of hit ratios is still to compare them over time (a barometer) to help alert you *to a substantial change to a system on a given day. While some people have deprecated hit ratios from their tuning arsenal, they are usually tool vendors who don't see the value of tracking hit ratios over time because their tools are point-in-time or reactive-based tuning solutions. Hit ratios should never be your only tool, but they should definitely be one of many proactive tools in your arsenal (especially with the advent of the invisible index).*

Oracle continues to downplay the importance of hit ratios by reducing the discussions on using hit ratios for tuning, but also continues to include them as *barometers*. Oracle is beginning to focus on analyzing system performance in terms of work done (CPU or service time) versus time spent waiting for work (wait time). Areas where hit ratios are still the primary tuning method are library cache and dictionary cache. See Chapter 14 on the AWR Report for more information on balancing the entire tuning arsenal, including hit ratios.

Using V$DB_CACHE_ADVICE in Tuning DB_CACHE_SIZE

V$DB_CACHE_ADVICE is a view to assist in tuning DB_CACHE_SIZE. The view can be queried directly, and the data in the view is used by the Oracle kernel (or database engine) to make automatic cache management decisions.

Here is a query to view the effect of changing DB_CACHE_SIZE on the data cache hit ratio:

```
select name, size_for_estimate, size_factor, estd_physical_read_factor
from   v$db_cache_advice;

NAME                 SIZE_FOR_ESTIMATE SIZE_FACTOR ESTD_PHYSICAL_READ_FACTOR
-------------------- ----------------- ----------- -------------------------
DEFAULT                              4       .1667                    1.8136
DEFAULT                              8       .3333                    1.0169
DEFAULT                             12          .5                    1.0085
DEFAULT                             16       .6667                         1
DEFAULT                             20       .8333                         1
DEFAULT                             24           1                         1
```

Reading these simple results from this very small SGA, you see the following:

- The current cache size in this example was small at 24M (SIZE_FACTOR = 1).
- You can decrease the cache size to be 16M and maintain the current cache hit ratio, since the PHYSICAL_READ_FACTOR remains at 1 up to a decrease to 16M.

Although this view provides an estimate of the effect of changing the cache size on the cache hit ratio, test any changes to validate that the results are as forecasted. Oracle Enterprise Manager provides a graphical view of the data in V$DB_CACHE_ADVICE. (Enterprise Manager is covered in Chapter 5.) To populate V$DB_CACHE_ADVICE, you have to enable the Dynamic Buffer Cache

Advisory feature, and it is not recommended to have this feature enabled on production systems all the time.

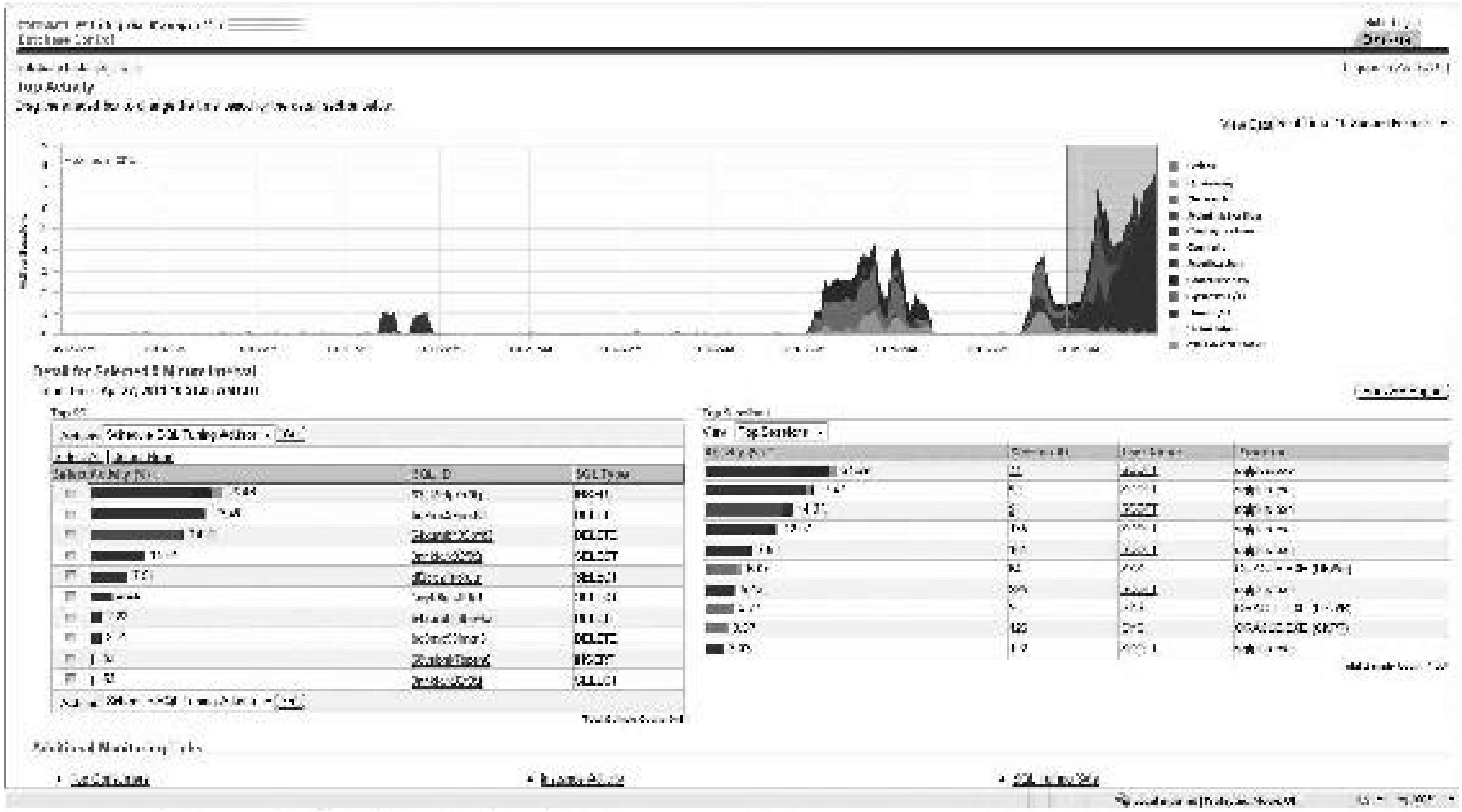
Using hit ratios to tune is not a good idea (nobody I know has ever said this), but using them as a barometer when things change is helpful to the great DBA who uses quick indicators to find potential trouble spots. Tool vendors and others hate these easy methods to see warning signs, because they would rather do it for you or charge you for a product you don't need. The hit ratio for the data cache is usually greater than 95 percent for most transactional systems. The best use for a hit ratio, however, is to study your system over time to see major changes that should warrant further investigation. Usually, if your hit ratio is less than 95 percent, you may need to increase the value of DB_CACHE_SIZE. In some instances, you can increase performance substantially by increasing the hit ratio from 95 to 98 percent—especially if the last 5 percent of the hits going to disk are the main lag on the system or the disk cache gets flooded (full with cached data).

Although hit ratios less than 95 percent could be a sign that your DB_CACHE_SIZE is set too low or that you have poor indexing, hit ratio numbers can be distorted and this should be taken into account while tuning (note that Exadata works differently and is covered in Chapter 11). Hit ratio distortion and non-DB_CACHE_SIZE issues include the following:

- Recursive calls
- Missing or suppressed indexes
- Data sitting in memory
- UNDO/ROLLBACK segments
- Multiple logical reads
- Physical reads causing the system to use CPU

Monitoring the V$SQLAREA View to Find Bad Queries

When issues occur, locate bad queries by monitoring the V$SQLAREA view or using Enterprise Manager. Once you isolate the queries that are causing performance hits, tune the queries or modify how the information is stored to solve the problem. Using the Performance page of Enterprise Manager Grid Control or Database Control, a DBA can generate a report of the Top Activity for his or her system. The Top Activity section of Enterprise Manager Database Control (see Figure 4-3) displays a list of the worst SQL statements in the current cache based on Activity and also the Top Sessions by Activity. The graph at the top of Figure 4-3 shows increasing performance issues. The graphs on the left and right show the problem SQL (left) and users (right). The DBA can then click the problem SQL to begin the process of analyzing and tuning the SQL statement. Chapter 5 discusses the benefits of Oracle Enterprise Manager in detail and how to tune the SQL statements using Enterprise Manager. Also note that Database Control is installed with the Oracle Database software. Grid Control is a separate product.


Top Activity

Detail for Selected 5 Minute Interval

FIGURE 4-3. *Use Oracle Enterprise Manager Database Control to find problem queries.*

TIP

Use Enterprise Manager Cloud Control or Database Control to find problem queries.

When an Index Is Suppressed

Consider the following query, where the CUSTOMER table is indexed on the unique CUSTNO column. It is *not* optimal to have this index suppressed by using the NVL (Null Value) because it results in a poor hit ratio.

```
select    custno, name
from      customer
where     nvl(custno,0)  = 5789;

Db block gets: 1
Consistent gets: 194
Physical reads: 184
Hit ratio = 1 - [184 / (194+1)] = 1 - 184/195 = 0.0564, or 5.64%
```

If you are looking at this in Enterprise Manager, you'll see an index missing on a query that is being executed at the current time. Focus on the query that is causing this problem and fix the query. The query can be found by accessing the V$SQLAREA view, as shown in Chapter 8. You could build a function-based index (see Chapter 2) to solve this problem as well. For Exadata, this might be fine if all of the data is in the Flash Cache on a cell or if the query brings back fewer blocks of data based on features like the Smart Scan or Storage Index (more in Chapter 11).

TIP
A low hit ratio for a query could be an indication of a missing or suppressed index.

Well-Indexed Queries

Consider the following query, where the CUSTOMER table is indexed on the unique CUSTNO column. In this situation, it is optimal to utilize the CUSTNO index because it results in an excellent hit ratio.

```
select     custno, name
from       customer
where      custno = 5789;

Db block gets: 0
Consistent gets: 192
Physical reads: 0
Hit ratio = 100%
```

If you are looking at this in Enterprise Manager, there is usually an index on the query that is being executed or the table could be cached in memory.

Bad Queries Executing a Second Time

When a full table scan is completed for the second time and the data is still in memory, you may see a good hit ratio even though the system is trying to run a bad query:

```
Db block gets: 1
Consistent gets: 105
Physical reads: 1
Hit ratio = 99% (A very high/usually good hit ratio)
```

If you are looking at this in Enterprise Manager, it appears that there is an index on the query being executed when, in fact, the data is in memory from the last time it was executed. The result is that you are “hogging up” a lot of memory even though it appears that an indexed search is being performed.

Since 10*g*, you can flush the buffer cache to clear it (similar to flushing the shared pool if you are familiar with that). You can also do this for an individual PDB. It is generally *not* intended for production use, but rather for system testing purposes. This can help with your tuning needs or as a Band-Aid if you have "free buffer" waits (there are better ways to fix free buffer waits, such as writing more often or increasing the DB_CACHE_SIZE). Note that any Oracle I/O not done in the SGA counts as a physical I/O. If your system has O/S caching or disk caching, the actual I/O that shows up as physical may indeed be a memory read outside of Oracle.

To flush the buffer cache, perform the following:

```
SQL> ALTER SYSTEM FLUSH BUFFER_CACHE;
```

TIP

Bad (slow) queries show in the V$SQLAREA view or V$SESSION_LONGOPS view (under certain conditions) with poor hit ratios the first time they are executed. You can also use Enterprise Manager to see statistical information. Make sure you tune them at that time. The second time that they execute, they may not show a poor hit ratio. Flushing the buffer cache for testing can help you get accurate results.

Other Distortions

You should consider several other hit ratio distortions:

- **Oracle Developer distortion** Systems that use Oracle Developer tools, JDeveloper (screens), or Application Express (APEX) to retrieve single rows of data frequently use the same information over and over. This reuse by some users of the system will drive up the hit ratio. Other users on the system may not be experiencing hit ratios that are as good as these users, yet the overall system hit ratio may look very good. The DBA must take into consideration that these users may be boosting the hit ratio to an artificially high level.
- **UNDO/ROLLBACK segment distortion** Because the header block of the UNDO/ROLLBACK segment is usually cached, the activity to the UNDO/ROLLBACK segment gives a falsely high hit ratio impact when truly there is no significant impact on the hit ratio.
- **Index distortion** An index range scan results in multiple logical reads on a very small number of blocks. I've seen hit ratios as high as 86 percent be recorded when none of the blocks are cached prior to the query executing. Make sure you monitor the hit ratio of individual, poorly tuned queries in addition to monitoring the big picture (overall hit ratio). You can also check bad indexes by making them invisible (see Chapter 2 for more information).
- **I/O distortion** Physical reads that appear to be causing heavy disk I/O may be actually causing you to be CPU bound. In tests, the same amount of CPU was used for 89 logical reads as was

used to process 11 physical reads. The result is that the physical reads are CPU costly because of buffer management. Fix the queries causing the disk I/O problems and you will usually free up a large amount of CPU as well. Performance degradation can be exponentially downward spiraling, but the good news is that when you begin to fix your system, it is often an exponentially upward-spiraling event. It's probably the main reason why some people live to tune; tuning can be exhilarating.

Setting DB_BLOCK_SIZE to Reflect the Size of Your Data Reads

The DB_BLOCK_SIZE is the size of the default data block size when the database is created. Since Oracle 10*g* Release 2, each tablespace can have a different block size, thus making block size selection a *less* critical selection before the database is created. That said, a separate cache memory allocation must be made for each different database block size. But it is still very important to choose wisely. Although you can have different block-size tablespaces, this is not truly a performance feature, as the nondefault buffer caches are not optimized for performance. You still want to put the bulk of your data in the default buffer cache. You must rebuild the database if you want to increase the DB_BLOCK_SIZE. The block size for data warehouses is often 32K (you want many rows to be read at a time) and OLTP systems are often 8K. Most experts recommend an 8K block size.

The data block cache for the default block size is set using the DB_CACHE_SIZE initialization parameter. Cache is allocated for other database block sizes by using the DB_*n*K_CACHE_SIZE, where *n* is the block size in K. The larger the DB_BLOCK_SIZE, the more that can fit inside a single block and the more efficiently large amounts of data can be retrieved. A small DB_BLOCK_SIZE actually lets you retrieve single records faster and saves space in memory. In addition, a smaller block size can improve transactional concurrency and reduce log file generation rates. As a rule of thumb, a data warehouse should use the maximum block size available for your platform (either 16K or 32K) as long as no bugs exist for the given block size (check My Oracle Support to make sure), whereas a transaction-processing system should use an 8K block size. Rarely is a block size smaller than 8K beneficial, but I've used a 2K block size for a stock exchange application and I've seen a 4K block size in benchmarks. If you have an extremely high transaction rate system or very limited system memory, you might consider a block size smaller than 8K.

Full table scans are limited to the maximum I/O of the box (usually 64K, but as high as 1M on many systems). Most systems support 1M I/O rates now. You can up the amount of data read into memory in a single I/O by increasing the DB_BLOCK_SIZE to 8K or 16K. You can also increase the DB_FILE_MULTIBLOCK_READ_COUNT to a maximum value of (max I/O size)/DB_BLOCK_SIZE.

Environments that run many single queries to retrieve data could use a smaller block size, but "hot spots" in those systems will still benefit from using a larger block size. Sites that need to read large amounts of data in a single I/O read should increase the DB_FILE_MULTIBLOCK_READ_COUNT. This may not be necessary with a parameter set, by default, to be much larger in 12*c*. My default for DB_FILE_MULTIBLOCK_READ_COUNT was 128, but check your system for variations to the default. The default value Oracle uses corresponds to the maximum I/O size that can be efficiently performed and is platform-dependent (according to Oracle docs). Setting the DB_FILE_MULTIBLOCK_READ_COUNT higher is especially important for data warehouses that retrieve lots of records. If the use of DB_FILE_MULTIBLOCK_READ_COUNT starts to cause many full table scans (since the optimizer now decides it can perform full table scans much faster and decides to do more of them), then set OPTIMIZER_INDEX_COST_ADJ between 1 and 10 (I usually use 10) to force index use more frequently.

TIP
The database must be rebuilt if you increase the DB_BLOCK_SIZE. Increasing the DB_FILE_MULTIBLOCK_READ_COUNT allows more block reads in a single I/O, giving a benefit similar to a larger block size.

Setting SGA_MAX_SIZE to 25 to 50 Percent of the Size Allocated to Main Memory

If you use it, the general rule of thumb is to start with an SGA_MAX_SIZE parameter of 20 to 25 percent of the size allocated to your main memory. A large number of users (300+) or a small amount of available memory may force you to make this 15 to 20 percent of physical memory. A small number of users (less than 100) or a large amount of physical memory may allow you to make this 30 to 50 percent of physical memory. If you set the SGA_MAX_SIZE less than 1G, then the _KSM_GRANULE_SIZE is 4M. If the SGA_MAX_SIZE is greater than 1G and less than 8G, then the _KSM_GRANULE_SIZE is 16M; from there, up to 16G is 32M, up to 32G is 64M, up to 64G is 128M, up to 128G is 256M, and if your SGA_MAX_SIZE is greater than 256G, then the _KSM_GRANULE_SIZE is 512M. This granule size determines the multiples for other initialization parameters. A granule size of 4M means that certain initialization parameters are rounded up to the nearest 4M. Therefore, if I set SGA_MAX_SIZE to 64M and DB_CACHE_SIZE to 9M, then the DB_CACHE_SIZE is rounded to 12M (since the granule size is 4M). If I set SGA_MAX_SIZE to 2000M and DB_CACHE_SIZE to 9M, then the DB_CACHE_SIZE is rounded to 16M (since the granule size is 16M). The V$SGA_DYNAMIC_COMPONENTS view allows you to see the sizes used for each SGA component (such as shared pool, buffer caches, etc.) and the granule size used.

TIP
The SGA_MAX_SIZE determines the granule size for other parameters. An SGA_MAX_SIZE < 1G means a 4M granule size, whereas an SGA_MAX_SIZE >= 256G means a 512M granule size. Some benchmarks have the granule size as high as 256M.

Tuning the SHARED_POOL_SIZE for Optimal Performance

Sizing the SHARED_POOL_SIZE correctly makes sharing identical SQL statements possible. Getting the statement parsed is your first priority. If the query never makes it into memory, it can never request the data to be accessed; that's where the SHARED_POOL_SIZE comes in. SHARED_POOL_SIZE specifies the memory allocated in the SGA for data dictionary caching and shared SQL statements.

The data dictionary cache is very important because that's where the data dictionary components are buffered. Oracle references the data dictionary several times when a SQL statement is processed. Therefore, the more information (database and application schema and structure) that's stored in memory, the less information that has to be retrieved from disk. While the dictionary cache is part of the shared pool, Oracle also caches SQL statements and their corresponding execution plans in the library cache portion of the shared pool (see the next section for how the shared SQL area works).

The data dictionary cache portion of the shared pool operates in a manner similar to the DB_CACHE_SIZE when caching information. For the best performance, it would be great if the entire Oracle data dictionary could be cached in memory. Unfortunately, this generally is not feasible, so Oracle uses a least recently used (LRU) algorithm for deciding what gets to stay in the cache.

Lastly, the Result Cache is part of the shared pool (allocated from the shared pool, but a separate area) as well, if you use it. Query function results and query fragments can be cached in memory for future executions. Choose calculations that frequently run over and over again. You should also choose data that does *not* frequently change. To use the Result Cache, set the RESULT_CACHE_SIZE=*amount* and the RESULT_CACHE_MODE=*force* parameters (set to *force* to automatically use it). The Result Cache takes its memory from the shared pool. You can use DBMS_RESULT_CACHE.FLUSH to clear the Result Cache. Note that anything cached is *not* passed between RAC/Grid nodes in 11*g*R1 (stays local to each instance), but data from the Result Cache is transferred over the interconnect to other RAC instances starting in 11*g*R2. Each Result Cache is local to each instance, as is the buffer cache, but can be shared over the interconnect since 11*g*R2. There is no global Result Cache. Please check the documentation for other restrictions and rules.

Using Stored Procedures for Optimal Use of the Shared SQL Area

Each time a SQL statement is executed, the statement is searched for in the shared SQL area and, if found, used for execution. This saves parsing time and improves overall performance. Therefore, to ensure optimal use of the shared SQL area, use stored procedures as much as possible since the SQL parsed is exactly the same every time and, therefore, shared. However, keep in mind that the only time the SQL statement being executed can use a statement already in the shared SQL area is if the statements are identical (meaning they have the same content exactly—the same case, the same number of spaces, etc.). If the statements are not identical, the new statement is parsed, executed, and placed in the shared SQL area (exceptions to this are possible when the initialization parameter CURSOR_SHARING has been set to SIMILAR or FORCE).

In the following example, the statements are identical in execution, but the word *from* causes Oracle to treat the two statements as if they were different, thus *not* reusing the original cursor that was located in the shared SQL area:

```
SQL>     select name, customer from customer_information;
SQL>     select name, customer FROM customer information;
```

TIP
SQL must be written exactly the same to be reused. Case differences and any other differences will cause a reparse of the statement.

In the following example, I am using different values for ENAME, which is causing multiple statements to be parsed:

```
declare
      temp VARCHAR2(10);
begin
      select ename into temp
      from   rich
      where  ename = 'SMITH';
      select ename into temp
      from   rich
      where  ename = 'JONES';
end;
```

A query of V$SQLAREA shows that two statements were parsed even though they were very close to the same thing. Note, however, that PL/SQL converted each SQL statement to uppercase *and* trimmed spaces *and* carriage returns (which is a benefit of using PL/SQL):

```
select sql_text
from   v$sqlarea
where  sql_text like 'SELECT ENAME%';

SQL_TEXT
-------------------------------------------------
SELECT ENAME   FROM RICH  WHERE ENAME = 'JONES'
SELECT ENAME   FROM RICH  WHERE ENAME = 'SMITH'
```

In the following example, there is a problem with third-party applications that do not use bind variables (they do this to keep the code "vanilla" or capable of working on many different databases without modification). The problem with this code is that the developer has created many statements that fill the shared pool and these statements can't be shared (since they're slightly different). You can build a smaller shared pool so there is less room for cached cursors and thus fewer cursors to search through to find a match (this is the Band-Aid inexperienced DBAs use). If the following is your output from V$SQLAREA, you may benefit from lowering the SHARED_POOL_SIZE, but using CURSOR_SHARING is a better choice.

```
SQL_TEXT
--------------------------------------------------
select empno from rich778 where empno =451572

select empno from rich778 where empno =451573
select empno from rich778 where empno =451574
select empno from rich778 where empno =451575
select empno from rich778 where empno =451576
etc. . .
```

Setting CURSOR_SHARING=*force* and the query to V$SQLAREA will change to the one listed next because Oracle builds a statement internally that can be shared by all of the preceding statements. Now the shared pool is not inundated with all of these statements, but only one simple statement that can be shared by all users:

```
SQL_TEXT
---------------------------------------------------
select empno from rich778 where empno =:SYS_B_0
```

Setting the SHARED_POOL_SIZE High Enough to Fully Use the DB_CACHE_SIZE

If the SHARED_POOL_SIZE is set too low, then you will not get the full advantage of your DB_CACHE_SIZE (since statements that can't be parsed can't be executed). The queries that can be performed against the Oracle V$ views to determine the data dictionary cache hit ratio and the shared SQL statement usage are listed in the sections that follow. These will help you determine if increasing the SHARED_POOL_SIZE will improve performance.

The SHARED_POOL_SIZE parameter is specified in bytes. The default value for the SHARED_POOL_SIZE parameter varies per system but is generally lower than necessary for large production applications.

Keeping the Data Dictionary Cache Objects Cached

The data dictionary cache is a key area to tune because the dictionary is accessed so frequently, especially by Oracle. At startup, the data dictionary cache contains no data. But as more data is read into cache, the likelihood of cache misses decreases. For this reason, monitoring the data dictionary cache should be done only after the system has been up for a while and stabilized. If the dictionary cache hit ratio is less than 95 percent, then you'll probably need to increase the size of the SHARED_POOL_SIZE parameter in the initialization parameter file. Implementing locally managed tablespaces (LMT) can also help your dictionary cache (see My Oracle Support Note 166474.1, "Can We Tune the Row Cache?"). However, keep in mind that the shared pool also includes the library cache (SQL statements), and Oracle decides how much of the distribution is for the library cache versus the row cache.

Use the following query against the Oracle V$ view to determine the data dictionary cache hit ratio:

```
select     ((1 - (Sum(GetMisses) / (Sum(Gets) + Sum(GetMisses)))) * 100) "Hit Rate"
from       V$RowCache
where      Gets + GetMisses <> 0;

  Hit Rate
----------
98.6414551
```

TIP

Measure hit ratios for the row cache (data dictionary cache) of the shared pool with the V$ROWCACHE view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios will be around 85 percent.

Using Individual Row Cache Parameters to Diagnose Shared Pool Use

To diagnose a problem with the shared pool or overuse of the shared pool, use a modified query to the V$ROWCACHE view. This shows how each individual parameter makes up the data dictionary cache, also referred to as the row cache (partial listing):

```
column parameter          format a20          heading 'Data Dictionary Area'
column gets               format 999,999,999  heading 'Total|Requests'
column getmisses          format 999,999,999  heading 'Misses'
column modifications      format 999,999      heading 'Mods'
column flushes            format 999,999      heading 'Flushes'
column getmiss_ratio      format 9.99         heading 'Miss|Ratio'
set pagesize 50
ttitle 'Shared Pool Row Cache Usage'

select  parameter, gets, getmisses, modifications, flushes,
       (getmisses / decode(gets,0,1,gets)) getmiss_ratio,
       (case when (getmisses / decode(gets,0,1,gets)) > .1 then '*' else ' ' end) " "
from    v$rowcache
where   Gets + GetMisses <> 0;
```

```
Tue Aug 27                                                                   page    1
                          Shared Pool Row Cache Usage
                            Total                                        Miss
Data Dictionary Area     Requests       Misses     Mods  Flushes Ratio
-------------------- ------------ ------------ -------- -------- ----- -
dc_segments                   637          184        0        0   .29 *
dc_tablespaces                 18            3        0        0   .17 *
dc_users                      126           25        0        0   .20 *
dc_rollback_segments          235           21       31       30   .09
dc_objects                    728          167       55        0   .23 *
dc_global_oids                 16            6        0        0   .38 *
dc_object_ids                 672          164       55        0   .24 *
dc_sequences                    1            1        1        1  1.00 *
dc_usernames                  193           10        0        0   .05
dc_histogram_defs              24           24        0        0  1.00 *
dc_profiles                     1            1        0        0  1.00 *
dc_user_grants                 24           15        0        0   .63 *
```

This query places an asterisk (*) for any query that has misses greater than 10 percent. It does this by using the CASE expression to limit the miss ratio to the tenth digit and then analyzes that digit for any value greater than 0 (which would indicate a hit ratio of 10 percent or higher). A 0.1 miss or higher returns an *. Explanations of each of the columns are provided in the next section.

Keeping the Library Cache Reload Ratio at 0 and the Hit Ratio Above 95 Percent

For optimal performance, you'll want to keep the library cache reload ratio [sum(reloads) / sum(pins)] at zero and the library cache hit ratio greater than 95 percent. If the reload ratio is not zero, then statements are being "aged out" that are later needed and brought back into memory. If the reload ratio is zero (0), it means items in the library cache were never aged or invalidated. If the reload ratio is greater than 1 percent, the SHARED_POOL_SIZE parameter should probably be increased. Likewise, if the library cache hit ratio comes in less than 95 percent, then the

SHARED_POOL_SIZE parameter may need to be increased. Also, if you are using ASMM, the SGA_TARGET includes both auto-tuned and manual parameters. When you decide to raise a parameter specifically (such as SHARED_POOL_SIZE), it influences the auto-tuned part. (Other parameters are affected; see My Oracle Support Notes 443746.1 and 295626.1, “How to Use Automatic Shared Memory (AMM) in 12*c*.”)

You can monitor the library cache in a couple of ways. The first method is to execute the STATSPACK report (STATSPACK is covered in detail in Chapter 14). The second is to use the V$LIBRARYCACHE view.

The following query uses the V$LIBRARYCACHE view to examine the reload ratio in the library cache:

```
select     Sum(Pins) "Hits",
           Sum(Reloads) "Misses",
           ((Sum(Reloads) / Sum(Pins)) * 100)"Reload %"
from       V$LibraryCache;

      Hits     Misses   Reload %
---------- ---------- ----------
   1032669        441 .042704874
```

This next query uses the V$LIBRARYCACHE view to examine the library cache’s hit ratio in detail:

```
select     Sum(Pins) "Hits",
           Sum(Reloads) "Misses",
           Sum(Pins) / (Sum(Pins) + Sum(Reloads)) "Hit Ratio"
from       V$LibraryCache;

      Hits     Misses  Hit Ratio
---------- ---------- ----------
   1033760        441 .999573584
```

This hit ratio is excellent (greater than 99 percent) and does not require any increase in the SHARED_POOL_SIZE parameter.

Using Individual Library Cache Parameters to Diagnose Shared Pool Use

Using a modified query on the same table, you can see how each individual parameter makes up the library cache. This may help diagnose a problem or reveal overuse of the shared pool.

```
set numwidth 3
set space 2
set newpage 0
set pagesize 58
set linesize 80
set tab off
set echo off
ttitle 'Shared Pool Library Cache Usage'
column namespace   format a20          heading 'Entity'
column pins        format 999,999,999  heading 'Executions'
column pinhits     format 999,999,999  heading 'Hits'
column pinhitratio format 9.99         heading 'Hit|Ratio'
column reloads     format 999,999      heading 'Reloads'
column reloadratio format .9999        heading 'Reload|Ratio'
spool cache_lib.lis
select   namespace, pins, pinhits, pinhitratio, reloads, reloads
         /decode(pins,0,1,pins) reloadratio
from     v$librarycache;

Sun Mar 19                                                    page    1
                      Shared Pool Library Cache Usage
                                          Hit                  Reload
Entity        Executions         Hits     Ratio     Reloads    Ratio
SQL AREA       1,276,366    1,275,672     1.00            2    .0000
TABLE/PROC       539,431      539,187     1.00            5    .0000
BODY                   0            0     1.00            0    .0000
TRIGGER                0            0     1.00            0    .0000
INDEX                 21            0      .00            0    .0000
CLUSTER               15            5      .33            0    .0000
OBJECT                 0            0     1.00            0    .0000
PIPE                   0            0     1.00            0    .0000
JAVA SRCE              0            0     1.00            0    .0000
JAVA RES               0            0     1.00            0    .0000
JAVA DATA              0            0     1.00            0    .0000

11 rows selected.
```

Use the following list to help interpret the contents of the V$LIBRARYCACHE view:

- **namespace** The object type stored in the library cache. The values SQL AREA, TABLE/PROCEDURE, BODY, and TRIGGER show the key types.
- **gets** Shows the number of times an item in the library cache was requested.
- **gethits** Shows the number of times a requested item was already in the library cache.
- **gethitratio** Shows the ratio of gethits to gets.
- **pins** Shows the number of times an item in the library cache was executed.
- **pinhits** Shows the number of times an item was executed when that item was already in the

library cache.

- **pinhitratio** Shows the ratio of pinhits to pins.
- **reloads** Shows the number of times an item had to be reloaded into the library cache because it aged out or was invalidated.

Keeping the Pin Hit Ratio for Library Cache Items Close to 100 Percent

The pin hit ratio for all library cache items—*sum*(*pinhits*)/*sum*(*pins*)—should be close to 1 (or a 100 percent hit ratio). A pin hit ratio of 100 percent means that every time the system needs to execute something, it is already allocated and valid in the library cache. Although you will always experience some misses the first time a request is made, misses can be reduced by writing identical SQL statements.

TIP
Measure hit ratios for the library cache of the shared pool with the V$LIBRARYCACHE view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios are around 85 percent.

Keeping the Miss Ratio Less Than 15 Percent

The miss ratio for data dictionary cache *sum*(*getmisses*)/*sum*(*gets*) should be less than 10 to 15 percent. A miss ratio of zero (0) means that every time the system went into the data dictionary cache, it found what it was looking for and did not have to retrieve the information from disk. If the miss ratio *sum*(*getmisses*)/*sum*(*gets*) is greater than 10–15 percent, the initialization SHARED_POOL_SIZE parameter should be increased.

Using Available Memory to Determine If the SHARED_POOL_SIZE Is Set Correctly

Here's the main question that people usually want answered: "Is there any memory left in the shared pool?" To find out how fast memory in the shared pool is being depleted (made noncontiguous or in use) and also what percent is unused (and still contiguous), run the following query after starting the database and running production queries for a short period of time (for example, after the first hour of the day):

```
col value for 999,999,999,999 heading "Shared Pool Size"
col bytes for 999,999,999,999 heading "Free Bytes"
select to_number(v$parameter.value) value, v$sgastat.bytes,
       (v$sgastat.bytes/v$parameter.value)*100 "Percent Free"
from   v$sgastat, v$parameter
where  v$sgastat.name = 'free memory'
and    v$parameter.name = 'shared_pool_size'
and    v$sgastat.pool = 'shared pool';

Shared Pool Size       Free Bytes Percent Free
---------------- ---------------- ------------
   1,073,741,824      581,983,848   54.2014696
```

If you have plenty of contiguous free memory (greater than 2M), after running most of the queries in your production system (you'll have to determine how long this takes), then you do not need to increase the SHARED_POOL_SIZE parameter. I have never seen this parameter go all the way to zero (Oracle saves a portion for emergency operations via the SHARED_POOL_RESERVED_SIZE parameter).

TIP
The V$SGASTAT view shows how fast the memory in the shared pool is being depleted. Remember it is only a rough estimate. It shows you any memory that has never been used combined with any piece of memory that has been reused. Free memory will go up and down as the day goes on, depending on how the pieces are fragmented.

Using the X$KSMSP Table to Get a Detailed Look at the Shared Pool

You can query the X$KSMSP table to get the total breakdown for the shared pool. This table will show the amount of memory that is free, memory that is freeable, and memory that is retained for large statements that won't fit into the current shared pool. Consider the following query for a more accurate picture of the shared pool. Refer to Chapter 13 (the X$ tables) for an in-depth look at this query and how it is adjusted as Oracle is started and as the system begins to access shared pool memory.

```
select     sum(ksmchsiz) Bytes, ksmchcls Status
from       x$ksmsp
group by   ksmchcls;

          Bytes STATUS
---------------- --------
     238,032,888 freeabl
     128,346,176 recr
           3,456 R-freea
     124,551,032 perm
      29,387,280 R-free
      16,771,472 R-perm
      66,884,304 free

7 rows selected.
```

Oracle does not state anywhere what the values for status in the X$KSMSP table indicate (KSMSP stands for Kernel Service layer Memory management SGA HEAP; I always remember it as Kernel Shared Memory Shared Pool instead). In the following table, I offer the following possible descriptions based on the behavior of these values as researched in Chapter 13. In Chapter 5, I also show how to graph these results in Enterprise Manager.

Status	Possible Meaning
Free	This is the amount of contiguous free memory available.
Freeabl	Freeable but not flushable shared memory currently in use.
Perm	I have read that this status is permanently allocated and non-freeable memory, but in testing it, I find that it behaves as free memory not yet moved to the free area for use.
Recr	Allocated memory that is flushable when the shared pool is low on memory.
R-free	This is SHARED_POOL_RESERVED_SIZE (default 5 percent of shared pool).
R-freea	This is probably reserved memory that is freeable but not flushable.
R-recr	Re-creatable chucks of memory in the reserved pool.
R-perm	Permanent chucks of memory in the reserved pool.

TIP

The general rule of thumb (exact sizing depends on your unique systems) is to make the SHARED_POOL_SIZE parameter around 50–150+ percent of the size of your DB_CACHE_SIZE. In a system that makes use of a large amount of stored procedures or Oracle supplied packages, but has limited physical memory, this parameter could make up as much as 150+ percent of the size of DB_CACHE_SIZE. In a system that uses no stored procedures, but has a large amount of physical memory to allocate to DB_CACHE_SIZE, this parameter may be 10–20 percent of the size of DB_CACHE_SIZE. I have worked on larger systems where the DB_CACHE_SIZE was set as high as tens of gigabytes. I'm sure that hundreds of gigabytes to terabyte SGAs already exist (see examples at the end of this chapter). Petabyte databases are currently starting to make their entry. Note that in a shared server configuration (previously known as MTS), items from the PGA are allocated from the shared pool rather than the session process space.

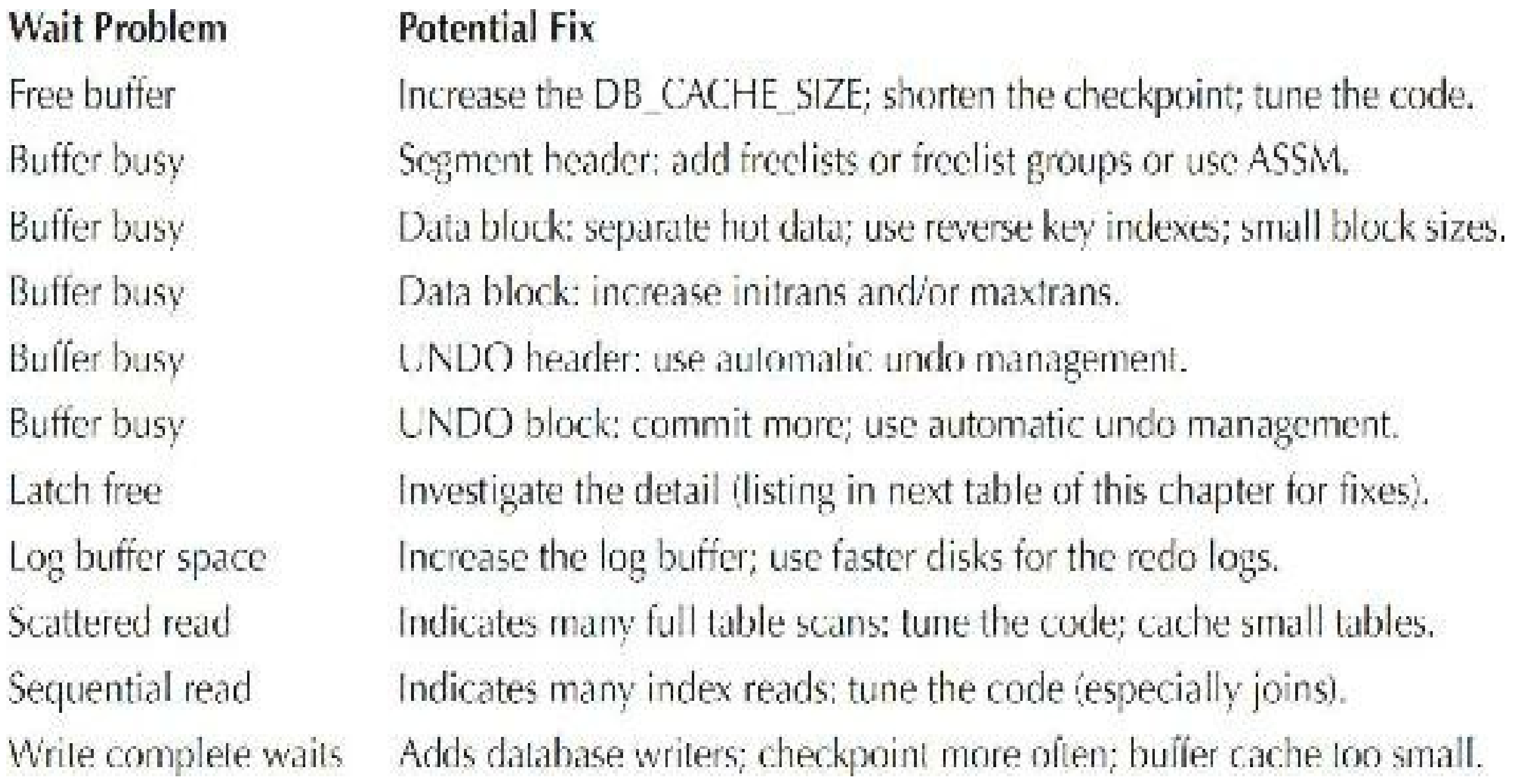
Points to Remember About Cache Size

Here are some further notes about setting your cache and share pool sizes:

- If the dictionary cache hit ratio is low (less than 95 percent), then consider investigating and increasing SHARED_POOL_SIZE.
- If the library cache reload ratio is high (>1 percent), then consider investigating and increasing SHARED_POOL_SIZE.
- Size the data cache and shared pool appropriately for your systems in terms of workload requirements.

Waits Related to Initialization Parameters

Setting initialization parameters incorrectly often results in various types of performance issues that show up as general "waits" or "latch waits" in a STATSPACK report. In Chapter 14, I cover every type of wait and latch issue related to this. The following tables identify some waits and latch waits and their potential fixes.



Wait Problem	Potential Fix
Free buffer	Increase the DB_CACHE_SIZE; shorten the checkpoint; tune the code.
Buffer busy	Segment header: add freelists or freelist groups or use ASSM.
Buffer busy	Data block: separate hot data; use reverse key indexes; small block sizes.
Buffer busy	Data block: increase initrans and/or maxtrans.
Buffer busy	UNDO header: use automatic undo management.
Buffer busy	UNDO block: commit more; use automatic undo management.
Latch free	Investigate the detail (listing in next table of this chapter for fixes).
Log buffer space	Increase the log buffer; use faster disks for the redo logs.
Scattered read	Indicates many full table scans: tune the code; cache small tables.
Sequential read	Indicates many index reads: tune the code (especially joins).
Write complete waits	Adds database writers; checkpoint more often; buffer cache too small.

Some latch problems have often been bug related in the past, so make sure you check My Oracle Support for issues related to latches. Any of the latches that have a hit ratio less than 99 percent should be investigated.

Latch Problem	Potential Fix
Library cache	Use bind variables; adjust the SHARED_POOL_SIZE.
Shared pool	Use bind variables; adjust the SHARED_POOL_SIZE.
Row cache objects	Increase the shared pool. This is not a common problem.
Cache buffers chain	Shouldn't be a problem in 12c. If you get this latch wait, it means you need to reduce logical I/O rates by tuning and minimizing the I/O requirements of the SQL involved. High I/O rates could be a sign of a hot block (meaning a block highly accessed). Cache buffer lru chain latch contention can be resolved by increasing the size of the buffer cache and thereby reducing the rate at which new blocks are introduced into the buffer cache. Multiple buffer pools, if it's found they are needed, can help reduce contention. You can also create additional cache buffer lru chain latches by adjusting the configuration parameter _DB_BLOCK_LRU_LATCHES. You may be able to reduce the load on the cache buffer chain latches by increasing the configuration parameter. _DB_BLOCK_HASH_BUCKETS may need to be increased or set to a prime number, but this should not be needed since 11g. Keep in mind there are now in-memory updates (IMUs) to consider as well.

Using Oracle Multiple Buffer Pools

There are pools for the allocation of memory. These pools relate to the DB_CACHE_SIZE and SHARED_POOL_SIZE. Each of these parameters, which were all-inclusive of the memory they allocate, now has additional options for memory allocation within each memory pool. I will cover the two separately.

Pools Related to DB_CACHE_SIZE and Allocating Memory for Data

In this section, I will focus on the Oracle pools that are used to store the actual data in memory. The initialization parameters DB_CACHE_SIZE, DB_KEEP_CACHE_SIZE, and DB_RECYCLE_CACHE_SIZE are the determining factors for memory used to store data. DB_CACHE_SIZE refers to the total size in bytes of the main buffer cache (or memory for data) in the SGA. Two additional buffer pools are DB_KEEP_CACHE_SIZE and DB_RECYCLE_CACHE_SIZE. These additional two pools serve the same purpose as the main buffer cache (DB_CACHE_SIZE), with the exception that the algorithm to maintain the pool is different for all three available pools. Note that the BUFFER_POOL_KEEP, DB_BLOCK_BUFFERS, and BUFFER_POOL_RECYCLE parameters have been deprecated and should no longer be used. Unlike BUFFER_POOL_KEEP and BUFFER_POOL_RECYCLE, DB_KEEP_CACHE_SIZE and DB_RECYCLE_CACHE_SIZE are not subtracted from DB_CACHE_SIZE; they are allocated in addition to DB_CACHE_SIZE.

The *main buffer cache* (defined by *DB_CACHE_SIZE*) maintains the LRU (least recently used) list and flushes the oldest buffers in the list. While all three pools utilize the LRU replacement policy, the goal for the main buffer cache is to fit most data being used in memory.

The *keep pool* (defined by *DB_KEEP_CACHE_SIZE*) is hopefully never flushed; it is intended for buffers that you want to be “pinned” indefinitely (buffers that are very important and need to stay in memory). Use the keep pool for small tables (that fit in their entirety in this pool) that are frequently accessed and need to be in memory at all times.

The *recycle pool* (defined by *DB_RECYCLE_CACHE_SIZE*) is a pool from which you expect the data to be regularly flushed because too much data is being accessed to stay in memory. Use the recycle pool for large, less important data that is usually accessed only once in a long while (ad hoc user tables for inexperienced users are often put here).

The following examples give a quick look at how information is allocated to the various buffer pools. Remember, if no pool is specified, then the buffers in the main pool are used.

1. Create a table that will be stored in the keep pool upon being accessed:
   ```
   Create table state_list (state_abbrev varchar2(2), state_desc varchar2(25))
   Storage (buffer pool keep);
   ```
2. Alter the table to the recycle pool:
   ```
   Alter table state list storage (buffer pool recycle);
   ```
3. Alter the table back to the keep pool:
   ```
   Alter table state list storage (buffer pool keep);
   ```
4. Find the disk and memory reads in the keep pool:
   ```
   select   physical_reads "Disk Reads",
            db_block_gets + consistent_gets "Memory Reads"
   from     v$buffer_pool_statistics
   where    name = 'KEEP';
   ```

Modifying the LRU Algorithm

In this section, I’m going to go over the deep edge for experts only. Skip this section if you’ve used Oracle for only a decade or less. There are five undocumented initialization parameters (defaults are in parentheses) that you can use to alter the LRU algorithm for greater efficiency when you really have studied and understand your system buffer usage well:

- **_DB_PERCENT_HOT_DEFAULT (50)** The percent of buffers in the hot region
- **_DB_AGING_TOUCH_TIME (3)** Seconds that must pass to increment touch count again
- **_DB_AGING_HOT_CRITERIA (2)** Threshold to move a buffer to the MRU end (hot end) of LRU chain
- **_DB_AGING_STAY_COUNT (0)** Touch count reset to this when moved to MRU end

- **_DB_AGING_COOL_COUNT (1)** Touch count reset to this when moved to LRU end
- **_DB_AGING_FREEZE_CR (FALSE)** Make CR (consistent read) buffers always too cold to keep in cache

By decreasing the value of the first of these parameters, you allow buffers to remain longer; increasing the values causes a flush sooner. Setting the second parameter lower gives higher value to buffers that are executed a lot in a short period of time. The third, fourth, and fifth parameters all relate to how quickly to move things from the hot end to the cold end and how long they stay on each end.

Pools Related to SHARED_POOL_SIZE and Allocating Memory for Statements

In this section, I focus on the pools that are used to store the actual statements in memory. Unlike the pools related to the data, the LARGE_POOL_SIZE is allocated outside the memory allocated for SHARED_POOL_SIZE, but it is still part of the SGA.

The LARGE_POOL_SIZE is a pool of memory used for the same operations as the shared pool. Oracle defines this as the size set aside for large allocations of the shared pool. You'll have to do your own testing to ensure where the allocations are coming from in your system and version of Oracle. The minimum setting is 300K, but the setting must also be as big as _LARGE_POOL_MIN_ALLOC, which is the minimum size of shared pool memory requested that will force an allocation in the LARGE_POOL_SIZE memory. Unlike the shared pool, the large pool does not have an LRU list. Oracle does not attempt to age memory out of the large pool.

You can view your pool settings by querying the V$PARAMETER view:

```
select     name, value, isdefault, isses_modifiable, issys_modifiable
from       v$parameter
where      name like '%pool%'
and        isdeprecated <> 'TRUE'
order by 1;

NAME                      VALUE       ISDEFAULT ISSES ISSYS_MOD
------------------------- ----------- --------- ----- ---------
java_pool_size            0           TRUE      FALSE IMMEDIATE
large_pool_size           0           TRUE      FALSE IMMEDIATE
olap_page_pool_size       0           TRUE      TRUE  DEFERRED
shared_pool_reserved_size 53687091    TRUE      FALSE FALSE
shared_pool_size          1073741824  FALSE     FALSE IMMEDIATE
streams_pool_size         0           TRUE      FALSE IMMEDIATE

6 rows selected.
```

TIP
The additional buffer pools (memory for data) available in Oracle are initially set to zero. You should not need to set them initially, but you may need to for your unique system.

Tuning PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT

The PGA_AGGREGATE_TARGET, now included as part of MEMORY_TARGET, specifies the total amount of session PGA memory that Oracle will attempt to allocate across all sessions. Oracle will allocate what it feels is appropriate based on MEMORY_TARGET, but you should set a minimum value based on what you've seen in prior versions. My Oracle Support Note 223730.1 describes Automatic PGA_AGGREGATE_TARGET Management quite well. PGA_AGGREGATE_TARGET was introduced in Oracle9*i* and should be used in place of the *_SIZE parameters such as SORT_AREA_SIZE, although a local session may still want to set a local SORT_AREA_SIZE for some local short-term operation. Also, since Oracle9*i*, the PGA_AGGREGATE_TARGET parameter does not automatically configure ALL *_SIZE parameters. For example, both the LARGE_POOL_SIZE and JAVA_POOL_SIZE parameters are not affected by PGA_AGGREGATE_TARGET. The advantage of using PGA_AGGREGATE_TARGET is the ability to cap the total user session memory to minimize OS paging.

When PGA_AGGREGATE_TARGET is set, WORKAREA_SIZE_POLICY must be set to AUTO. Like the V$DB_CACHE_ADVICE view, the V$PGA_TARGET_ADVICE (Oracle 9.2 and later versions) and V$PGA_TARGET_ADVICE_HISTOGRAM views exist to assist in tuning the PGA_AGGREGATE_TARGET. Oracle Enterprise Manager provides graphical representations of these views.

The PGA_AGGREGATE_TARGET should be set to attempt to keep the ESTD_PGA_CACHE_HIT_PERCENTAGE greater than 95 percent. By setting this appropriately, more data will be sorted in memory that may have been sorted on disk.

The next query returns the minimum value for the PGA_AGGREGATE_TARGET that is projected to yield a 95 percent or greater cache hit ratio:

```
select min(pga_target_for_estimate)
from   v$pga_target_advice
where  estd_pga_cache_hit_percentage > 95;

MIN(PGA_TARGET_FOR_ESTIMATE)
----------------------------
                   299892736
```

Since the PGA_AGGREGATE_TARGET would get too high in 11*g*, Oracle created an additional parameter. In 12*c*, there is a new 12*c* initialization parameter called PGA_AGGREGATE_LIMIT.

The PGA makes up part of the MEMORY_TARGET. Set the parameter as follows:

```
ALTER SYSTEM SET PGA_AGGREGATE_TARGET=1024M;
ALTER SYSTEM SET PGA_AGGREGATE_LIMIT=2048M;
```

Modifying the Size of Your SGA to Avoid Paging and Swapping

Before you increase the size of your SGA, you must understand the effects on the physical memory of your system. If you increase parameters that use more memory than what is available on your system, then serious performance degradation may occur. When your system processes jobs, if it doesn't have enough memory, it starts paging or swapping to complete the active task.

When *paging* occurs, information that is *not currently* being used is moved from memory to disk. This allows memory to be used by a process that *currently* needs it. If paging happens a lot, the system will experience decreases in performance, causing processes to take longer to run.

When *swapping* occurs, an *active* process is moved from memory to disk temporarily so that another *active* process that also desires memory can run. Swapping is based on system cycle time. If swapping happens a lot, your system is dead. Depending on the amount of memory available, an SGA that is too large can cause swapping.

Understanding the Oracle Optimizer

The Oracle optimizer was built to make your tuning life easier by choosing better paths for your poorly written queries. Rule-based optimization (now obsolete and unsupported) was built on a set of rules for how Oracle processes statements. Oracle 10*g* Release 2 only supported the use of the cost-based optimizer; the rule-based optimizer was no longer supported. Since Oracle 10*g* Release 2, Oracle has automatic statistics gathering turned on to aid the effectiveness of the cost-based optimizer. In Oracle, many features are only available when using cost-based optimization. The cost-based optimizer now has two modes of operation: normal mode and tuning mode. *Normal* mode should be used in production and test environments; *tuning* mode can be used in development environments to aid developers and DBAs in testing specific SQL code.

How Optimization Looks at the Data

Rule-based optimization is *Oracle-centric*, whereas cost-based optimization is *data-centric*. The optimizer mode under which the database operates is set via the initialization parameter OPTIMIZER_MODE. The possible optimizer modes are as follows:

- **ALL_ROWS** Gets all rows faster (generally forces index suppression). This is good for untuned, high-volume batch systems. This is the default.

- **FIRST_ROWS** Gets the first row faster (generally forces index use). This is good for untuned systems that process lots of single transactions.
- **FIRST_ROWS (1|10|100|1000)** Gets the first *n* rows faster. This is good for applications that routinely display partial results to users such as paging data to a user in a web application.
- **CHOOSE** Now obsolete and unsupported but still allowed. Uses cost-based optimization for all analyzed tables. This is a good mode for well-built and well-tuned systems (for advanced users). This option is not documented for 12*c*R2 but is still usable.
- **RULE** Now obsolete and unsupported but still allowed. Always uses rule-based optimization. If you are still using this, you need to start using cost-based optimization, as rule-based optimization is no longer supported under Oracle 10*g* Release 2 and higher. This option is not documented for 12*c*R2 but is still usable.

The default optimizer mode for 12*c*R2 is ALL_ROWS. Also, cost-based optimization is used even if the tables are not analyzed. Although RULE/CHOOSE are definitely desupported and obsolete and people are often scolded for even talking about using rule-based optimization, I was able to set the mode to RULE in 12*c*R2. Consider the following error I received when I set OPTIMIZER_MODE to a mode that doesn't exist (SUPER_FAST):

```
SQL> alter system set optimizer_mode=super_fast

ERROR:
ORA-00096: invalid value SUPER_FAST for parameter optimizer_mode, must be
from among first_rows_1000, first_rows_100, first_rows_10, first_rows_1,
first_rows,all_rows, choose, rule
```

NOTE
The optimizer in Oracle 12c Release 2 uses cost-based optimization regardless of whether the tables have been analyzed or not.

TIP
In Oracle 12c Release 2, the main OPTIMIZER_MODEs to use are ALL_ROWS (the default) and FIRST_ROWS.

Creating Enough Dispatchers

When using Shared Server, some of the things you need to watch for are high busy rates for the existing dispatcher processes and increases in wait times for response queues of existing dispatcher processes. If the wait time increases, as the application runs under normal use, you may wish to add more dispatcher processes, especially if the processes are busy more than 50 percent of the time.

Use the following statement to determine the busy rate:

```
select     Network,
           ((Sum(Busy) / (Sum(Busy) + Sum(Idle))) * 100) "% Busy Rate"
from       V$Dispatcher
group by   Network;

NETWORK          % Busy Rate
TCP1                       0
TCP2                       0
```

Use the following statement to check for responses to user processes that are waiting in a queue to be sent to the user:

```
select     Network Protocol,
           Decode (Sum(Totalq), 0, 'No Responses',
           Sum(Wait) / Sum(TotalQ) || ' hundredths of a second')
           "Average Wait Time Per Response"
from       V$Queue Q, V$Dispatcher D
where      Q.Type = 'DISPATCHER'
and        Q.Paddr = D.Paddr
group by   Network;

PROTOCOL          Average Wait Time Per Response
TCP1              0 hundredths of a second
TCP2              1 hundredths of a second
```

Use the following statement to check the requests from user processes that are waiting in a queue to be sent to the user:

```
select     Decode (Sum(Totalq), 0, 'Number of Requests',
           Sum(Wait) / Sum(TotalQ) || 'hundredths of a second')
           "Average Wait Time Per Request"
from       V$Queue
where      Type = 'COMMON';

Average Wait Time Per Request
12 hundredths of a second
```

Have Enough Open Cursors (OPEN_CURSORS)

If you don’t have enough open cursors, then you will receive errors to that effect. The key is to stay ahead of your system by increasing the OPEN_CURSORS initialization parameter before you run out of open cursors.

Don’t Let Your DDL Statements Fail (DDL_LOCK_TIMEOUT)

DDL statements (CREATE/ALTER/DROP) require exclusive locks and thus sometimes fail due to bad timing when they conflict with other statements that lock the table. The parameter DDL_LOCK_TIMEOUT specifies the amount of time (in seconds) the DDL statement will wait for the lock before timing out and failing. The default value is 0; the max value is 100,000 (27.77 hours). The following example shows setting the value to 1 hour or 3600 seconds.

```
SQL> alter session set DDL_LOCK_TIMEOUT = 3600;
Session altered.
```

Two Important Exadata Initialization Parameters (Exadata Only)

Oracle has two very important parameters to use to test major features of Exadata. The first is CELL_OFFLOAD_PROCESSING, which relates to Smart Scans (cell scans). The default value is TRUE, which means that Smart Scans are turned on for Exadata (if you are using it). You can set this value to FALSE to turn off Smart Scans and check other features or compare speeds with and without this feature.

The second parameter is undocumented and should only be used with the consent of Oracle Support and also only for testing purposes. The second is _KCFIS_STORAGEIDX_DISABLED, which is used to disable storage indexes. This tells Oracle *not* to use storage index optimization on storage cells if set to TRUE. The default is FALSE. Another undocumented parameter (again check with Oracle Support) is also related to how the Smart Scan works and uses Bloom filters. The parameter _BLOOM_FILTER_ENABLED is set to TRUE by default. With Exadata, Bloom filters are used for join filtering with Smart Scans. _BLOOM_PRUNING_ENABLED also has a default of TRUE. Set these parameters to FALSE to disable them. See Chapter 11 for additional information.

Top 25 Initialization Parameters

The following list is *my* list of the top 25 most important initialization parameters, in order of importance. Your top 25 may vary somewhat from my top 25 because everyone has a unique business, unique applications, and unique experiences.

1. **MEMORY_TARGET** This is the initialization parameter setting for all of the memory allocated to *both* the PGA and SGA combined (new in 11*g*). Setting MEMORY_TARGET enables Automatic Memory Management, so Oracle allocates memory for you based on system needs, but you can also set minimum values for key parameters. MEMORY_TARGET is used for everything that SGA_TARGET was used for but now additionally includes the PGA (especially important as MEMORY_TARGET now includes the important area PGA_AGGREGATE_TARGET). Important parameters such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, LARGE_POOL_SIZE, and JAVA_POOL_SIZE are all set automatically when you set MEMORY_TARGET. Setting minimum values for important initialization parameters in your system is also a *very* good idea.
2. **MEMORY_MAX_TARGET** This is the maximum memory allocated for Oracle and the maximum value to which MEMORY_TARGET can be set.
3. **DB_CACHE_SIZE** Initial memory allocated to data cache or memory used for data itself. This parameter doesn't need to be set if you set MEMORY_TARGET or SGA_TARGET, but setting a value for this as a minimum setting is a good idea. Your goal should always be toward a memory-resident database or at least toward getting all data that will be queried in memory.
4. **SHARED_POOL_SIZE** Memory allocated for the data dictionary and for SQL and PL/SQL statements. The query itself is put in memory here. This parameter doesn't need to be set if you set MEMORY_TARGET, but setting a value for this as a minimum is a good idea. Note that SAP recommends setting this to 400M. Also note that the Result Cache gets its memory from the shared pool and is set with the RESULT_CACHE_SIZE and RESULT_CACHE_MODE (FORCE/AUTO/MANUAL) initialization parameters. Lastly, an important note since 11*g* is that this parameter now includes some SGA overhead (12M worth) that it previously did not in version 10*g*. Set this 12M higher than you did in 10*g*!
5. **INMEMORY_SIZE** The In-Memory column store resides in this area, which is separate from the buffer cache used to store data in memory. Tables, tablespaces, partitions, and other objects can have single columns stored in this memory area in a compressed fashion. This allows for much faster analytics (like summing an individual column). Oracle builds indexes to make this even faster based on ranges of values. This is new in 12*c*.
6. **SGA_TARGET** If you use Oracle's Automatic Shared Memory Management, this parameter is used to determine the size of your data cache, shared pool, large pool, and Java pool automatically (see Chapter 1 for more information). Setting this to 0 disables it. This parameter doesn't need to be set if you set MEMORY_TARGET, but you may want to set a value for this as a minimum setting for the SGA if you've calibrated it in previous versions. The SHARED_POOL_SIZE, LARGE_POOL_SIZE, JAVA_POOL_SIZE, and DB_CACHE_SIZE are all set automatically based on this parameter (or MEMORY_TARGET if used). INMEMORY_SIZE is also included in this number.
7. **PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT** The _TARGET is a soft memory cap for the total of all users' PGAs. This parameter doesn't need to be set if you set MEMORY_TARGET, but setting a value as a minimum setting is a good idea. Note that SAP

specifies to set this to 20 percent of available memory for OLTP and 40 percent for OLAP. The _LIMIT sets the upper limit that is allowed (the hard memory cap).

8. **SGA_MAX_SIZE** Maximum memory that SGA_TARGET can be set to. This parameter doesn't need to be set if you set MEMORY_TARGET, but you may want to set a value if you use SGA_TARGET.
9. **OPTIMIZER_MODE** FIRST_ROWS, FIRST_ROWS_*n*, or ALL_ROWS. Although RULE/CHOOSE are definitely desupported and obsolete and people are often scolded for even talking about using rule-based optimization, I was able to set the mode to RULE. Consider the following error I received when I set OPTIMIZER_MODE to a mode that doesn't exist (SUPER_FAST):

```
SQL> alter system set optimizer_mode=super_fast
ERROR:
ORA-00096: invalid value SUPER_FAST for parameter optimizer_mode, must be from
among first_rows_1000, first_rows_100, first_rows_10, first_rows_1, first_rows,
all_rows, choose, rule
```

10. **SEC_MAX_FAILED_LOGIN_ATTEMPTS** If the user fails to enter the correct password after this many tries (new as of 11*g*) the server process drops the connection and the server process is terminated. The default is 3 (consider increasing this value for *less* secure systems). A similar parameter in my top 25 list in the prior edition included **SEC_CASE_SENSITIVE_LOGON**, which was new as of 11*g*, but is deprecated as of 12.1. Be careful if you're still using this parameter in 11*g* (fix case issues with passwords by ensuring passwords can be lower, upper, or mixed case before you upgrade to 12*c*!).
11. **CURSOR_SHARING** Converts literal SQL to SQL with bind variables, reducing parse overhead. The default is EXACT. Consider setting it to FORCE after research.
12. **OPTIMIZER_USE_INVISIBLE_INDEXES** The default is FALSE to ensure invisible indexes are *not* used by default (new in 11*g*). Set this parameter to TRUE to use *all* of the indexes and to check which ones might have been set incorrectly to be invisible; this could be a helpful tuning exercise, or it could also bring the system to halt, so only use it in development.
13. **OPTIMIZER_USE_PENDING_STATISTICS** The default is FALSE to ensure pending statistics are *not* used, whereas setting this to TRUE enables all pending statistics to be used (new in 11*g*).
14. **OPTIMIZER_INDEX_COST_ADJ** Coarse adjustment between the cost of an index scan and the cost of a full table scan. Set between 1 and 10 to force index use more frequently. Setting this parameter to a value between 1 and 10 pretty much guarantees index use, however, even when not appropriate, so be careful because it is highly dependent on the index design and implementation being correct. Please note that if you are using Applications 11*i*, setting OPTIMIZER_INDEX_COST_ADJ to any value other than the default (100) is not supported (see My Oracle Support Note 169935.1). I've seen a benchmark where this was set to 200. Also, see bug 4483286. SAP suggests that you *not* set it for OLAP, but set it to 20 for OLTP.
15. **DB_FILE_MULTIBLOCK_READ_COUNT** For full table scans to perform I/O more efficiently, this parameter reads the given number of blocks in a single I/O. The default value is 12812*c*R2, but it is usually noted *not* to change this from the default.
16. **LOG_BUFFER** Server processes making changes to data blocks in the buffer cache generate

redo data into the log buffer. SAP says to use the default, whereas Oracle Applications sets it to 10M. I've seen benchmarks with it set over 100M.

17. **DB_KEEP_CACHE_SIZE** Memory allocated to the keep pool or an additional data cache that you can set up outside the buffer cache for very important data that you don't want pushed out of the cache.
18. **DB_RECYCLE_CACHE_SIZE** Memory allocated to a recycle pool or an additional data cache that you can set up outside the buffer cache and in addition to the keep pool described in item 17. Usually, DBAs set this up for ad hoc user query data with poorly written queries.
19. **OPTIMIZER_USE_SQL_PLAN_BASELINES** The default is TRUE, which means Oracle uses these baselines if they exist (new in 11*g*). Note that Stored Outlines are deprecated (discouraged but they still work) in 11*g*, as they are replaced with SQL Plan Baselines.
20. **OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES** The default is FALSE, which means that Oracle does not capture them by default, but if you create some, it will use them as stated in the previous parameter (new in 11*g*).
21. **LARGE_POOL_SIZE** Total bytes in the large pool allocation for large PL/SQL and a few other Oracle options less frequently used.
22. **STATISTICS_LEVEL** Used to enable advisory information and optionally keep additional OS statistics to refine optimizer decisions. TYPICAL is the default.
23. **JAVA_POOL_SIZE** Memory allocated to the JVM for Java stored procedures.
24. **JAVA_MAX_SESSIONSPACE_SIZE** Upper limit on memory that is used to keep track of the user session state of Java classes.
25. **OPEN_CURSORS** Specifies the size of the private area used to hold (open) user statements. If you get an "ORA-01000: maximum open cursors exceeded," you may need to increase this parameter, but make sure you are *closing* cursors that you no longer need. Prior to 9.2.0.5, these open cursors were also cached and, at times, caused issues (ORA-4031) if OPEN_CURSORS was set too high. As of 9.2.0.5, SESSION_CACHED_CURSORS now controls the setting of the PL/SQL cursor cache. Do *not* set the parameter SESSION_CACHED_CURSORS as high as you set OPEN_CURSORS, or you may experience ORA-4031 or ORA-7445 errors. SAP recommends setting this to 2000; Oracle Applications has OPEN_CURSORS at 600 and SESSION_CACHED_CURSORS at 500.

TIP
Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly before implementing those changes in a production environment.

Initialization Parameters over the Years

Oracle has moved from a time when there were over four times as many documented parameters as undocumented in Oracle 6, to the undocumented parameters exceeding the documented in Oracle 8*i*, to four times as many undocumented as documented parameters in Oracle 10*g*, to six times more in 11*g*. In 12*c*, the increase is less on documented, but substantially more on the undocumented side. Clearly, Oracle has migrated to a place where experts have more dials to set in 12*c* (undocumented), but the number of dials to set for the standard database setup (documented parameters) is not increasing as much and is becoming standardized. The following table charts the changing numbers of documented and undocumented parameters:

Version	Documented	Undocumented	Total
6	111	19	130
7	117	68	185 (+42% vs. V6)
8.0	193	119	312
8.1	203	301	504 (+62% vs. V7)
9.0	251	436	687
9.2	257	540	797 (+58% vs. 8*i*)
10.2	257 (+0%)	1124 (+108%)	1381 (+73% vs. 9*i*)
11.2	341 (+33%)	2053 (+83%)	2394 (+73% vs. 10*g*)
12.2	412 (+21%)	4237 (+106%)	4649 (+94% vs. 11*g*)

Finding Undocumented Initialization Parameters

Querying the table X$KSPPI shows you documented as well as undocumented initialization parameters. The query may only be done as user SYS, so be careful. See Chapter 13 for a complete look at the X$ tables. My top 13 undocumented initialization parameters are listed in Appendix A. Appendix C gives a complete listing as of the writing of this book of the X$ tables.

```
Col name for a15
Col value for a15
Col default1 for a15
Col descl for a30

select      a.ksppinm name, b.ksppstvl value, b.ksppstdf default1, a.ksppdesc descl
from        x$ksppi a, x$ksppcv b
where       a.indx = b.indx
and         substr(ksppinm,1,1) = '_'
order       by ksppinm;
```

The following is a brief description of the columns in the X$KSPPI and X$KSPPCV tables:

- **KSPPINM** Parameter name
- **KSPPSTVL** Current value for the parameter
- **KSPPSTDF** Default value for the parameter

A partial output listing of the initialization parameters is shown here:

```
KSPPINM                        KSPPSTVL             KSPPSTDF
------------------------------ -------------------- ----------
...
 write clones                  3                    TRUE
_yield_check_interval          100000               TRUE
active instance count                               TRUE
aq_tm_processes                1                    FALSE
archive_lag_target             0                    TRUE
...
```

TIP
Using undocumented initialization parameters can cause corruption. Never use these if you are not an expert and you are not directed by Oracle Support! Ensure that you work with Oracle Support before setting these parameters.

Understanding the Typical Server

There's nothing typical about most unique systems. The key to understanding Oracle is to understand its dynamic nature. Oracle continues to have many attributes of previous versions while also leading the way by implementing the future of distributed database and object-oriented programming. Experience from earlier versions of Oracle always benefits the DBA in future versions of Oracle. Here are some of the future changes to consider as you build your system:

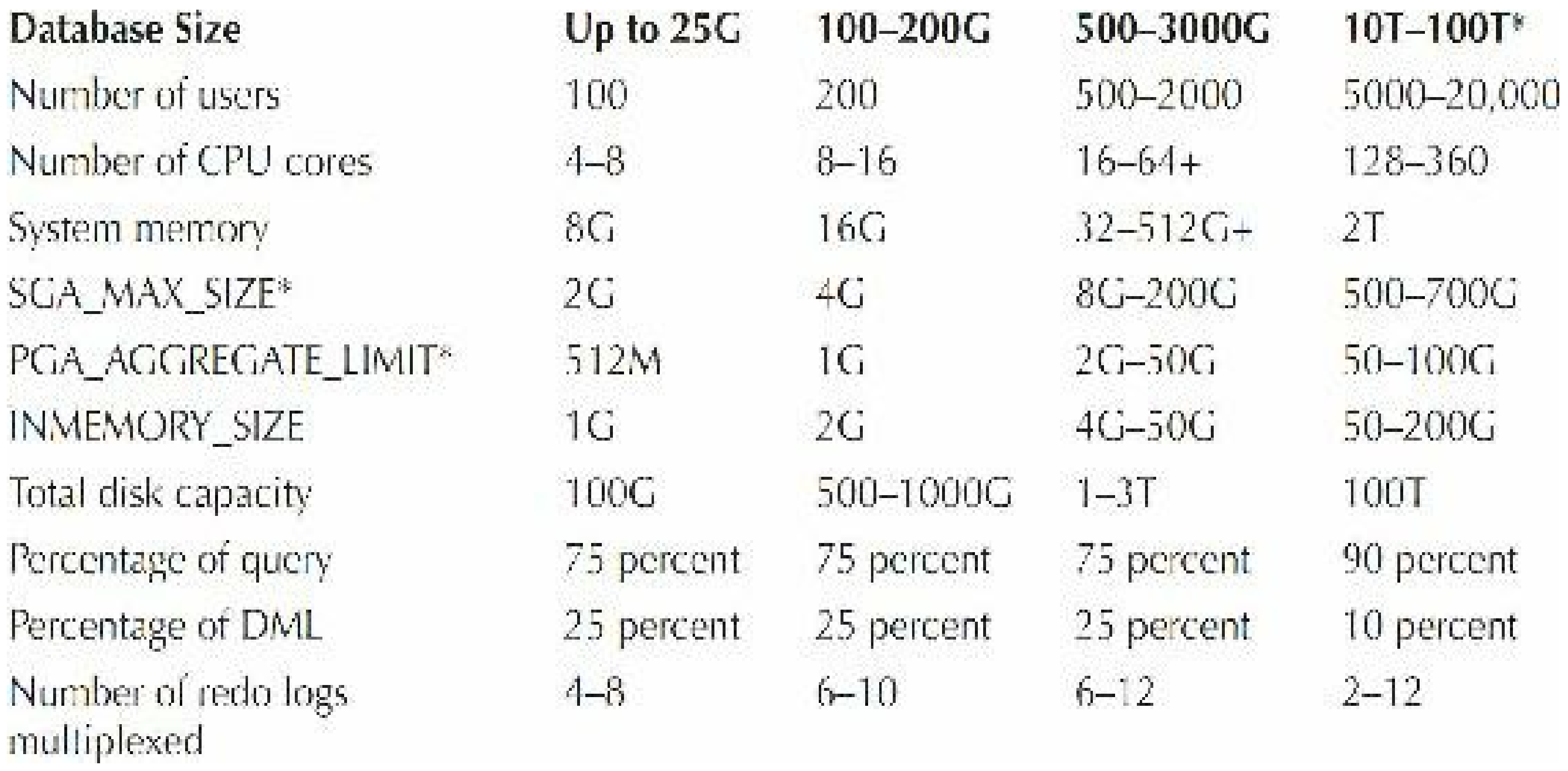
- With pluggable databases (PDBs) and the public cloud, Oracle can be consolidated and maintained at a single point. (Many databases with fewer DBAs managing the system looks like the corporate future.)
- Database maintenance is becoming more visual (all point-and-click maintenance as in Enterprise Manager). The V$ views are still your lowest-performance-cost access method, but Enterprise Manager is easier to use for more complex inquiries that may require multiple V$ views to get the same result.
- Hardware and CPUs continue to get faster, eliminating the CPU as a bottleneck. (I/O

limitations are solved with flash, DRAM, and correct design.)

- Object-oriented and Agile development is crucial to rapid system development.
- Graphics, big data, and image storage is leading to databases that are soon to become increasingly larger. Also, the fact that disk space and flash are getting less expensive has made businesses more willing to keep historical data.
- While Oracle has excelled in the software market, no hardware maker has kept up over the past decade. With the advent of Exadata, Oracle is getting us to exabyte databases faster than anticipated.

Modeling a Typical Server

This section contains very rough estimates designed as setup guidelines. However, it is important to emphasize that these are only guidelines and that the reality is that every system is different and must be tuned to meet that system's demands. (CPU speed depends on the type of processor, e.g., RISC or SPARC vs. Intel.) The following table does not include guidelines for Oracle Applications. Oracle Applications tends to have unique issues that are addressed by Oracle in the application documentation and on My Oracle Support.



Database Size	Up to 25G	100–200G	500–3000G	10T–100T*
Number of users	100	200	500–2000	5000–20,000
Number of CPU cores	4–8	8–16	16–64+	128–360
System memory	8G	16G	32–512G+	2T
SGA_MAX_SIZE*	2G	4G	8G–200G	500–700G
PGA_AGGREGATE_LIMIT*	512M	1G	2G–50G	50–100G
INMEMORY_SIZE	1G	2G	4G–50G	50–200G
Total disk capacity	100G	500–1000G	1–3T	100T
Percentage of query	75 percent	75 percent	75 percent	90 percent
Percentage of DML	25 percent	25 percent	25 percent	10 percent
Number of redo logs multiplexed	4–8	6–10	6–12	2–12

Number of control files	4	4	4	4
Percent batch	20 percent	20 percent	20 percent	50 percent
Percent online	80 percent	80 percent	80 percent	50 percent
Archiving used	Yes	Yes	Yes	Yes
Other system software (other than Oracle)	Minimum	Minimum	Minimum	Minimum
Use parallel query?	Depends on queries	Depends on queries	In many queries	In many queries

*These are not typical. I've seen as high as 1T– SGA with about 1000G devoted to data caches (multiple). I've also seen an approximately 500G SGA, broken into about 400G of data cache in multiple data caches of different block sizes (none >300G) as well as keep/recycle caches (__KSMG_GRANULE_SIZE of larger caches are anywhere from 50–250M). I've seen a 100G shared pool and as high as 50G PGA_AGGREGATE_TARGET as well. Large SGAs present many considerations, including watching out for the dreaded "ORA-00064: Object is too large to allocate on this O/S." Larger corporate SGAs are currently in the low Gigs to 10s of Gigs (500G+ is still very rare at this time, 2016). Most very large systems have multiple caches and block sizes.

The following variables can be reason to deviate from the typical server configuration:

- Heavy DML processing may require much larger ROLLBACK/UNDO, REDO, and TEMP tablespace sizes. Exadata best practice is a 32G logfile; you don't need as many at this size!
- Poorly tuned systems require more CPU and memory.
- A greater number of disks, cache on disks, and controllers always increase performance by reducing I/O contention.
- An increase in the disk capacity can speed backup and recovery time by going to disk and not tape. Faster tape speeds lower backup and recovery times as well. Oracle's purchase of Sun also netted them StorageTek.
- Using *all* flash changes everything. Leading-edge companies often have all flash!

Sizing the Oracle Applications Database

The Oracle Applications Development team wrote a note on My Oracle Support (Note 216205.1 for 11*i* and 396009.1 for Release 12) that shows the initialization parameters that should be used (or not used) with various versions of Oracle Applications. I always review the settings that the Oracle Applications Development team recommends, as they often are dealing with large systems and they've learned some nice tricks. The common database parameters suggested are listed in Appendix A and version-specific parameters follow that listing (note that many comments were removed for brevity; see the actual My Oracle Support note for full detail). For a given Oracle E-Business Suite (EBS) instance, always make sure that the init.ora parameters are set according to the My Oracle

Support document "Database Initialization Parameters for Oracle E-Business Suite Release 12" (Doc ID 396009.1). An EBS database instance has to adhere to these recommendations since they went through rigorous testing inside Oracle Labs' systems simulating various EBS data patterns/modules... etc. Of course, Oracle wrote the code for EBS and developed it, so they know better than anybody else how the application code would behave at certain points in time. The following table gives an example of how to size the memory of an EBS database.

Parameter Name	Development or Test Instance	11–100 Users	101–500 Users	501–1000 Users	1001–2000 Users
Processes	200	200	800	1200	2500
Sessions	400	400	1600	2400	5000
SGA_TARGET	1G	1G	2G	3G	14G
SHARED_POOL_SIZE (csp)	N/A	N/A	N/A	1800M	3000M
SHARED_POOL_RESERVED_SIZE (csp)	N/A	N/A	N/A	180M	300M
SHARED_POOL_SIZE (no csp)	400M	600M	800M	1000M	2000M
SHARED_POOL_RESERVED_SIZE (no csp)	40M	60M	80M	100M	100M
PGA_AGGREGATE_TARGET	1G	2G	4G	10G	20G
Total Memory Required	~2 G	~3 G	~6 G	~13 G	~34 G

The range of user counts provided in the table refers to active Oracle Applications users, not total or named users. For example, if you plan to support a maximum of 500 active Oracle Applications users, then you should use the sizing per the range 101–500 users. The parameter values provided in this document reflect a development/test instance configuration, and you should adjust the relevant parameters according to the Applications user counts (refer to the table).

On the other hand, EBS does allow all sorts of customizations to use the underlying Database features. So, any number of partitioning can be done for huge tables for a better performance with the approval of Oracle Support. The only caveat with having many customizations is to keep a tab on them for maintenance, patching, and future upgrades.

Let's assume that as part of the problem identification process, we have determined that the Auto Invoice Import concurrent program is running slower than normal. We have also eliminated user login issues (people are able to successfully log in to the EBS home page from multiple sites) and have verified other concurrent programs are finishing on time. That narrowed down the problem to a single concurrent request. By having the concurrent request ID, we can tie that to a specific database session

ID (SID) and serial number by running the following query (or by using any of the traditional methods like OEM, AWR, ASH reports, V$ views, etc.):

```
Set linesize 150
Set Pages 1000
Set head on
```

```
Column Manager   Format A10
Column Request   Format 999999
Column Program   Format A40
Column User_Name Format A10
Column Started   Format A18
Column Status    Format A6
Column Phase     Format A6

Prompt
prompt Request Information
prompt -------------------
prompt ;

Select /*+ RULE */
       --Concurrent_Queue_Name Manager,
Request_Id Request, User_name,
       --, Run_Alone_Flag,
Substr(User_Concurrent_Program_Name,1,40) Program,
To_Char(Actual_Start_Date, 'DD-MON-YY HH24:MI:SS') Started
,Decode(Fcr.Status_Code,'R','Normal',Fcr.Status_Code) Status
,Decode(Fcr.Phase_Code,'R','Normal',Fcr.Phase_Code)  Phase
fromFnd_Concurrent_QueuesFcq, Fnd_Concurrent_RequestsFcr,
Fnd_Concurrent_Programs_TlFcp, Fnd_User Fu, Fnd_Concurrent_ProcessesFpro
where
Phase_Code = 'R' And
Fcr.Controlling_Manager = Concurrent_Process_Id       And
      (Fcq.Concurrent_Queue_Id = Fpro.Concurrent_Queue_Id    And
Fcq.Application_Id      = Fpro.Queue_Application_Id ) And
      (Fcr.Concurrent_Program_Id = Fcp.Concurrent_Program_Id And
Fcr.Program_Application_Id = Fcp.Application_Id )     And
Fcr.Requested_By = User_Id                            And
Fcr.Request_Id = '&&Request_id'
;

Column Full_Name Forma A40
Prompt
Prompt Full name of the User running the program
Prompt -----------------------------------------
Prompt

Select /*+ RULE */
substr(Emp.Full_name,1,50) Full_Name
fromFnd_User Fu, Hr_EmployeesEmp
whereFu.Employee_Id  = Emp.Employee_Id  (+)
andFu.user_id =
( selectrequested_by
fromFnd_concurrent_Requests
whererequest_id = '&&Request_id' )
;
```

```
Set Pages 1000
Set head on
Column Sid          Format    999999
Column SerialNo  Format    999999
Column UserName  Format A10
Column Program   Format A30
Column OSUser    Format A10
Column Status    Format A8
Column Type      Format A10
Column Backgrnd  Format A8
Column LogonTime Format A18

prompt
prompt Oracle (v$session) information for this request ;
Prompt -------------------------------------------------------
prompt ;
selecta.sid Sid, a.serial# SerialNo, substr(a.username,1,10) UserName,
substr(a.program,1,30) Program,
substr(a.osuser,1,10) OSUser, b.pidOSProcess,a.status Status, a.type Type,
b.backgroundBackgrnd,
to_char(a.logon_time,'DD-MON-YY HH24:MI:SS') LogonTime
fromv$session a, v$process b
where  a.paddr = b.addr and
b.spid = (
select ORACLE_PROCESS_ID
fromfnd_concurrent_requests
whererequest_id = '&&Request_id')
;

Prompt
Prompt Oracle Process Id and Application Process Id for this given request
Prompt ==================================================================
Prompt

Column ORACLE_PROCESS_ID Format A30
Column APPLICATION_PROCESS_ID Format A30
selectsubstr(ORACLE_PROCESS_ID,1,30) ORACLE_PROCESS_ID, substr(OS_PROCESS_
ID,1,30)  APPLICATION_PROCESS_ID
fromfnd_concurrent_requests
whererequest_id = '&&Request_id'
;

prompt
prompt Oracle SQL run by this request currently is ;
Prompt ===============================================
prompt ;
selecta.sql_text
fromv$sqltext_with_newlines a, v$session b
wherea.address = b.sql_address and
a.hash_value = b.sql_hash_value and
       b.sid = (select a.sid
fromv$session a, v$process b
where  a.paddr = b.addr and
b.spid = (
select ORACLE_PROCESS_ID
fromfnd_concurrent_requests
where request_id = '&&Request_id'))
;
```

Once a specific database session is identified, we can drill down further by collecting a runtime EXPLAIN PLAN and looking at various wait events that are associated with a particular SQL query that's being executed in the database. We can also run the SQLT tracing/diagnostic tools as described in the My Oracle Support Note "All About the SQLT Diagnostic Tool" (Doc ID 215187.1). After identifying and looking at the SQL Plans and and the raw tkprof/trace files, we can go through all the tables/indexes that are in question and verify when the database statistics were last collected for these tables/indexes that are involved in the query. For all the seeded queries, do a general search on the short name of the program at the MOS website. You might be running into an already known issue and there could be a performance fix patch available. If not, open up a service request (SR) with Oracle Support asking for a code fix. In most cases, Oracle Support will have you collect most of the diagnostic data discussed here and upload the raw tkprof/trace files to the SR.

For custom DML statements/complex select queries, EBS does allow you to create custom indexes, histograms, etc. We can also use the SQL Performance Analyzer or SQL Plan Management features to make certain we have good plans as "Accepted" and "Fixed" plans, so that the optimizer will always choose those plans irrespective of what the optimizer engine says about the current data, as long as there were no DDL changes in the underlying objects of a query. This can be done using Oracle Enterprise Manager (OEM) or SQL*Plus commands. Please refer to the SQL Plan Management chapter (Chapter 8) in this book for more detailed information.

For more generic, database-wide slow response times, we can make use of all of the tips and techniques discussed in the other chapters of this book and troubleshoot further. For example, running the AWR report during a problem window, running an ASH report, or running an ADDM report for a specific problem window will all help narrow down the problem. Please refer to Chapter 14 for further information on AWR, ASH, ADDM, and OEM monitoring.

At a high level, make sure that the Gather Schema Stats concurrent program is scheduled to run at a frequent interval. Schedule this program to run once a week for *all* the schemas with a 20 percent or 30 percent estimate, and leave all the other parameters to their defaults for stable performance in the database. Module-specific or tables/indexes-specific versions of this program can be run depending on the need and just after any major custom concurrent program, data load programs, or DML statements that might skew the data pattern in the database.

Run daily reports to find the object lists based on the *last_modified* time stamp and created columns from DBA_OBJECTS for the last 24 hours. The idea is to identify any objects at the database level that were created/modified and are being accounted/reconciled against the internal change request system. Often, unaccounted, unapproved, and untested code changes prove to harm the stability of the production systems. Run a daily report to identify the list of users and responsibilities for which the debug/trace profile options are turned on. Turn them off if they are no longer needed. Ideally, the production environment should not have any trace or debugs enabled unless a specific issue is being worked on. Unnecessary trace/debugs would put pressure and overhead on the database and filesystem space and also cause a poor response time for the EBS from an end-user perspective.

Look for orphaned M$LOG tables with a large number of rows in the database. If the volume keeps growing over a period of time, then it is an indication of an orphaned materialized view (MV). Materialized views are based on a trigger logic and, depending on the complete or full refresh and the way in which the MVs are maintained (or not maintained), the M$LOG table would tend to grow. In a normal scenario during a complete or fast refresh or at the end of the refresh, the underlying M$LOG table would get deleted in the source for the already updated rows in the target. When this process is broken, the trigger on the source table is on and it will make the M$LOG grow exponentially, using large amounts of database low-level resources such as enqueues and latches. This could put enormous overhead on the database and eventually on the applications. Additional Oracle Applications notes are at the end of Appendix A.

Tips Review

- The key initialization parameters in Oracle are MEMORY_TARGET, MEMORY_MAX_TARGET, SGA_TARGET, SGA_MAX_SIZE, PGA_AGGREGATE_TARGET, PGA_AGGREGATE_LIMIT, DB_CACHE_SIZE, SHARED_POOL_SIZE, and INMEMORY_SIZE. If you use ASMM, then SGA_TARGET is also a key initialization parameter.
- Setting INMEMORY_SIZE can lead to unbelievably fast analytics, but only set this parameter when properly licensed for this option. Active Data Guard can also use the In-Memory column store, and there are also In-Memory virtual columns allowed.
- If you use the ALTER SYSTEM commands to write to the SPFILE only, and then on startup realize you have set them incorrectly, the database will not start, and you cannot use an ALTER SYSTEM command to fix the problem. You can, however, create a PFILE from the SPFILE, modify the PFILE, and then use that to start the database. Afterward you need to create the SPFILE again and restart the database with the SPFILE.
- If you can't figure out why your system isn't using the value in your init.ora file, you probably have an SPFILE overriding it. And don't forget, you can also use a hint to override parameters at the query level in 12*c*. Different PDBs (pluggable databases) can have some parameters set at the PDB level.
- Changing initialization parameters dynamically is a powerful feature for both developers and DBAs. Consequently, a user with the ALTER SESSION privilege is capable of irresponsibly allocating 100M+ for the SORT_AREA_SIZE for a given session, if it is not restricted.
- Retrieving data from physical memory is generally substantially faster than retrieving it from disk, so make sure the SGA and PGA are large enough. One Oracle study showed Oracle memory access as averaging about 100 times faster than disk access. However, this takes into account disk-caching advances and flash, which you may or may not have on your system. The same study also showed an individual case where Oracle memory access was well over 10,000 times faster than disk (which was hard for me to believe), but it shows how important it is to measure this on your own unique system.

- Poor joins and poor indexing also yield very high hit ratios, so make sure your hit ratio isn't high for a reason other than a well-tuned system. An unusually high hit ratio may indicate the introduction of code that is poorly indexed or includes join issues.
- Hit ratios are useful to experienced DBAs but can be misleading or of little use to inexperienced DBAs. The best use of hit ratios is still to compare them over time (a barometer) to help alert you to a substantial change to a system on a given day. While some people have deprecated hit ratios from their tuning arsenal, they are usually tool vendors who don't see the value of tracking hit ratios over time because their tools are point-in-time or reactive-based tuning solutions. Hit ratios should never be your only tool, but they should definitely be one of many proactive tools in your arsenal (especially with the advent of the invisible index).
- In Oracle 12*c* Release 2, use Enterprise Manager Cloud Control to find problem queries.
- A low hit ratio for a query could be an indication of a missing, invisible, or suppressed index.
- Bad (slow) queries show in V$SQLAREA or V$SESSION_LONGOPS (under certain conditions) views with poor hit ratios the first time they are executed. You can also use Enterprise Manager to see statistical information. Make sure you tune them at that time. The second time that they execute, they may not show a poor hit ratio (may be in memory). Flushing the buffer cache for testing can help you get accurate results.
- The database must be rebuilt if you change the DB_BLOCK_SIZE. Increasing the DB_FILE_MULTIBLOCK_READ_COUNT allows more block reads in a single I/O, giving a benefit similar to a larger block size. In 12*c*, the default is 128, so it may not need to be changed.
- The SGA_MAX_SIZE determines the granule size for other parameters. An SGA_MAX_SIZE < 1G means a 4M granule size, whereas an SGA_MAX_SIZE >= 256G means a 512M granule size. Some benchmarks have the granule size as high as 256M.
- SQL must be written *exactly* the same to be reused. Case differences and any other differences will cause a reparse of the statement unless you use CURSOR_SHARING.
- Measure hit ratios for the row cache (data dictionary cache) of the shared pool with the V$ROWCACHE view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios will be around 85 percent.
- Measure hit ratios for the library cache of the shared pool with the V$LIBRARYCACHE view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios are around 85 percent.
- The V$SGASTAT view shows how fast the memory in the shared pool is being depleted. Remember that it is only a rough estimate. It shows you any memory that has never been used combined with any piece of memory that has been reused. Free memory will go up and down as the day goes on, depending on how the pieces are fragmented.
- The *general* rule of thumb (exact sizing depends on your unique systems) is to make the SHARED_POOL_SIZE parameter 50–150+ percent of the size of your DB_CACHE_SIZE. In a system that makes use of a large amount of stored procedures or Oracle supplied packages,

but has limited physical memory, this parameter could make up as much as 150+ percent of the size of DB_CACHE_SIZE. In a system that uses no stored procedures, but has a large amount of physical memory to allocate to DB_CACHE_SIZE, this parameter may be 10–20 percent of the size of DB_CACHE_SIZE. I have worked on larger systems where the DB_CACHE_SIZE was set as high as 10s of Gigs. I'm sure that 100s of Gigs to Terabyte SGAs already exist. Petabyte databases are currently starting to make their entry. Note that in a shared server configuration (previously known as MTS), items from the PGA are allocated from the shared pool rather than the session process space.

- The additional buffer pools (memory for data) available in Oracle are initially set to zero. You should not need to set them initially, but you may need to for your unique system.
- The optimizer in Oracle 12*c* Release 2 uses cost-based optimization regardless of whether the tables have been analyzed or not. CHOOSE and RULE are obsolete and unsupported settings for OPTIMIZER_MODE, yet they are still allowed; ALL_ROWS is the default.
- There is no OPTIMIZER MODE called COST (a misconception). If you are using Oracle Database 9*i* Release 2 or an earlier version and are not sure what optimizer mode to use, then use CHOOSE or FIRST_ROWS and analyze all tables. As the data in a table changes, tables need to be reanalyzed at regular intervals. In Oracle 12*c* Release 2, the main OPTIMIZER_MODEs to use are ALL_ROWS and FIRST_ROWS (ALL_ROWS is the default).
- Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly before implementing those changes in a production environment.
- Using undocumented initialization parameters can cause corruption. Never use these if you are not an expert and you are not directed by Oracle Support! Ensure that you work with Oracle Support before setting these parameters.

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Performance Tuning Guide (Oracle Corporation).
Craig Shallahamer, "All About Oracle's Touch-Count Data Block Buffer Algorithm" (OraPub, excellent!).
Murali Vallath "Using Oracle Database 11*g* Release 2 Result Cache in an Oracle RAC Environment," www.oracle.com/technetwork/articles/datawarehouse/vallath-resultcache-rac-284280.html.

Thanks to Mike Messina, who did the primary update for the chapter to 12*c*, and Palani Kasi, who provided the Oracle Applications section update at the end. Thanks to Randy Swanson, who did the update for this chapter in the 9*i* version of the book (where were you this time around?). Thanks to Lucas Niemiec for finding the scripts that show Oracle's installation settings. Thanks to Binu Joy, who provided some great installation notes and SAP parameters for this chapter and Appendix A.

CHAPTER
5

Tuning with Enterprise Manager Cloud Control (DBA and Developer)

Oracle Enterprise Manager Cloud Control finally matches or exceeds the market's answer to monitoring and tuning the Oracle database. Oracle has usually been behind the market with okay-to-good products over the years. No longer is this the case; Oracle has stepped up to the plate and delivered one of the best products ever (including support for Exadata and the cloud). This chapter provides a quick tour of why Oracle Enterprise Manager Cloud Control (called both OEM or EM) is now at the next level. The tour neither explores the entire product nor teaches you how to use all of the features (that would take an entire book). Rather, this chapter exposes you to some of the tools and tuning features that you will find helpful in your tuning endeavors. With Oracle's focus on the grid since Oracle 10*g* and continuing into 11*g*, many screenshots show multiple instances so you can see either a single-instance or multi-instance cluster with the product. The grid of servers can now be in the cloud or on-premises and also can be RAC or non-RAC (especially with 12*c* sharding). With multitenant databases in 12*c*, OEM also shows all pluggable databases (PDBs) with drill-down screens. OEM is an excellent tuning tool for all levels of DBAs and is especially valuable as you head into the growing decade of the cloud.

One way to ensure great performance for your system is to monitor your system for potential performance issues before they become major problems. One vehicle that provides a graphical user interface (GUI) for tuning is OEM, along with related performance-tuning add-on products (which are an added cost). The OEM product suite continues to change over time, but this particular version has taken a giant leap forward with its support for both on-premises and cloud databases. With the statistics from the Automatic Workload Repository (AWR), this tool is now tremendously powerful. AWR snapshots are taken every hour by default, and once the AWR snapshot is taken, the Automatic Database Diagnostic Monitor (ADDM) analysis occurs immediately (STATISTICS_LEVEL must be set to TYPICAL or ALL) via the MMON background process. The results of ADDM are also stored in the AWR and accessible via OEM. All of these streamline managing both on-premises and cloud databases.

In addition to monitoring, spectacular screens will show you where a problem is occurring, down to the "latch wait" or "global cache cr transfer wait." The tools for running the AWR Report (covered in detail in Chapter 14) are included, as are tools to change the `spfile.ora` or `init.ora` file. The tools for monitoring a group of servers are equally spectacular (yes, they are that good). Screens showing performance on every instance and piece of hardware (each in a different color) allow you to click the graph to branch to an individual instance or look at a particular piece of hardware. You can delve into performance at the database, host, application server, network, or disk (ASM or non-ASM) level. Of all the Oracle products I have seen hit a home run over time, this one hit a grand slam with the Oracle OEM Cloud Control release.

Oracle Enterprise Manager standard applications include a central management console and additional packs, and many products (like Diagnostics Pack) have an additional cost (please check with Oracle for any price implications for different modules/packs). Accessing the AWR requires the Diagnostics Pack, and running SQL Tuning Sets requires the Tuning Pack. You can use ADDM to see what Oracle advises after an hour of gathering statistics to AWR. You can use the SQL Tuning Advisor for tuning a specific SQL statement or set of statements (you can also run this from the Top Activity screen). Use the SQL Performance Analyzer to tune statements in a Guided Workflow, which shows the before and after tuning results for a set of SQL statements. You can compare an Oracle version's effect on SQL statements; for instance, you can compare a tuning set from one version to another, and you can even look at the before and after comparison of initialization parameter changes. Finally, you can even perform an Exadata simulation and run an AWR Report or Active Session History (ASH, or *mini-AWR*) report from OEM.

The following tips are covered in this chapter:

- Enterprise Manager basics and accessing OEM via Oracle Cloud Services
- Monitoring policies and alerts
- Monitoring the database
- Evaluating potential changes with SQL Performance Analyzer
- Tuning the Oracle database using OEM's ADDM
- Monitoring and tuning via the OEM menus
- Viewing the Oracle topology
- Monitoring and tuning the hosts
- Monitoring and tuning application servers and web applications (using APM)
- Viewing and scheduling jobs
- Accessing available reports, including the ASH and AWR Reports
- Real Application Testing (Database Replay)

Oracle Enterprise Manager Basics and Accessing OEM via Oracle Cloud

Once OEM is installed, the login screen (shown in Figure 5-1) is displayed. Depending on how security is set up, you may need to enter the username, password, or database information at login screens, depending on which screens are accessed within the product. Once installed, you can log in, but if you don't, you will need the remember this URL (I suggest bookmarking this URL).

FIGURE 5-1. *Oracle Enterprise Manager Cloud Control 12c login screen*

Shortly after logging in to OEM, you will be in the main screen showing enterprise-level architecture and actions. Figure 5-2 shows the Enterprise tab with options for monitoring, reporting, configuring, as well as provisioning and patching. The Inventory and Usage information on the right side of the screen shows different servers in the architecture. With this version of OEM, you can monitor systems that are both on-premises and in the cloud. Shortly, we'll go into the Enterprise Summary choice on the Enterprise menu to do some performance tuning on some of the databases there, but first let's look at some of the basics included in the product.

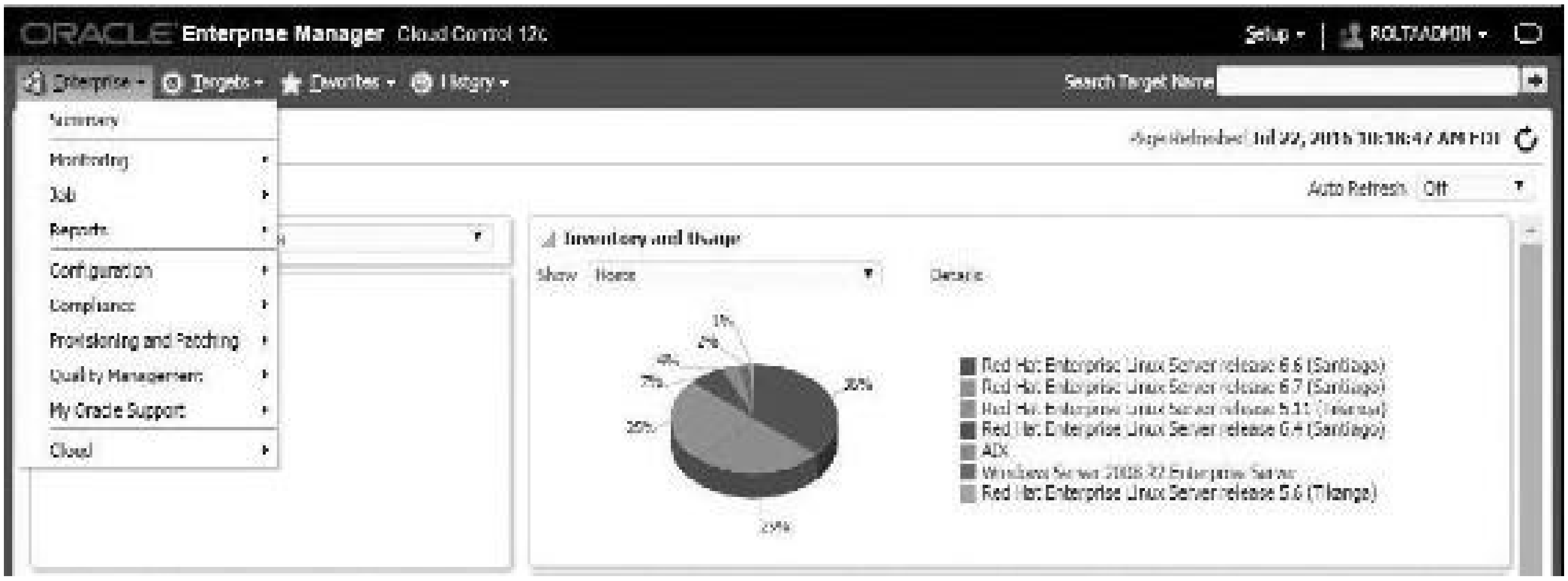
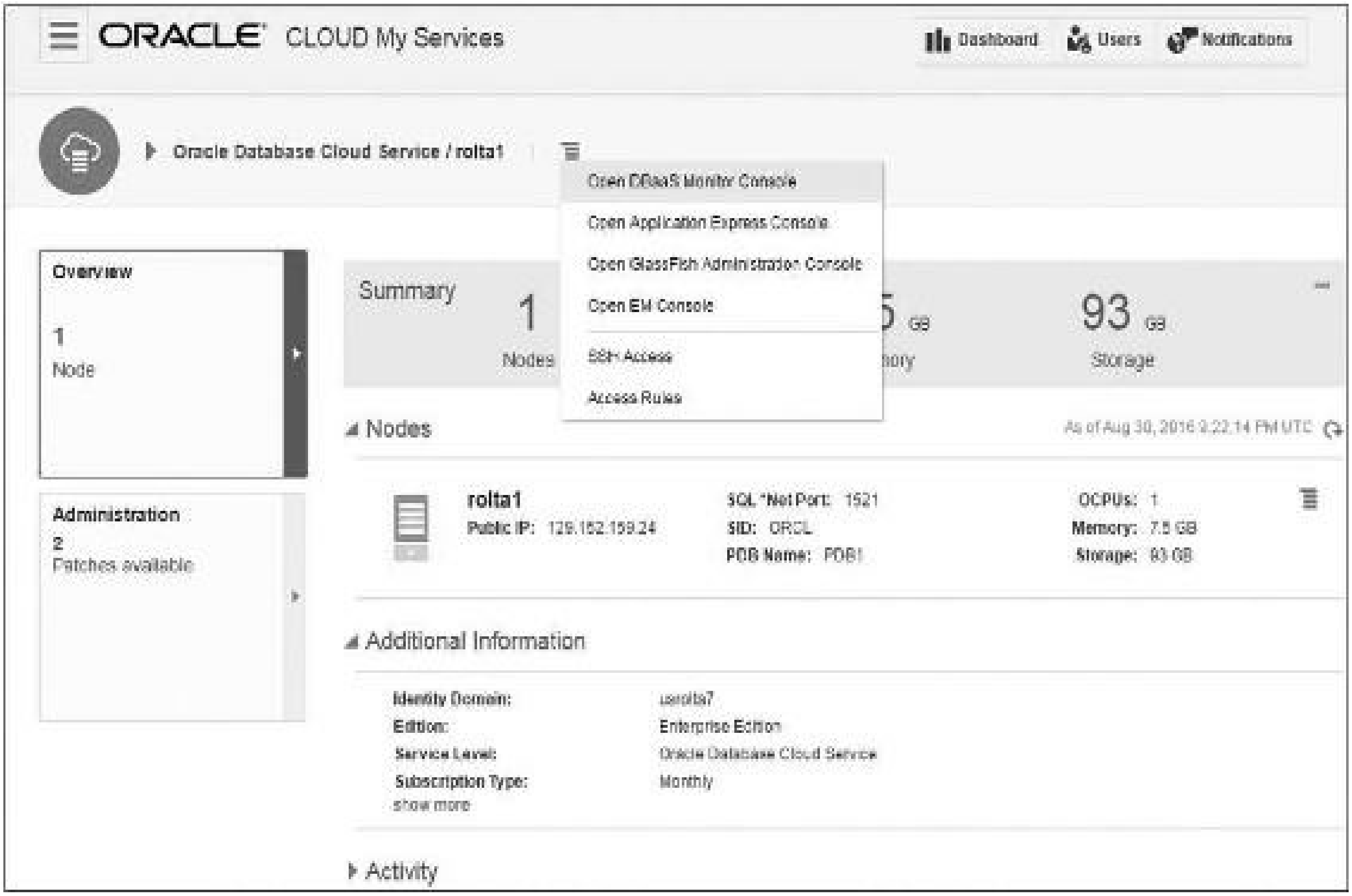

ORACLE Enterprise Manager Cloud Control 12c
Setup
ROLTAADMIN
Enterprise
Targets
Favorites
History
Search Target Name
Summary
Monitoring
Job
Reports
Configuration
Compliance
Provisioning and Patching
Quality Management
My Oracle Support
Cloud
Page Refreshed Jul 22, 2015 10:38:47 AM EDT
Auto Refresh Off
Inventory and Usage
Show Hosts
Details
1%
2%
4%
7%
25%
30%
25%
Red Hat Enterprise Linux Server release 6.6 (Santiago)
Red Hat Enterprise Linux Server release 6.7 (Santiago)
Red Hat Enterprise Linux Server release 5.11 (Tikanga)
Red Hat Enterprise Linux Server release 6.4 (Santiago)
AIX
Windows Server 2008 R2 Enterprise Server
Red Hat Enterprise Linux Server release 5.6 (Tikanga)

FIGURE 5-2. *OEM Enterprise-level screen and the Enterprise drop-down menu*

If you set up the cloud separately, you can either use the main version of OEM to monitor the cloud service directly, or you can use a cloud-only OEM Express version that comes with the cloud service. Figure 5-3 shows the menu from which to access the 12*c* OEM Console from a cloud service (rolta1 in this example) and gives a feel for how the OEM Express screen looks. Oracle Cloud My Services has a pull-down list from your cloud service that allows you to open the OEM Express console. All of the OEM screens in the cloud are the same or similar to those on-premises (although OEM Express is a cloud-only lighter version). The rest of the examples in the chapter will show the OEM screens from on-premises (see Chapter 11 for more on the Oracle Cloud).



1 Node

2 Patches available

1 Nodes · 5 GB Memory · 93 GB Storage

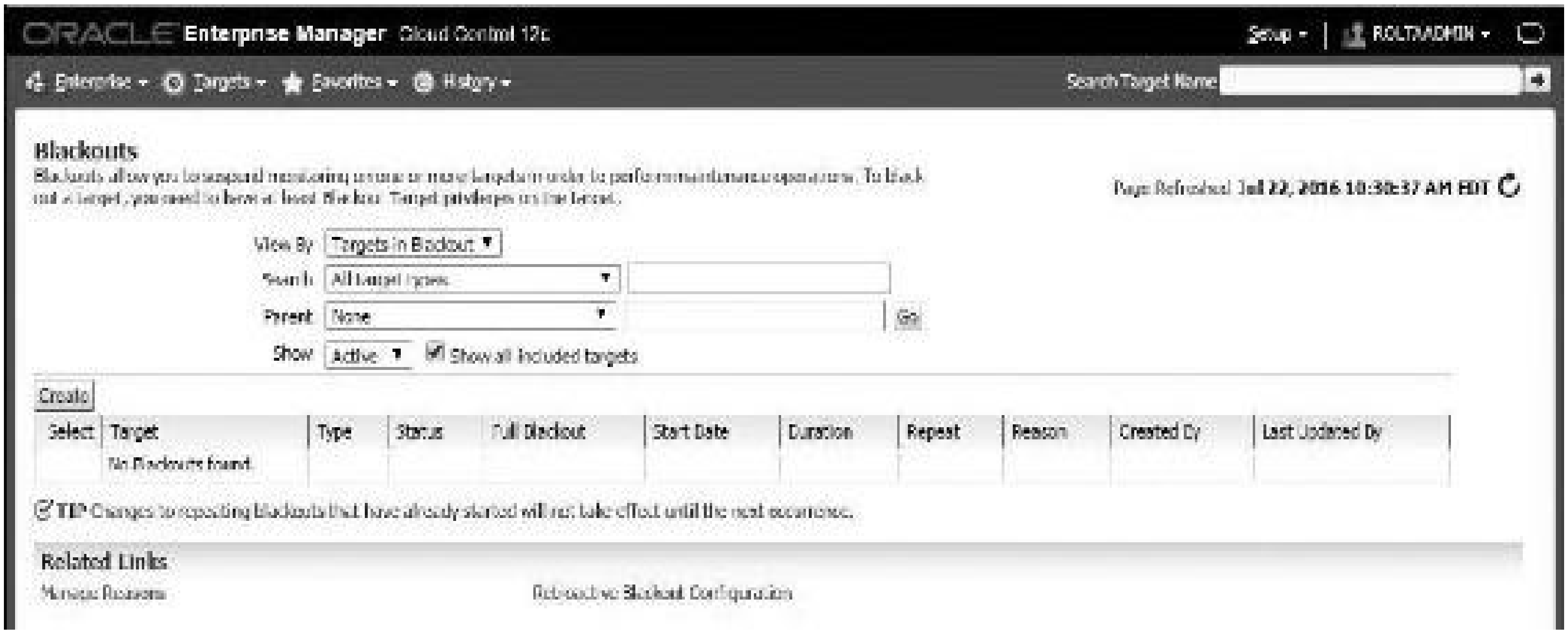
As of Aug 30, 2016 3:22:14 PM UTC

rolta1
Public IP: 129.152.159.24
SQL*Net Port: 1521
SID: ORCL
PDB Name: PDB1
OCPUs: 1
Memory: 7.5 GB
Storage: 93 GB

Identity Domain: usrolta7
Edition: Enterprise Edition
Service Level: Oracle Database Cloud Service
Subscription Type: Monthly

FIGURE 5-3. *Oracle Cloud My Services pull-down menu to open the OEM Express Console*

As shown in Figure 5-2, some of the available setup options on the Enterprise menu include Monitoring, Configuration, Provisioning and Patching, and access to various tools and other configuration items. For example, if you choose Enterprise | Monitoring | Blackouts, you'll see the screen shown in Figure 5-4. *Blackouts* are periods of time that allow the system to suspend monitoring for the performance of maintenance activities. This eliminates the skewing of the data during normal operating hours. Even though statistics gathering is suspended, the period is still recorded to ensure too many blackouts aren't scheduled by a DBA.


ORACLE Enterprise Manager Cloud Control 12c

Setup ▾ | ROLTAADMIN ▾

Enterprise ▾ Targets ▾ Favorites ▾ History ▾ Search Target Name

Blackouts

Blackouts allow you to suspend monitoring on one or more targets in order to perform maintenance operations. To black out a target, you need to have at least Blackout Target privileges on the target.

Page Refreshed Jul 22, 2016 10:30:37 AM EDT

View By: Targets in Blackout

Search: All target types

Parent: None

Show: Active ☑ Show all included targets

Create

Select	Target	Type	Status	Full Blackout	Start Date	Duration	Repeat	Reason	Created By	Last Updated By
	No Blackouts found.									

TIP Changes to repeating blackouts that have already started will not take effect until the next occurrence.

Related Links

Manage Reasons   Retroactive Blackout Configuration

FIGURE 5-4. *Setup and configuration for blackouts*

After familiarizing themselves with OEM, DBAs should set up the preferences that are deemed best for the environment being monitored. At any time while using the product, you can click Setup (the setup options tab is located at the upper-right hand of the Figure 5-2 screen) to see all the preference options, as displayed in Figure 5-5 (in this case I chose the Provisioning and Patching option from the Setup tab). Several preferences should be set, including the e-mail addresses for sending various alerts or messages as well as notification rules. You can even change the tabs to be exactly what seems most intuitive for the environment. It is best to stay within the Oracle standard configuration, however, so another DBA can easily follow what's been done. Spend some time investigating all of the nice links from the Setup tab.

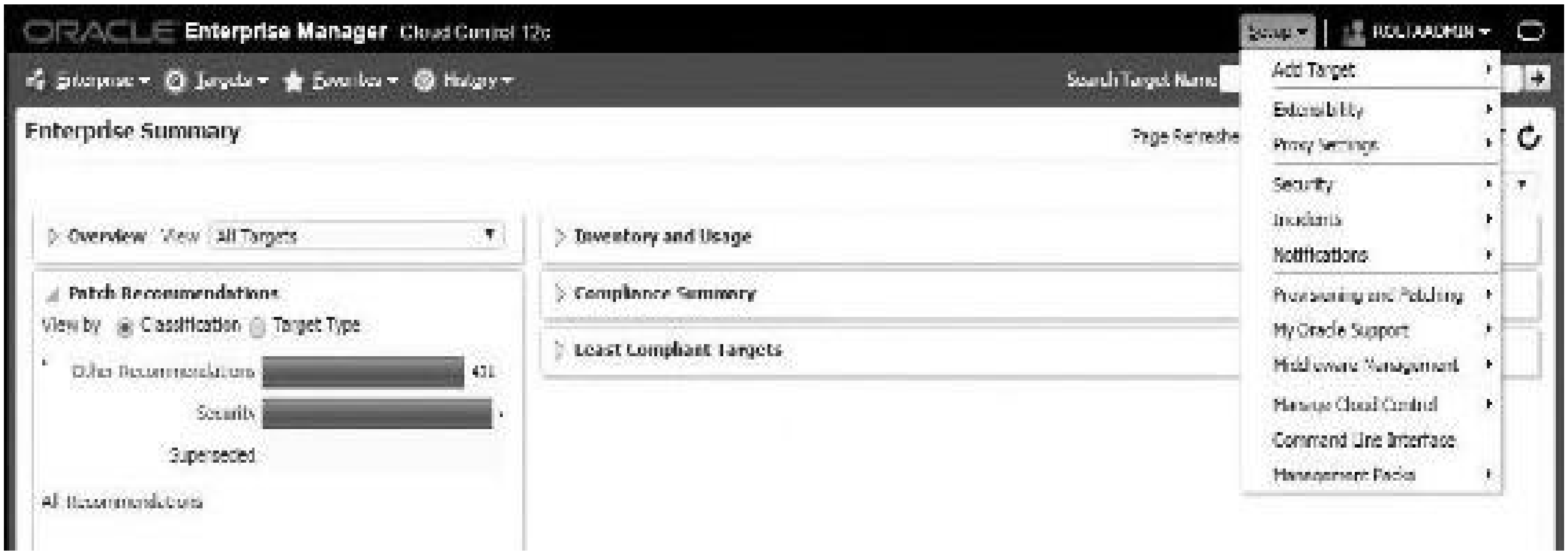
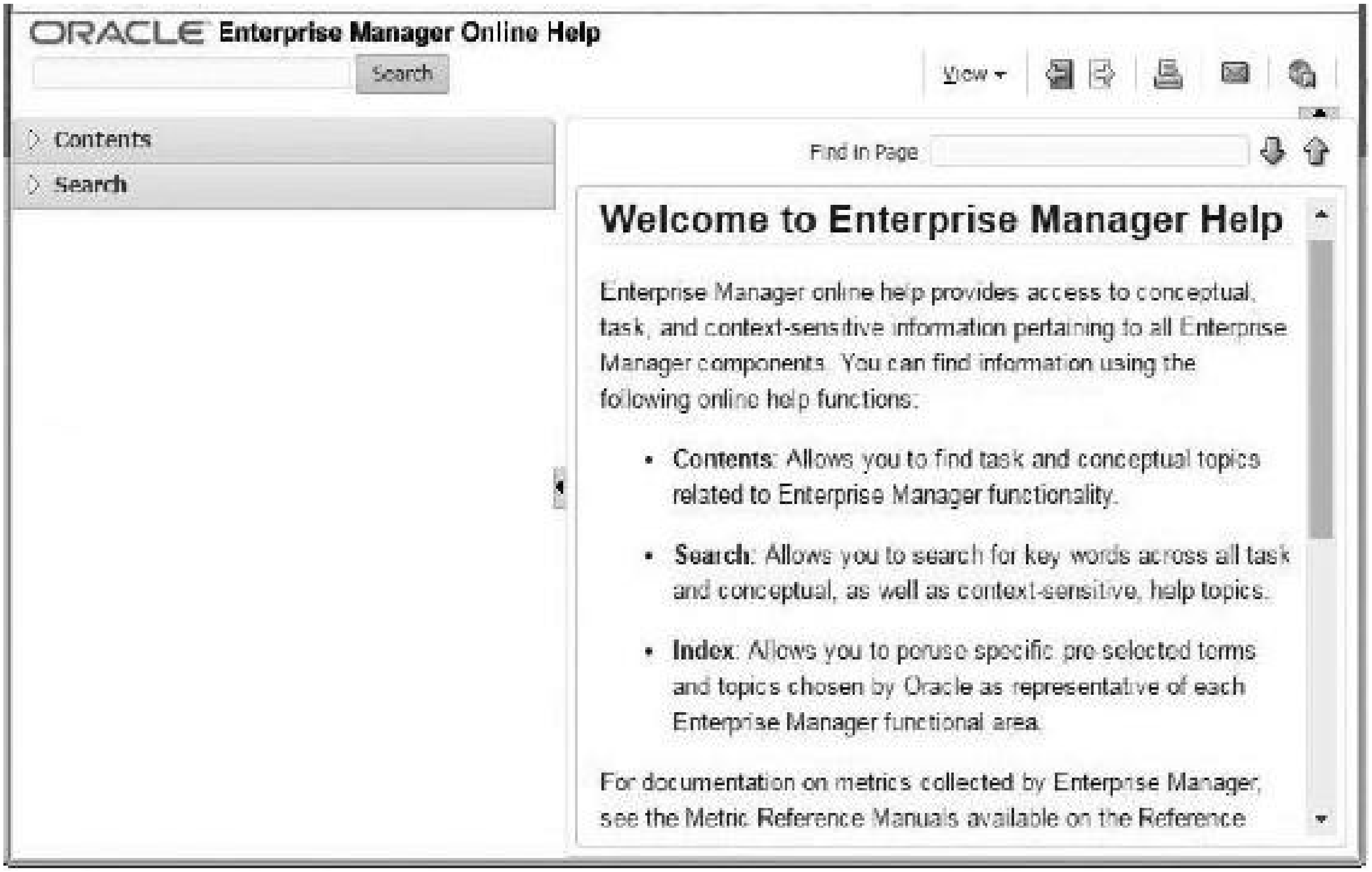


FIGURE 5-5. *Setting preferences – Patch Recommendations*

One of the best parts of OEM is the great online help that is provided (Figure 5-6). No matter where you are, you can always access the Help option from the drop-down menu of your username (located in the upper-right of the screen; my username is ROLTAADMIN, as shown in Figure 5-5). You can then search for either a very general area like “monitoring database performance” or something very specific like “setting e-mail address.” Substantial help is included in the product on how to tune the various areas of Oracle at the host, database, application server, ASM, OS, or network levels. Also, an interesting feature is the Oracle Database 2 Day series of books that are incorporated into the OEM help. You can browse through *2 Day DBA* within OEM, for example. The key is to take advantage of these resources and learn something every time you access OEM.



Welcome to Enterprise Manager Help

Enterprise Manager online help provides access to conceptual, task, and context-sensitive information pertaining to all Enterprise Manager components. You can find information using the following online help functions:

- **Contents**: Allows you to find task and conceptual topics related to Enterprise Manager functionality.
- **Search**: Allows you to search for key words across all task and conceptual, as well as context-sensitive, help topics.
- **Index**: Allows you to peruse specific pre-selected terms and topics chosen by Oracle as representative of each Enterprise Manager functional area.

For documentation on metrics collected by Enterprise Manager, see the Metric Reference Manuals available on the Reference

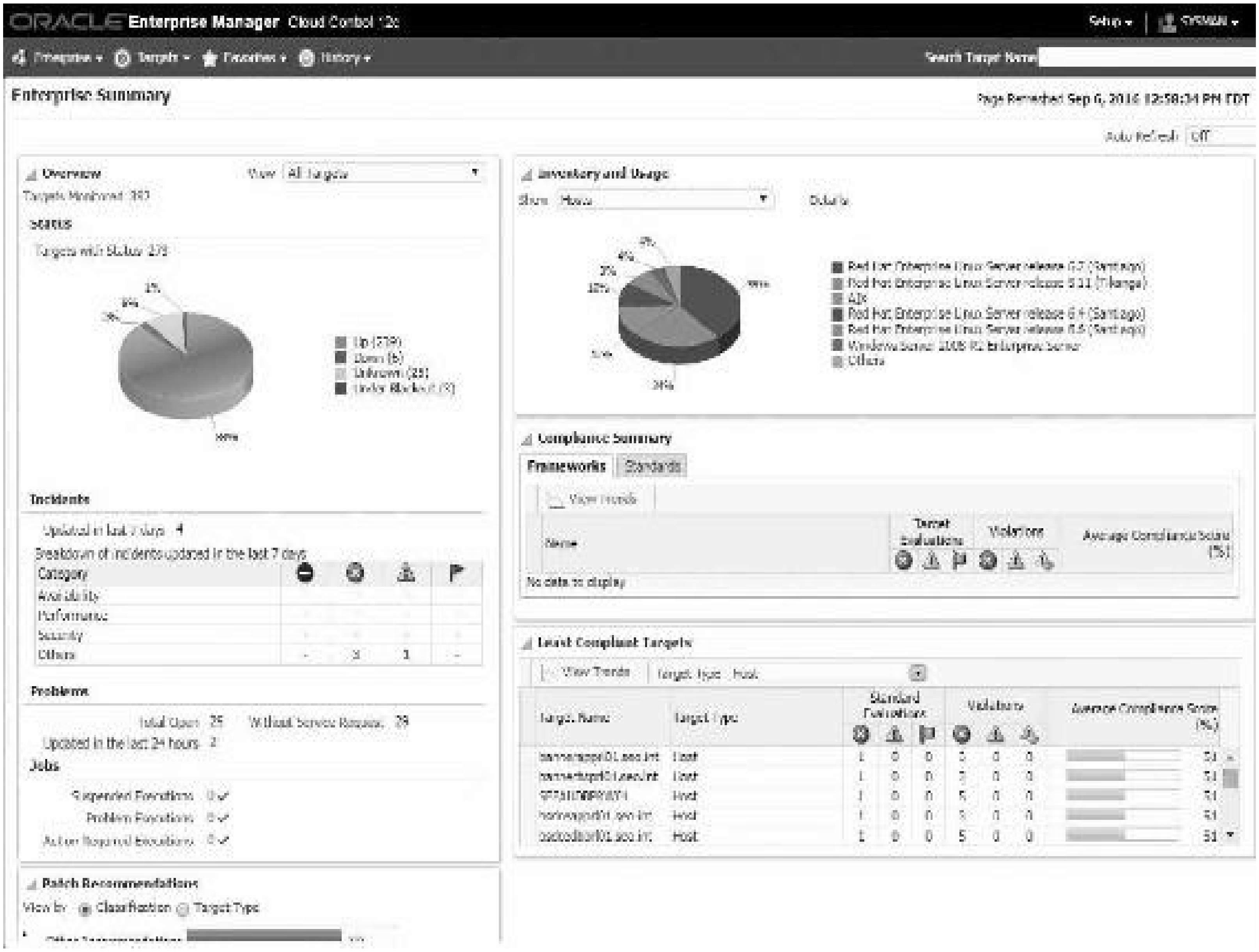
FIGURE 5-6. *Enterprise Manager Online Help window*

TIP
In Oracle Enterprise Manager 12c, the online help is spectacular. Learn something every day by reading or searching for topics in the new Enterprise Manager Online Help window.

Starting with All Targets and Other Groupings

The Enterprise Summary is the first option displayed after logging into OEM and clicking the

Enterprise tab pull-down in Figure 5-2. The Enterprise Summary window is then displayed with five panes: Overview, Patch Recommendations, Inventory and Usage, Compliance Summary, and Least Compliant Targets. Figure 5-7 shows that the Overview pane is open to the All Targets view with 273 targets being currently monitored. In the Status section, green indicates targets are up, red indicates targets are down, yellow indicates targets with an unknown status, and black indicates targets under blackout. The Overview pane also reports incidents, problems, and jobs. The Inventory and Usage pane shows all hosts that are being monitored. By viewing these two panes, you will immediately know whether instances are up or down, the status of jobs that were executed, and the ability to drill deeper to get the details of given server or database instance or cluster database. This window is the one that I want to see first thing in the morning so I know that everything being monitored is up and running efficiently. It also has a Patch Recommendations section to make you aware of available patches, and Compliance Summary and Least Compliant Targets sections to identify security policy violations and targets that need special attention. With OEM 12*c*, a nice feature is the ability to group common areas together. For instance, you can group all databases together into a group called PROD_DB so the group can be monitored together to see if they are all running. The same can be done for development databases (call them DEV_DB). A DBA usually configures things so the PROD_DB group is more proactive in sending alerts, pages, or e-mails than the DEV_DB group.


ORACLE Enterprise Manager Cloud Control 12c
Setup
SYSMAN
Enterprise
Targets
Favorites
History
Search Target Name
Up (279)
Down (6)
Unknown (23)
Under Blackout (3)
Red Hat Enterprise Linux Server release 6.7 (Santiago)
Red Hat Enterprise Linux Server release 5.11 (Tikanga)
AIX
Red Hat Enterprise Linux Server release 6.4 (Santiago)
Red Hat Enterprise Linux Server release 6.6 (Santiago)
Windows Server 2008 R2 Enterprise Server
Others

Enterprise Summary

Page Refreshed Sep 6, 2016 12:58:34 PM EDT

Auto Refresh: Off

Overview   View: All Targets

Targets Monitored: 282

Status

Targets with Status 273

Incidents

Updated in last 7 days: 4

Breakdown of incidents updated in the last 7 days

Category	⊖	⊗	⚠	⚑
Availability	-	-	-	-
Performance	-	-	-	-
Security	-	-	-	-
Others	-	3	1	-

Problems

Total Open: 25   Without Service Request: 29

Updated in the last 24 hours: 2

Jobs

Suspended Executions: 0 ✓

Problem Executions: 0 ✓

Action Required Executions: 0 ✓

Patch Recommendations

View by: (● Classification) ○ Target Type

Inventory and Usage

Show: Hosts   Details

Compliance Summary

Frameworks | Standards

View Trends

Name	Target Evaluations ⊗	⚠	⚑	Violations ⊗	⚠	⚠	Average Compliance Score (%)
No data to display							

Least Compliant Targets

View Trends   Target Type: Host

Target Name	Target Type	Standard Evaluations ⊗	⚠	⚑	Violations ⊗	⚠	⚠	Average Compliance Score (%)
[illegible]	Host	1	0	0	5	0	0	51
[illegible]	Host	1	0	0	5	0	0	51
[illegible]	Host	1	0	0	5	0	0	51
[illegible]	Host	1	0	0	5	0	0	51
[illegible]	Host	1	0	0	5	0	0	51

FIGURE 5-7. *OEM Enterprise Summary window in OEM 12c*

While I used OEM 12*c* as the main focus of this chapter, I also include coverage of new products such as Application Performance Monitoring (APM). OEM 13*c*, while recently available, doesn't support Linux prior to Release 6, and the overall screens and flow are very similar to those in 12*c* (I stuck with what most people will be using to support both 12*c* and 11*g* as well as various releases of Linux; you must use a 12.1.0.2+ repository with OEM 13*c*). For reference, I've included a comparable OEM 13*c* Enterprise Summary screenshot in Figure 5-8.

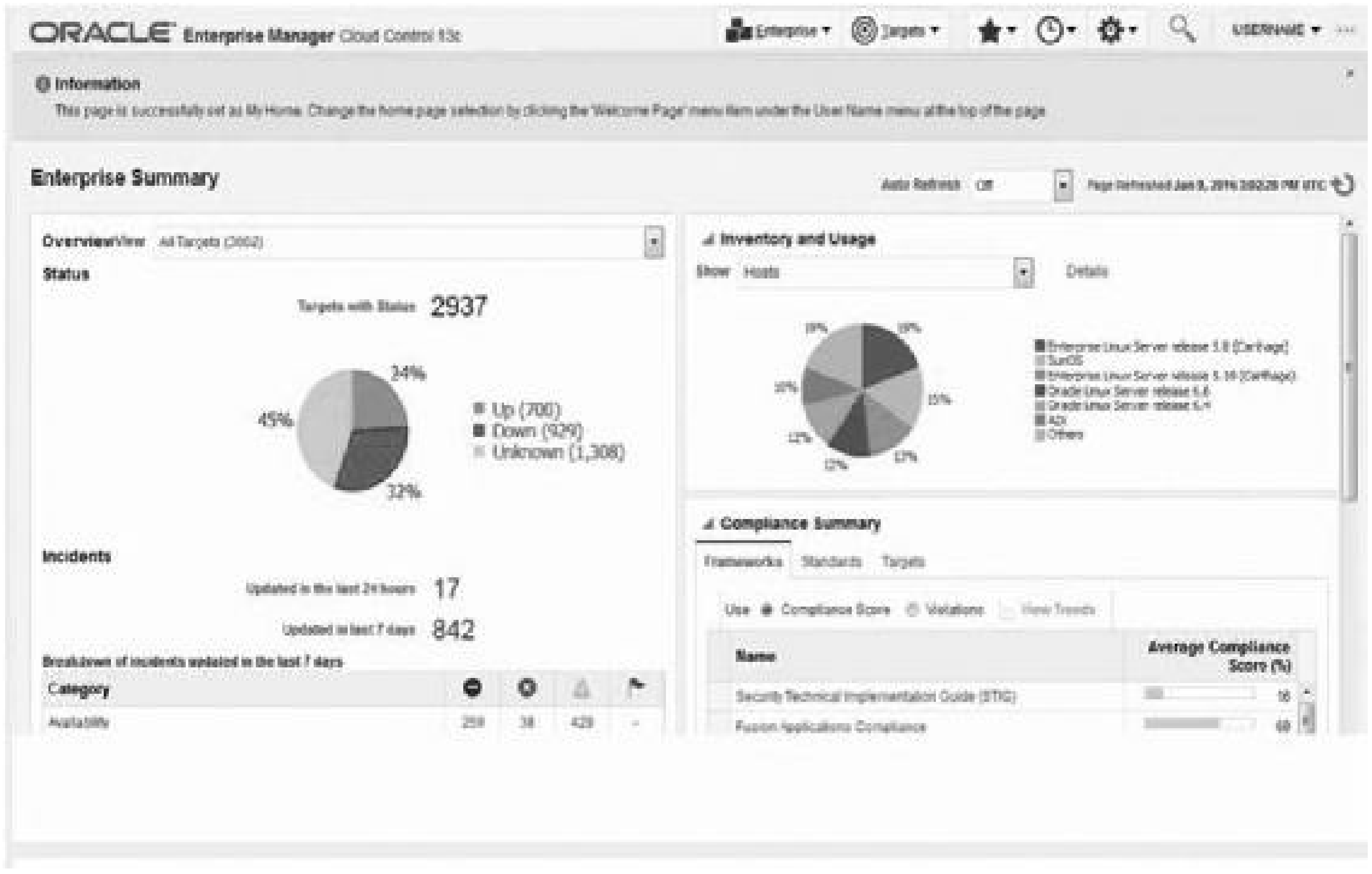

ORACLE Enterprise Manager Cloud Control 13c
Enterprise
Targets
USERNAME
Information
This page is successfully set as My Home. Change the home page selection by clicking the 'Welcome Page' menu item under the User Name menu at the top of the page
Enterprise Summary
Auto Refresh Off
Overview View All Targets
Status
Targets with Status 2937
34%
45%
32%
Up (700)
Down (929)
Unknown (1,308)
Incidents
Updated in the last 24 hours 17
Updated in last 7 days 842
Breakdown of incidents updated in the last 7 days
Category
Availability
Inventory and Usage
Show Hosts
Details
Others
Compliance Summary
Frameworks
Standards
Targets
Use Compliance Score Violations View Trends
Name
Average Compliance Score (%)
Security Technical Implementation Guide (STIG)
Fusion Applications Compliance

FIGURE 5-8. *OEM Enterprise Summary window in OEM 13c*

We'll look at a few other options from this screen later, such as Hosts and Job Activity, but I want to focus on performance tuning first. For performance-related issues, you can click the value next to Targets Monitored (upper-left side of Figure 5-7) and then click Database Instance under the Databases tab. We'll choose to monitor the PRODDB (Container Database) as displayed in Figure 5-9. You can see in the Performance pane that we have three container databases: PROD, PDB$SEED, and CDB$ROOT. You can also see the main Performance tab pull-down menu with many options we will investigate in the coming sections including: Top Activity, SQL Performance Analyzer, Real-Time ADDM, Access Advisor, Optimizer Statistics, AWR, and ASH Analytics. The menu can also take you to the Database Replay (covered near the end of this chapter).

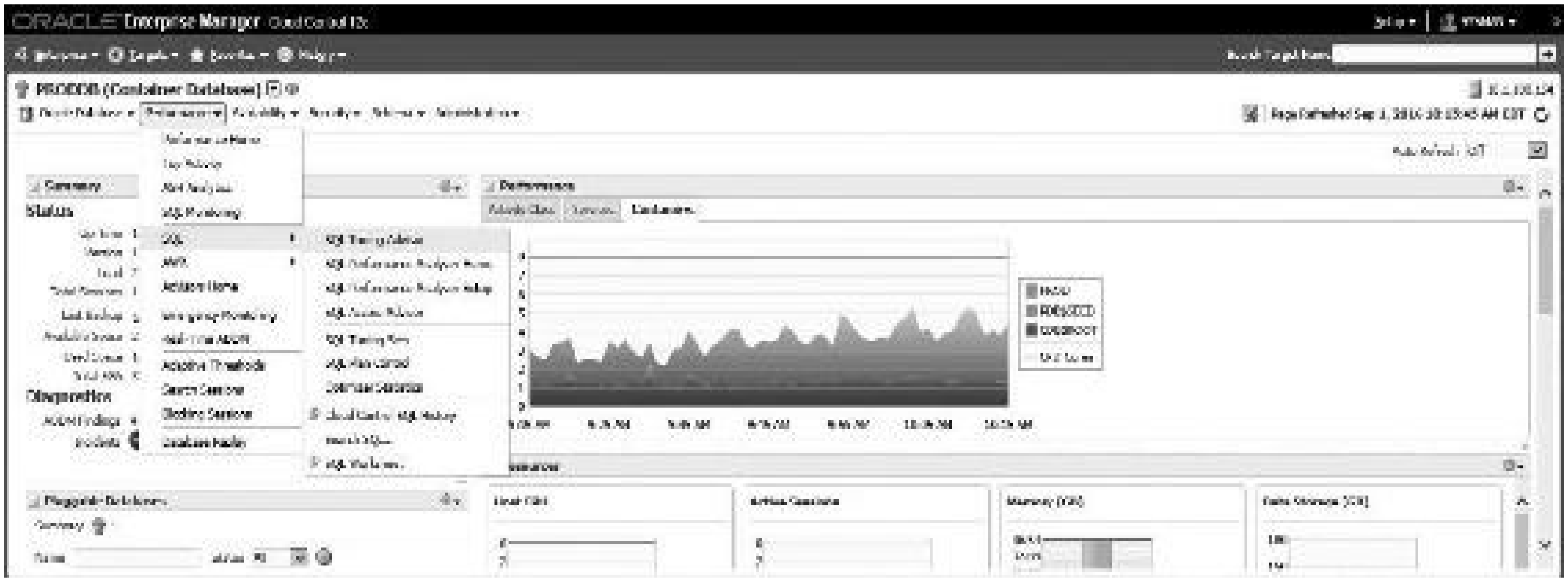


FIGURE 5-9. *The Performance tab drop-down for PRODDB (Container Database)*

Monitoring and Tuning Using the OEM Performance Menu

You'll find several tabs under the Database Instance Server or Cluster Database (depending on which one you select). Clicking the Performance menu will show a list of helpful options shown in Figure 5-9. In this section, I want to focus on those menu items that are most beneficial to quick performance improvements. The most important when the system is in serious trouble is the Top Activity screen. The Top Activity will show the SQL and Users waiting the most and overall system performance. When the system is less busy, you might want to look into the SQL Performance Analyzer and tuning queries with ADDM and Tuning SQL Tuning Sets.

Performance Tab: Top Activity

The Top Activity Screen quickly shows how the system is running overall, where problems exist, and what specific problems need to be fixed. Clicking Top Activity in the pull-down menu in Figure 5-9 will bring up the Top Activity screen displayed in Figure 5-10. The waits are shown in various colors and also listed to the right of the graph. You can also go directly to a Wait Activity by clicking the item you want to see in more detail. Also note that the Top Activity screen option is listed at the bottom of most performance-related screens in OEM. When systems have serious issues, I spend a lot of time on the Top Activity screen. Figure 5-10 shows a Top Activity screen with some serious performance spikes, especially between 11:40 and 11:47 AM. You can move (click and drag) the shaded rectangle on the graph to the area that you would like to focus in on (you can look back in time to what happened before an issue occurred as well as after an issue happens). In the lower part of the screen you will see the associated Top SQL statements (on the lower left) and the associated Top Sessions (on the lower right). If you scroll down, you can instantly see the cost of each SQL statement and how the statement adds up to the graph in the shaded rectangle area. You can instantly check the boxes next to all of the Top SQL statements that you would like the Tuning Advisor to tune for you (or at least make suggestions).

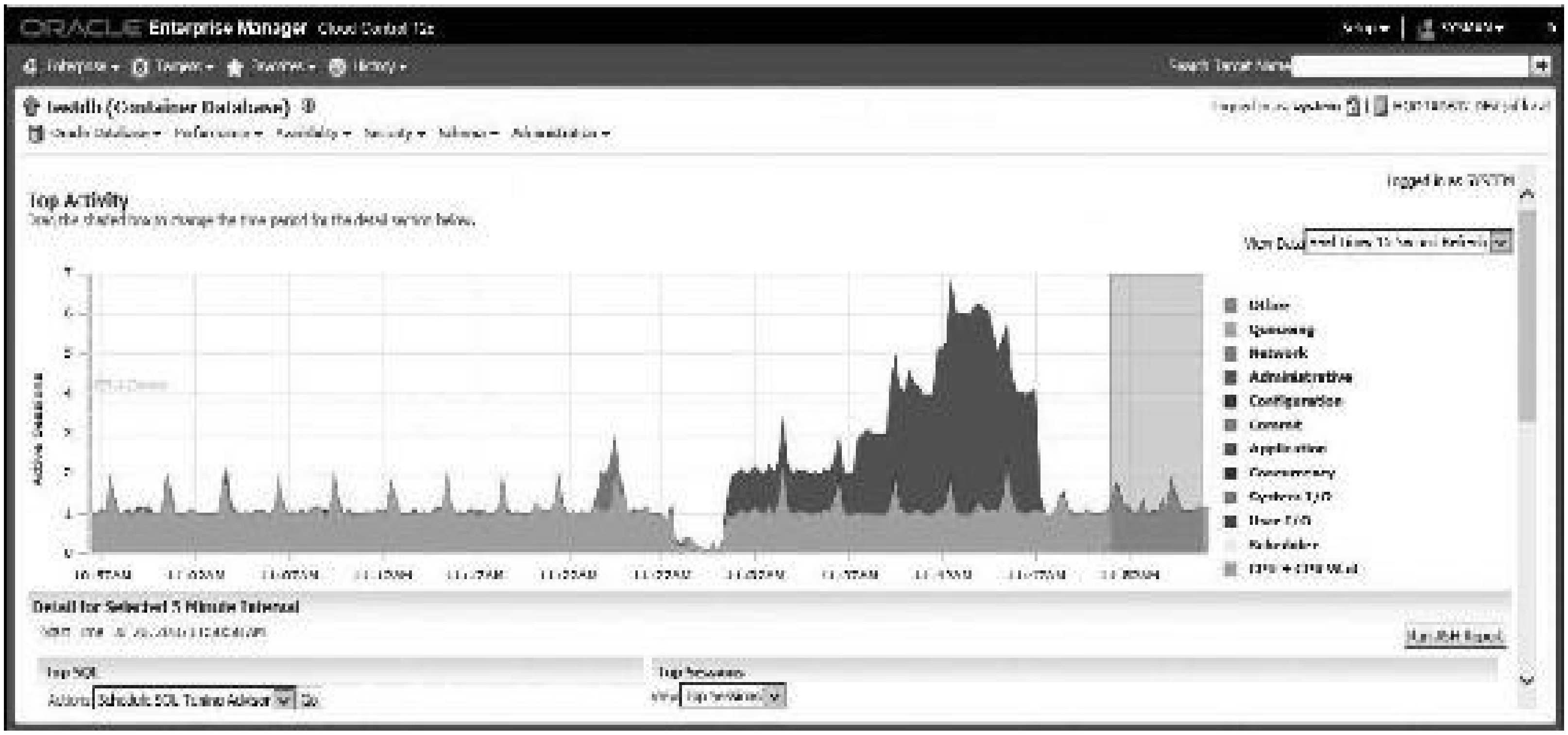
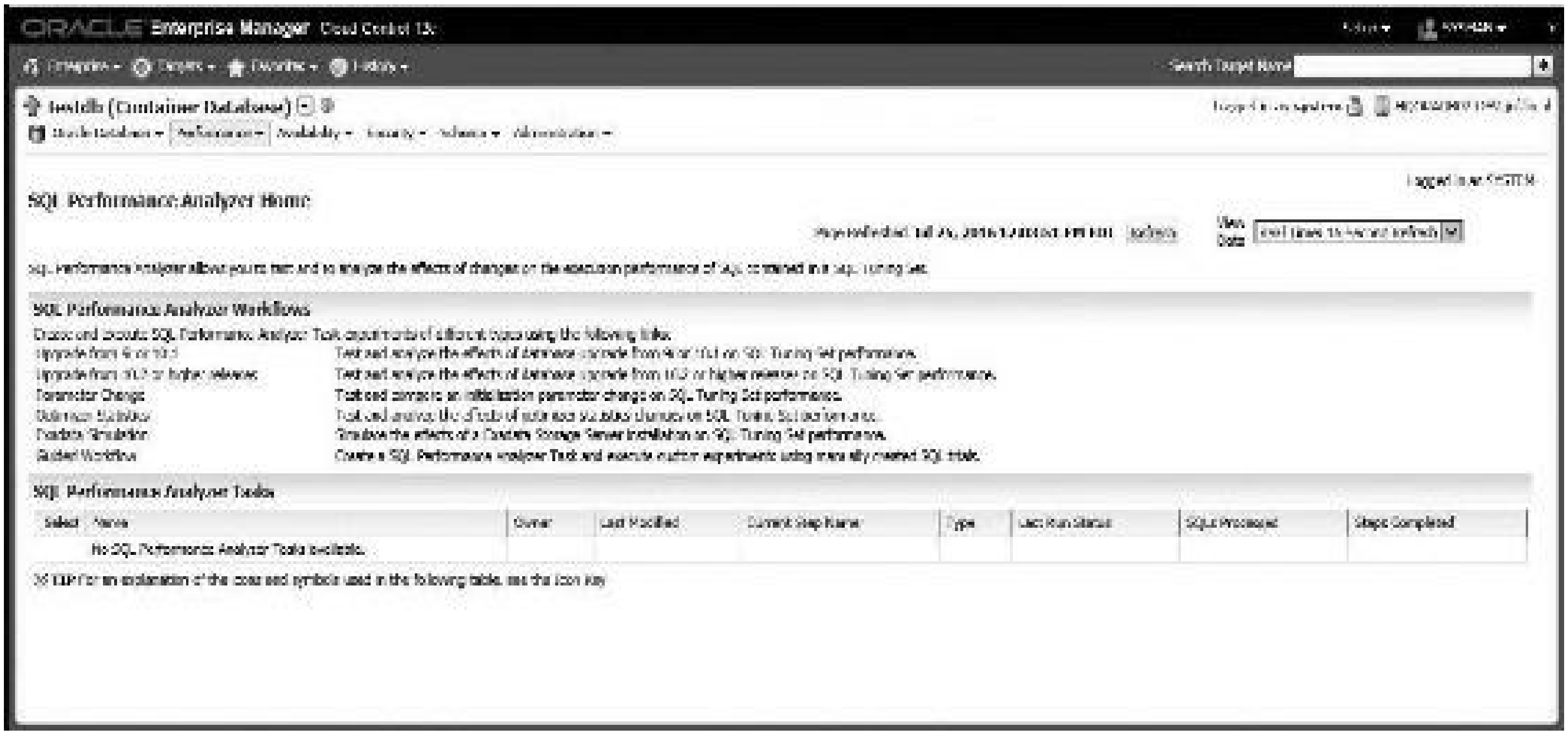


FIGURE 5-10. *Top Activity screen*

Performance Tab: SQL | SQL Performance Analyzer

Clicking SQL Performance Analyzer Home in the pull-down menu in Figure 5-9 under Performance | SQL | SQL Performance Analyzer Home will bring up the SPA screen displayed in Figure 5-11. The SQL Performance Analyzer (SPA) gives a variety of options for tuning Oracle. You can use a Guided Workflow, even comparing different releases for a SQL Tuning Set. You can compare the effect of changing an initialization parameter, and you can even perform an Exadata simulation. Although I can't show all of the steps for each of these tasks, I'll try to show a few of the key screens here.



SQL Performance Analyzer Home

Page Refreshed Jul 26, 2016 12:0[illegible] PM EDT Refresh View Data Real Time: 15 Second Refresh

SQL Performance Analyzer allows you to test and to analyze the effects of changes on the execution performance of SQL contained in a SQL Tuning Set.

SQL Performance Analyzer Workflows

Create and execute SQL Performance Analyzer Task experiments of different types using the following links.

Upgrade from 9i or 10.1	Test and analyze the effects of database upgrade from 9i or 10.1 on SQL Tuning Set performance.
Upgrade from 10.2 or higher releases	Test and analyze the effects of database upgrade from 10.2 or higher releases on SQL Tuning Set performance.
Parameter Change	Test and compare an initialization parameter change on SQL Tuning Set performance.
Optimizer Statistics	Test and analyze the effects of optimizer statistics changes on SQL Tuning Set performance.
Exadata Simulation	Simulate the effects of a Exadata Storage Server installation on SQL Tuning Set performance.
Guided Workflow	Create a SQL Performance Analyzer Task and execute custom experiments using manually created SQL trials.

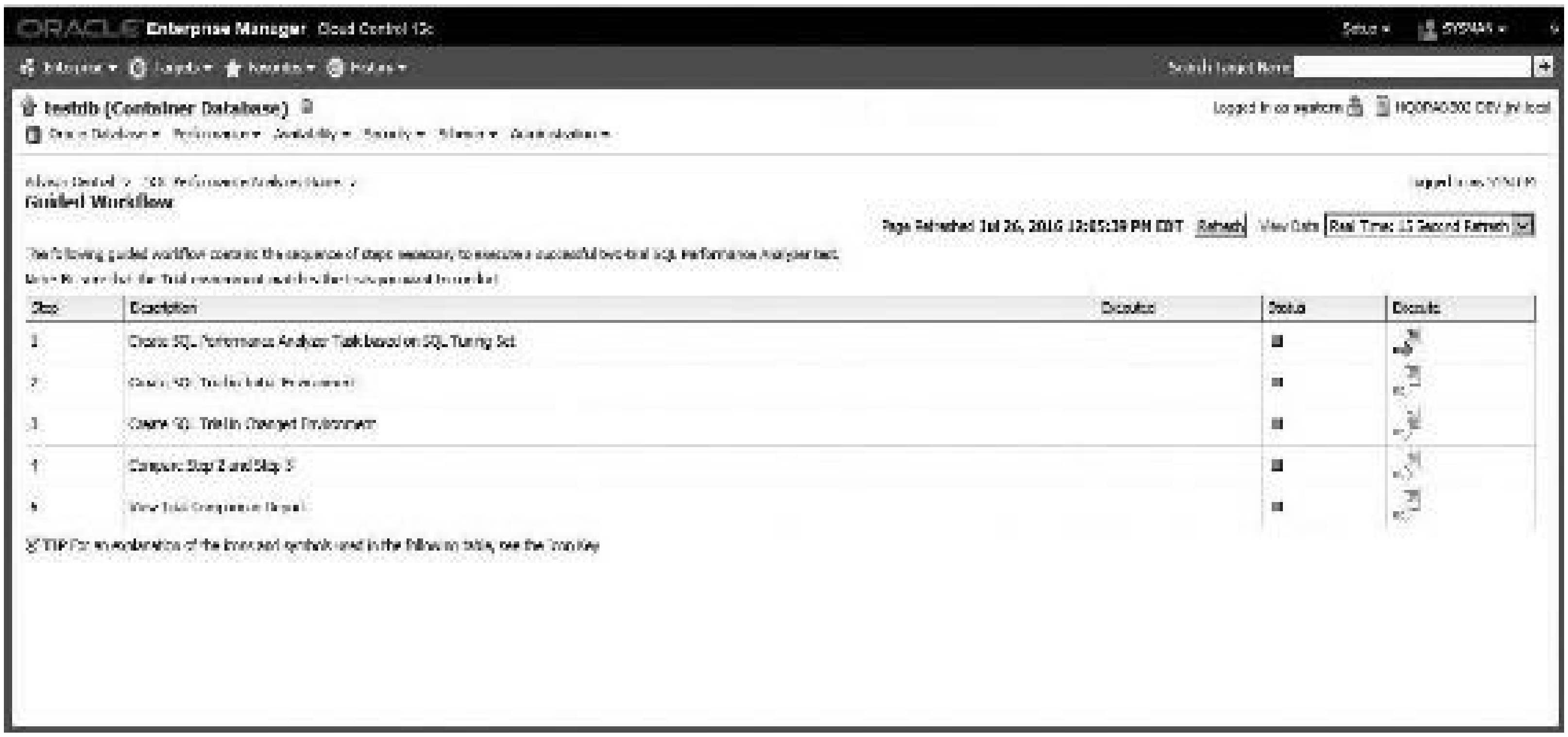
SQL Performance Analyzer Tasks

Select	Name	Owner	Last Modified	Current Step Name	Type	Last Run Status	SQLs Processed	Steps Completed
	No SQL Performance Analyzer Tasks available.							

TIP For an explanation of the icons and symbols used in the following table, see the Icon Key

FIGURE 5-11. *SQL Performance Analyzer screen*

Clicking the Guided Workflow option brings up a step-by-step way to compare two different SQL Tuning Sets (Figure 5-12). This allows you to make changes to an environment, tune the SQL statements, or test another change.



Guided Workflow

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The following guided workflow contains the sequence of steps necessary to execute a successful two-trial SQL Performance Analyzer test.

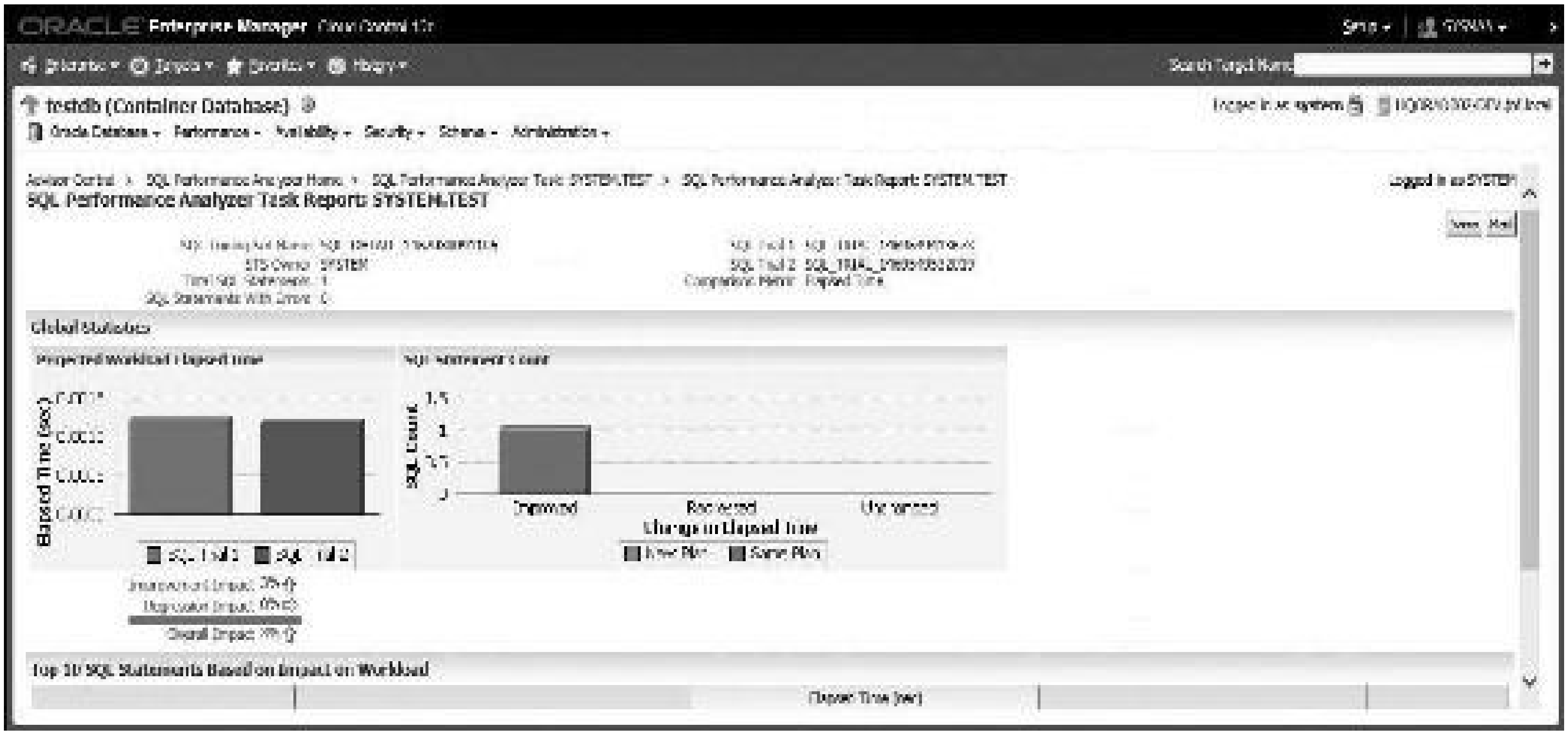
[illegible]

Step	Description	Executed	Status	Execute
1	Create SQL Performance Analyzer Task based on SQL Tuning Set		■	
2	Create SQL Trial in Initial Environment		■	
3	Create SQL Trial in Changed Environment		■	
4	Compare Step 2 and Step 3		■	
5	View Trial Comparison Report		■	

TIP For an explanation of the icons and symbols used in the following table, see the Icon Key

FIGURE 5-12. *Guided Workflow screen*

After completing all of the Guided Workflow steps, the SQL Performance Analyzer shows the output comparing the SQL Tuning Sets before and after changes. Figure 5-13 shows the before and after elapsed times.


testdb (Container Database)

Advisor Central > SQL Performance Analyzer Home > SQL Performance Analyzer Task: SYSTEM.TEST > SQL Performance Analyzer Task Report: SYSTEM.TEST

SQL Performance Analyzer Task Report: SYSTEM.TEST

SQL Tuning Set Name: [illegible]
STS Owner: SYSTEM
Total SQL Statements: 1
SQL Statements With Errors: 0

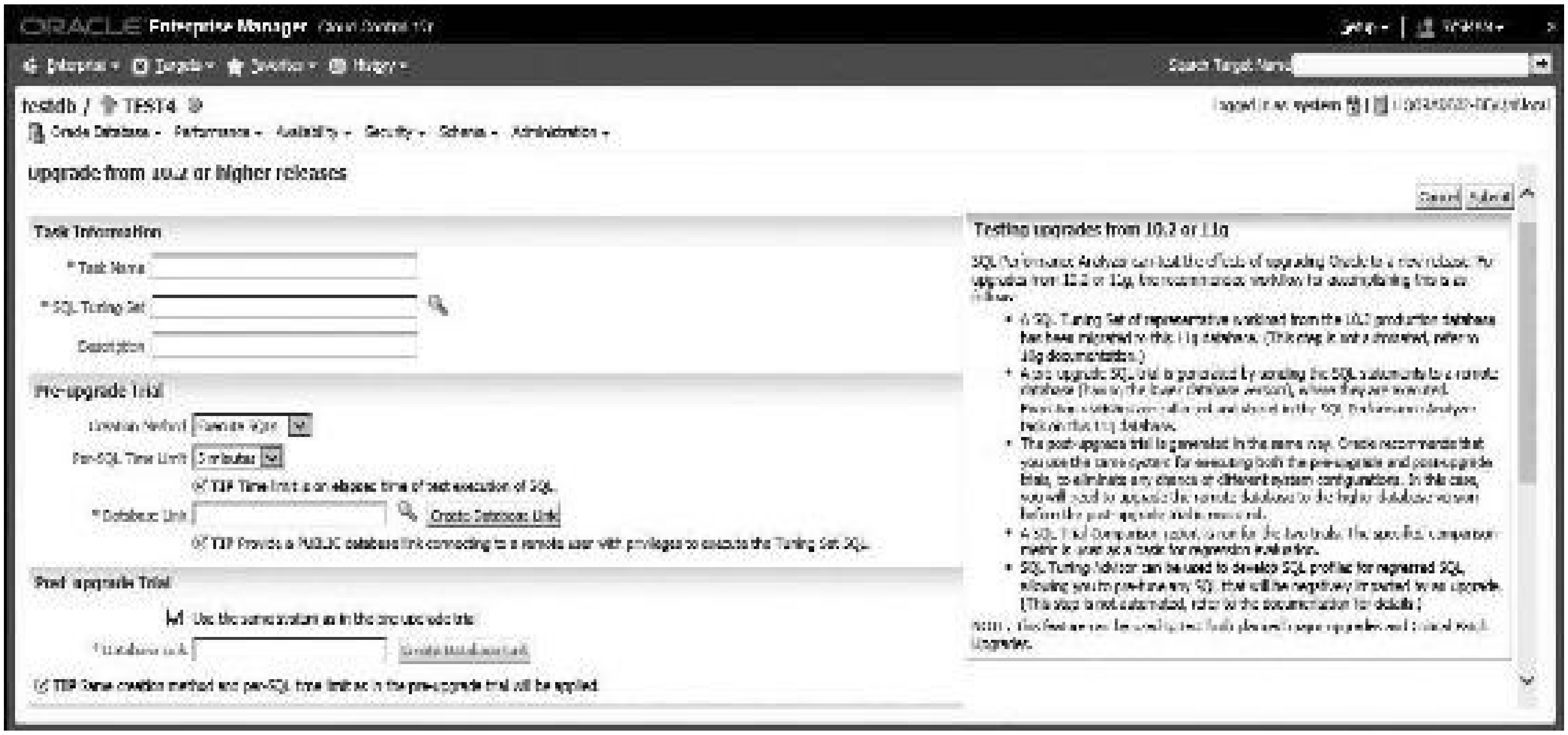
SQL Trial 1: [illegible]
SQL Trial 2: SQL_TRIAL_[illegible]
Comparison Metric: Elapsed Time

Global Statistics

Top 10 SQL Statements Based on Impact on Workload

FIGURE 5-13. *SQL Performance Analyzer Task Report for a Guided Workflow*

Instead of choosing the Guided Workflow option in the SPA, this time let's choose the Upgrade from 10.2 or higher releases option (see Figure 5-10) to compare upgrades from 10.2 or 11*g* to 12*c*. Figure 5-14 shows one of the screens that appear for this comparison. You need to fill in the Task Name, SQL Tuning Set, and two Database Link fields for a successful test.


testdb / TEST4

Upgrade from 10.2 or higher releases

Task Information

* Task Name
* SQL Tuning Set
Description

Pre-upgrade Trial

Creation Method: Execute SQLs
Per-SQL Time Limit: 5 minutes
TIP Time limit is on elapsed time of test execution of SQL.
* Database Link
TIP Provide a PUBLIC database link connecting to a remote user with privileges to execute the Tuning Set SQL.

Post-upgrade Trial

☑ Use the same system as in the pre-upgrade trial
* Database Link
TIP Same creation method and per-SQL time limit as in the pre-upgrade trial will be applied.

Testing upgrades from 10.2 or 11g

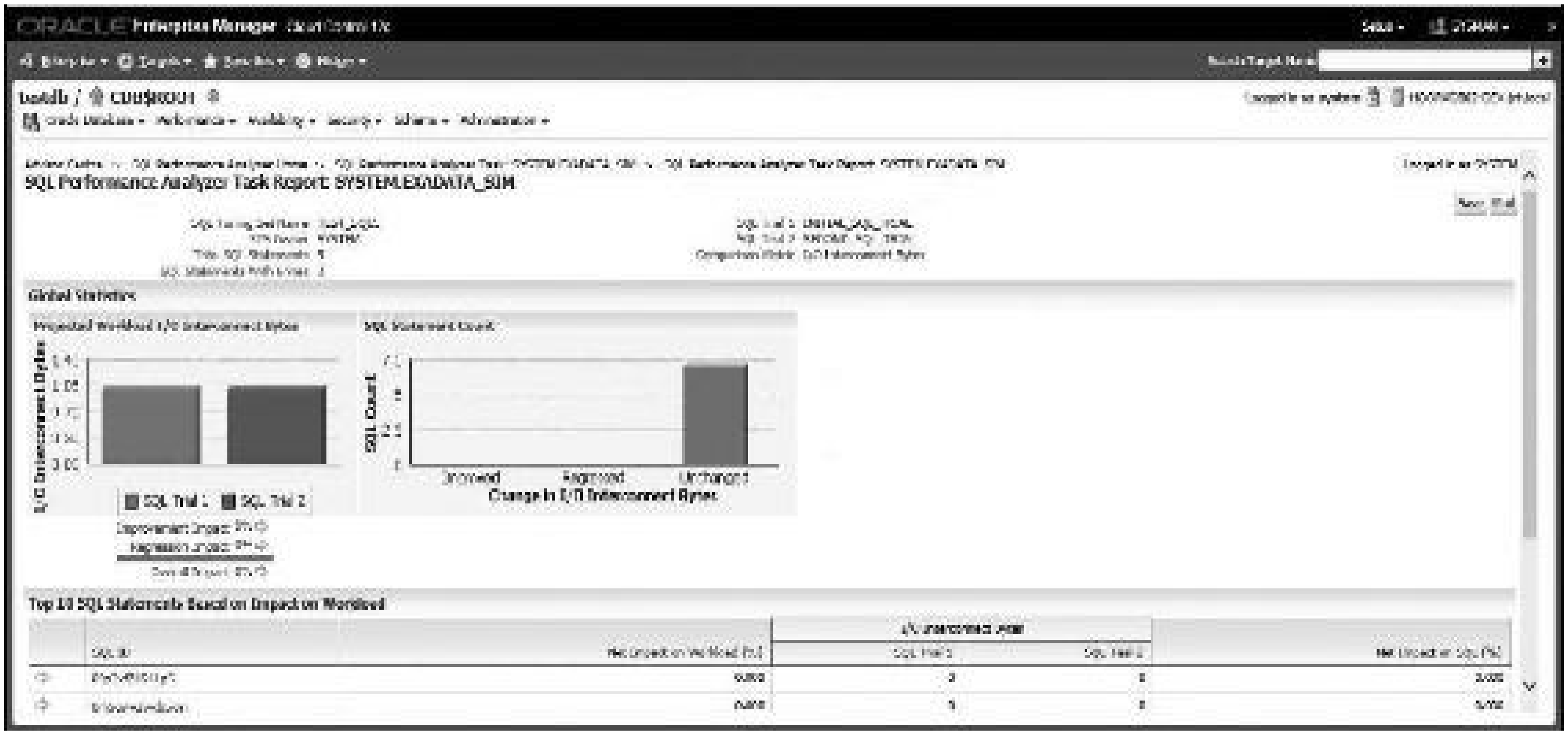
SQL Performance Analyzer can test the effects of upgrading Oracle to a new release. For upgrades from 10.2 or 11g, the recommended workflow for accomplishing this is as follows:

- A SQL Tuning Set of representative workload from the 10.2 production database has been migrated to this 11g database. (This step is not automated, refer to 10g documentation.)
- A pre-upgrade SQL trial is generated by sending the SQL statements to a remote database (that is, the lower database version), where they are executed. [illegible] are collected and stored in the SQL Performance Analyzer task on this 11g database.
- The post-upgrade trial is generated in the same way. Oracle recommends that you use the same system for executing both the pre-upgrade and post-upgrade trials, to eliminate any chance of different system configurations. In this case, you will need to upgrade the remote database to the higher database version before the post-upgrade trial is executed.
- A SQL Trial Comparison report is run for the two trials. The specified comparison metric is used as a basis for regression evaluation.
- SQL Tuning Advisor can be used to develop SQL profiles for regressed SQL, allowing you to pre-tune any SQL that will be negatively impacted by an upgrade. (This step is not automated, refer to the documentation for details.)

NOTE: [illegible] Upgrades.

FIGURE 5-14. *SPA task comparing upgrades from 10.2 or 11g to 12c for a SQL Tuning Set*

Once I complete the steps for the comparison, the SPA displays a detailed comparison similar to the output shown in Figure 5-16.

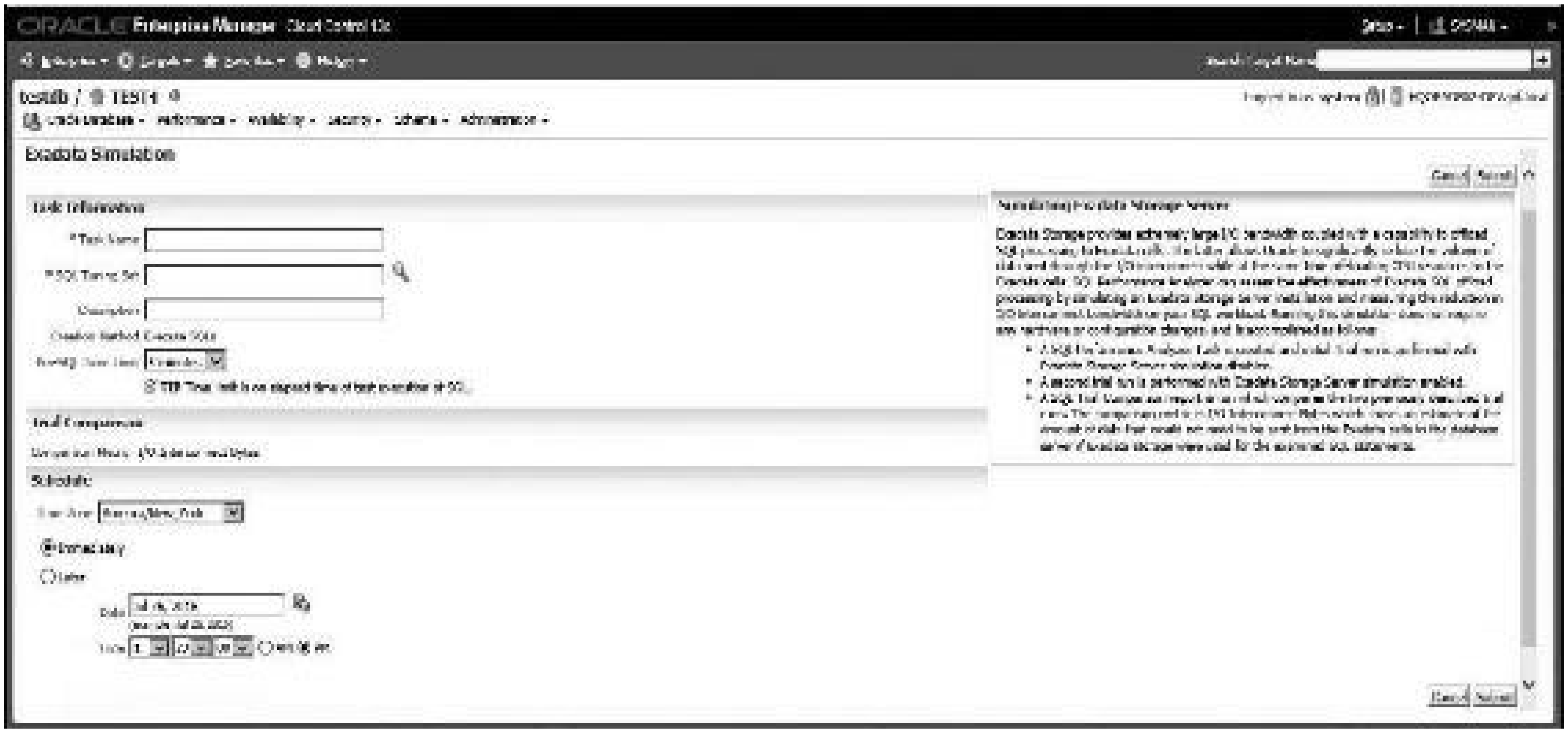

SQL Performance Analyzer Task Report: SYSTEM.EXADATA_SIM

Global Statistics

Top 10 SQL Statements Based on Impact on Workload

FIGURE 5-16. *SPA Task Report for an Exadata Simulation*

In OEM 12*c* there is the ability to simulate Exadata. Clicking the Exadata Simulation option in the SPA (see Figure 5-10) displays the Exadata Simulation screen (Figure 5-15).


Exadata Simulation

Task Information

Trial Comparison

Schedule

Exadata Storage provides extremely large I/O bandwidth coupled with a capacity to offload [illegible]

- [illegible]
- A second trial run is performed with Exadata Storage Server simulation enabled.
- [illegible]

FIGURE 5-15. *Exadata Simulation screen*

Once I enter all of the information and run the associated jobs for the Exadata Simulation, the SPA displays a comparison of my current system to Exadata to see if it would be beneficial (Figure 5-16). For my test, I tried something easy to see if even the most simple queries would show I needed Exadata (when, in fact, I didn't). Fortunately, the SPA indeed showed that Exadata would *not* be beneficial, as all statements were unchanged—to which I give Oracle credit (I thought surely they would try to talk me into Exadata!).

Performance Tab: Real-Time ADDM

Clicking Real-Time ADDM in the pull-down menu in Figure 5-9 under Performance | Real-Time ADDM will bring up the Real-Time ADDM Results screen displayed in Figure 5-17. There are also other screens that you can click a button to get Real-Time ADDM as well. This shows performance based on the last time ADDM was generated.

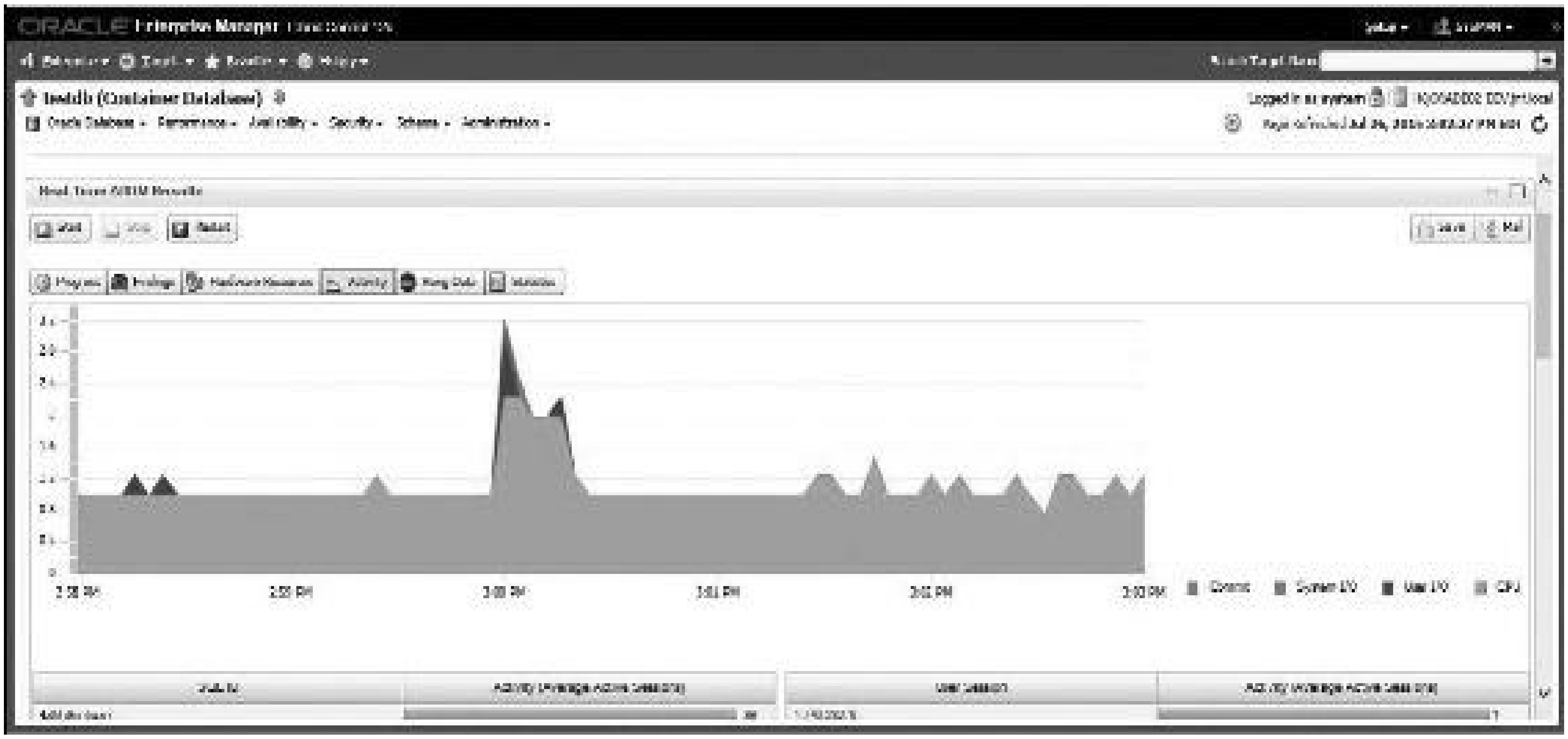


FIGURE 5-17. *Real-Time ADDM Results screen*

As stated earlier, Oracle gathers stats every hour on the hour for the AWR and runs an ADDM report directly after that. However, if a problem occurs after the hour (perhaps at 3:01 PM as you see in Figure 5-17), the ADDM report that ran at 3 pm doesn't reveal the problem, and perhaps you really don't want to wait until 4 pm if the problem is severe. The answer is the ability to Run ADDM now. You can start the Real-Time ADDM now by clicking Start. After the ADDM is complete, you'll see the screen in Figure 5-18 under the Progress tab showing it with a status of Finished.

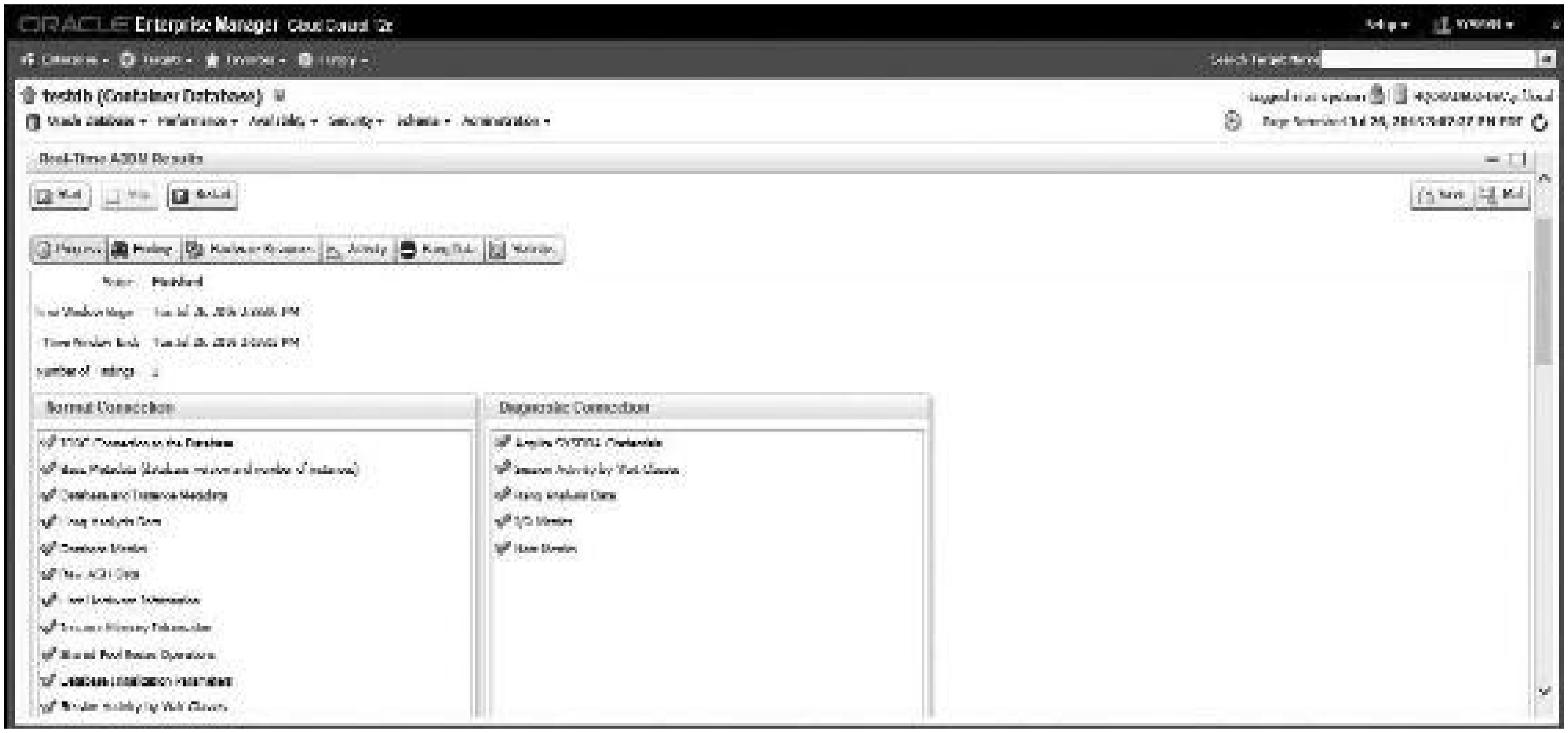


FIGURE 5-18. *Real-Time ADDM Results Finished screen*

You can also run an ADDM Report (`addmrpt.sql`) in SQL*Plus to see these findings. In an effort to increase performance, the ADDM analyzes a number of different database-related problems, including:

- Memory-related issues such as shared pool latch contention, log buffer issues, or database buffer cache–related problems
- CPU bottlenecks
- Disk I/O performance issues
- Database configuration problems
- Space-related issues, such as tablespaces running out of space
- Application and SQL tuning issues such as excessive parsing and excessive locking
- RAC-related issues such as global cache interconnect issues, lock manager issues, global resource contention issues, and any other *globally significant* issues

TIP
Use the SQL Tuning Advisor only to tune SQL statements, not conditions such as row locks.

By clicking the Findings tab, the Findings for ADDM are displayed. This screen displays the finding(s)/problem(s) as well as offering action(s) needed for fixing the problem or related SQL. In the example in Figure 5-19, the issue has to do with SQL statements consuming significant database time (the Priority is Medium).

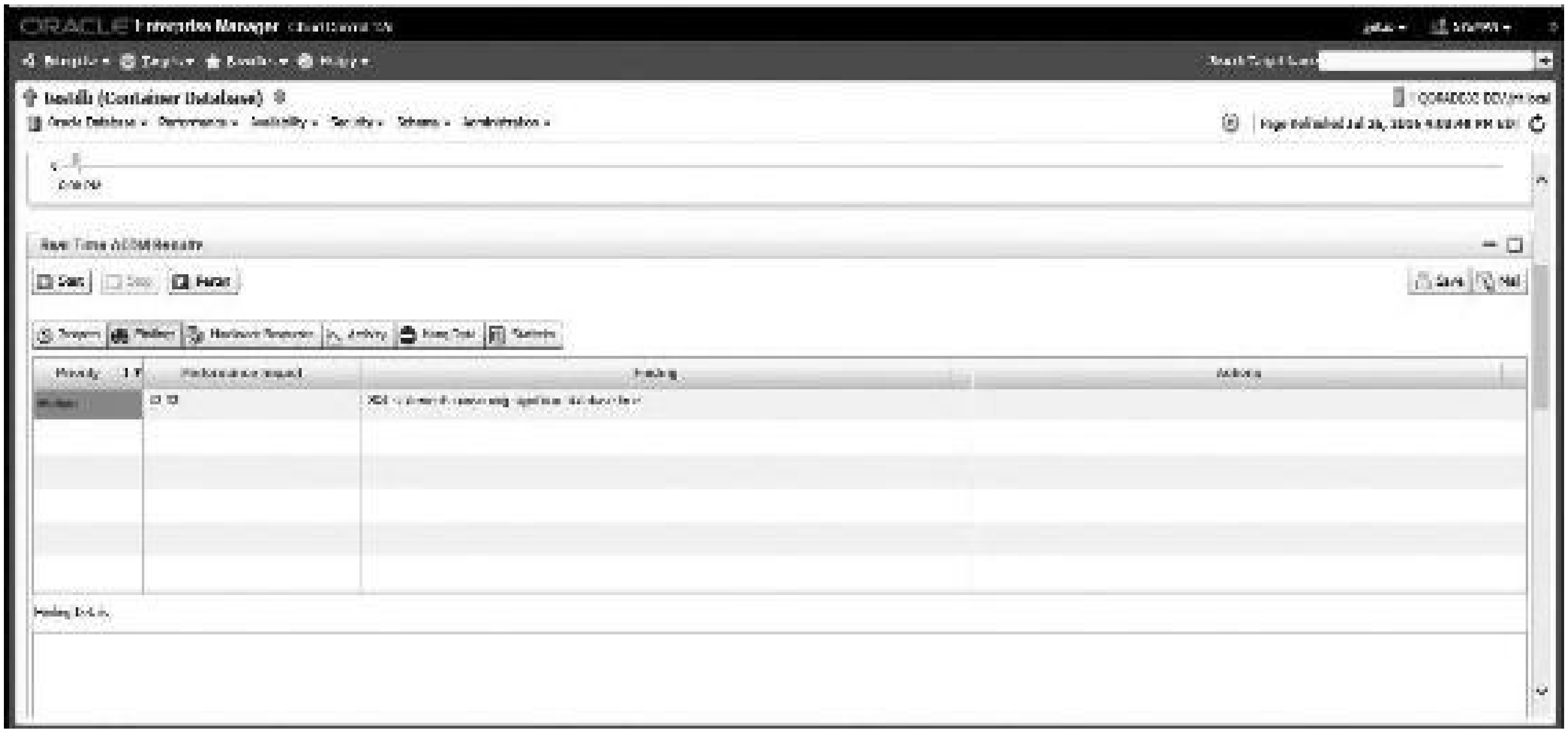
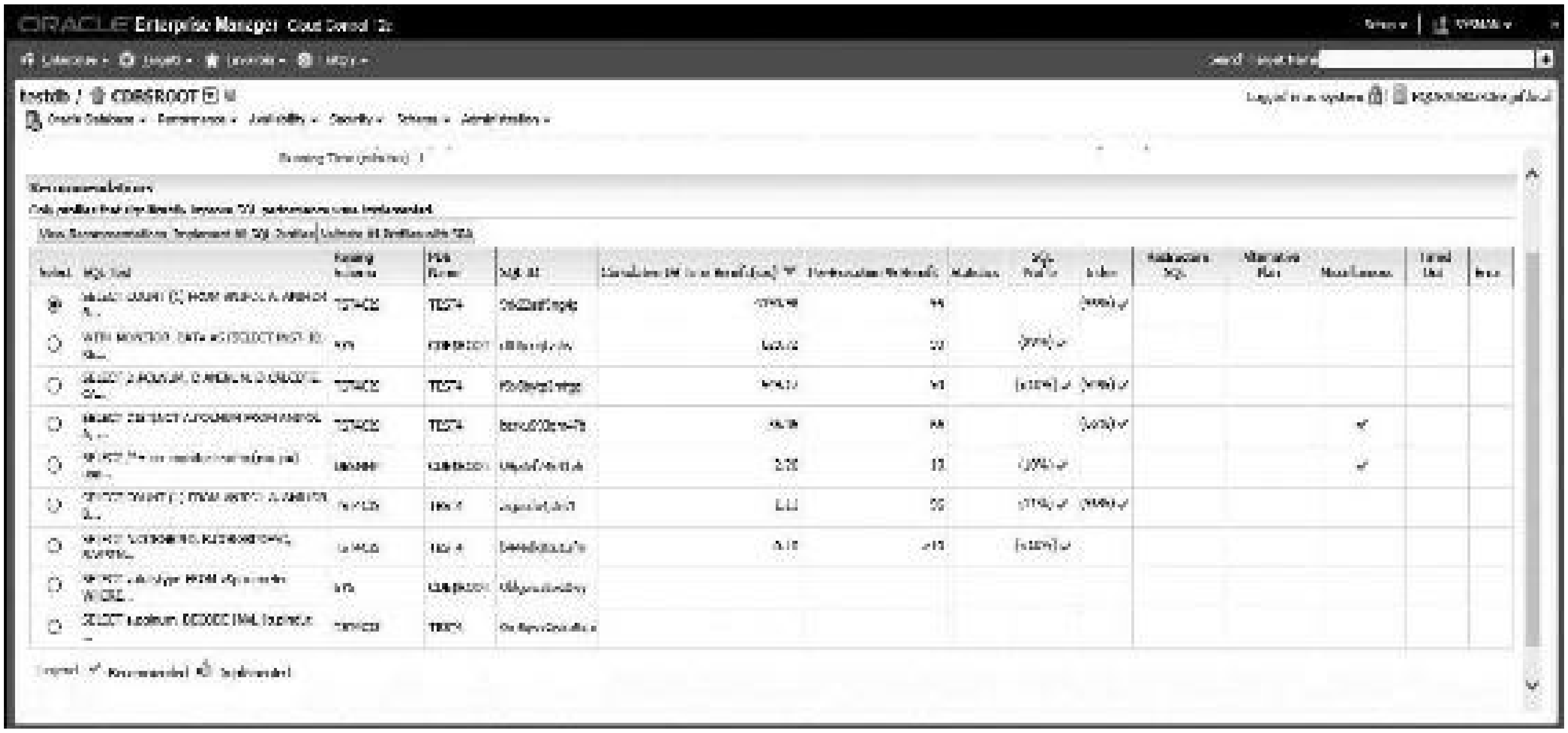


FIGURE 5-19. *Real-Time ADDM Results Findings screen*

You can schedule the SQL Tuning Advisor (note that this is part of the SQL Tuning Pack) to investigate the SQL in greater detail and get recommend changes in the problem SQL. Choosing Performance in Figure 5-9, and clicking | SQL | SQL Tuning Advisor opens the SQL Tuning Advisor, ready to tune any SQL in question and offer suggestions. In Figure 5-20, the recommendations for the subpar SQL statements for a given SQL Tuning Set are identified by check marks. The worst SQL (SQL ID = 9rk22atf5ng4p) seems like it will benefit from implementing an index.



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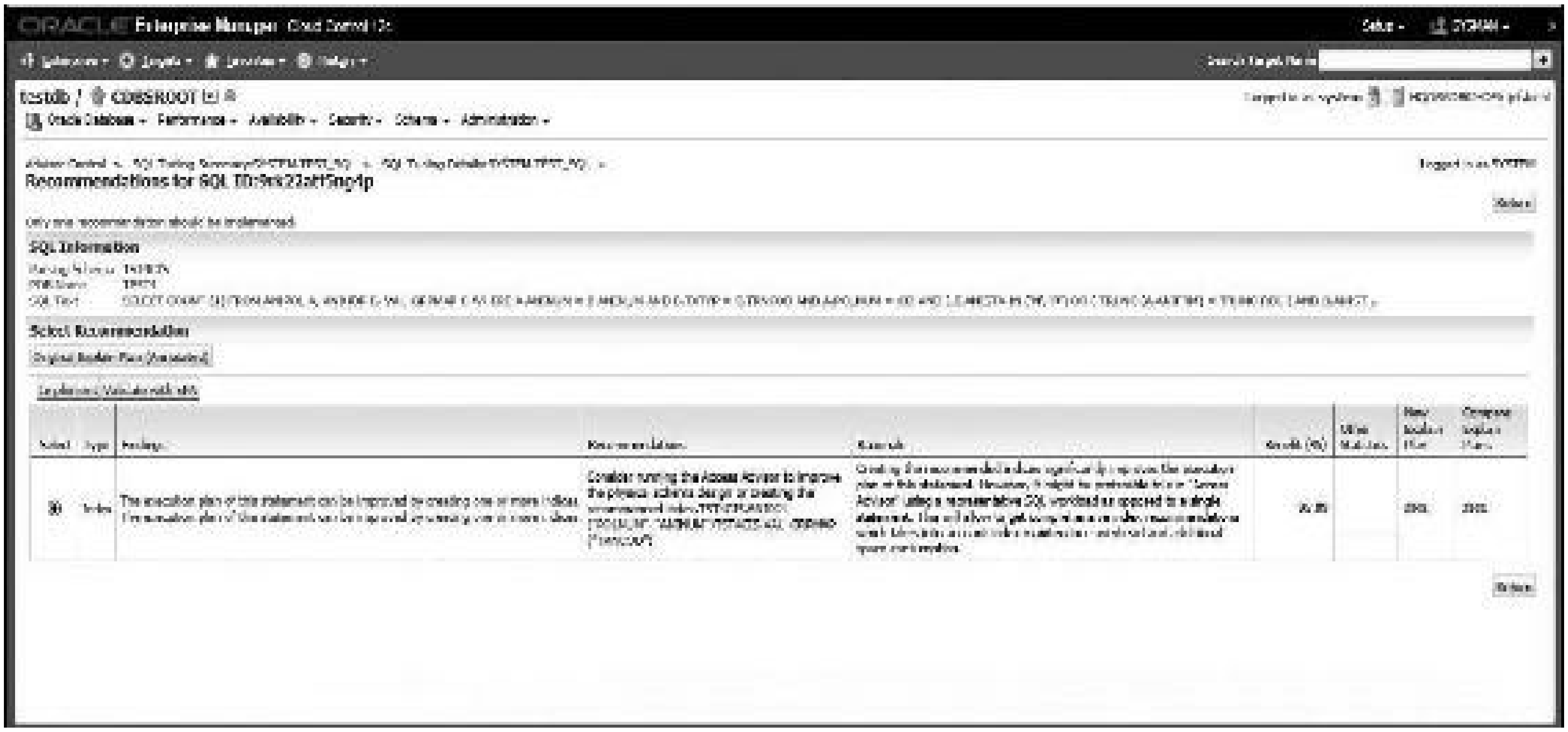
testdb / CDB$ROOT

Recommendations

[illegible]

FIGURE 5-20. *SQL Tuning Advisor, SQL Tuning Recommendations*

By selecting the radio button corresponding to the worst SQL text and then clicking View Recommendations, you can see the SQL and the recommendations to enhance the SQL (Figure 5-21). Implementing the index should help by 95.89 percent according to the recommendations. You can also click the link in the rightmost column to compare the Explain Plans to see what is being changed and what the benefit will be.



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Recommendations for SQL ID:[illegible]

SQL Information

Select Recommendation

[illegible]

FIGURE 5-21. *SQL Tuning Advisor recommends adding an index or running the Access Advisor to check indexes.*

The Explain Plans comparison shows that the order of table access has been changed as well as some of the joining methods. Creating the index would not require the SQL to perform full table scans, as seen in Figure 5-22.

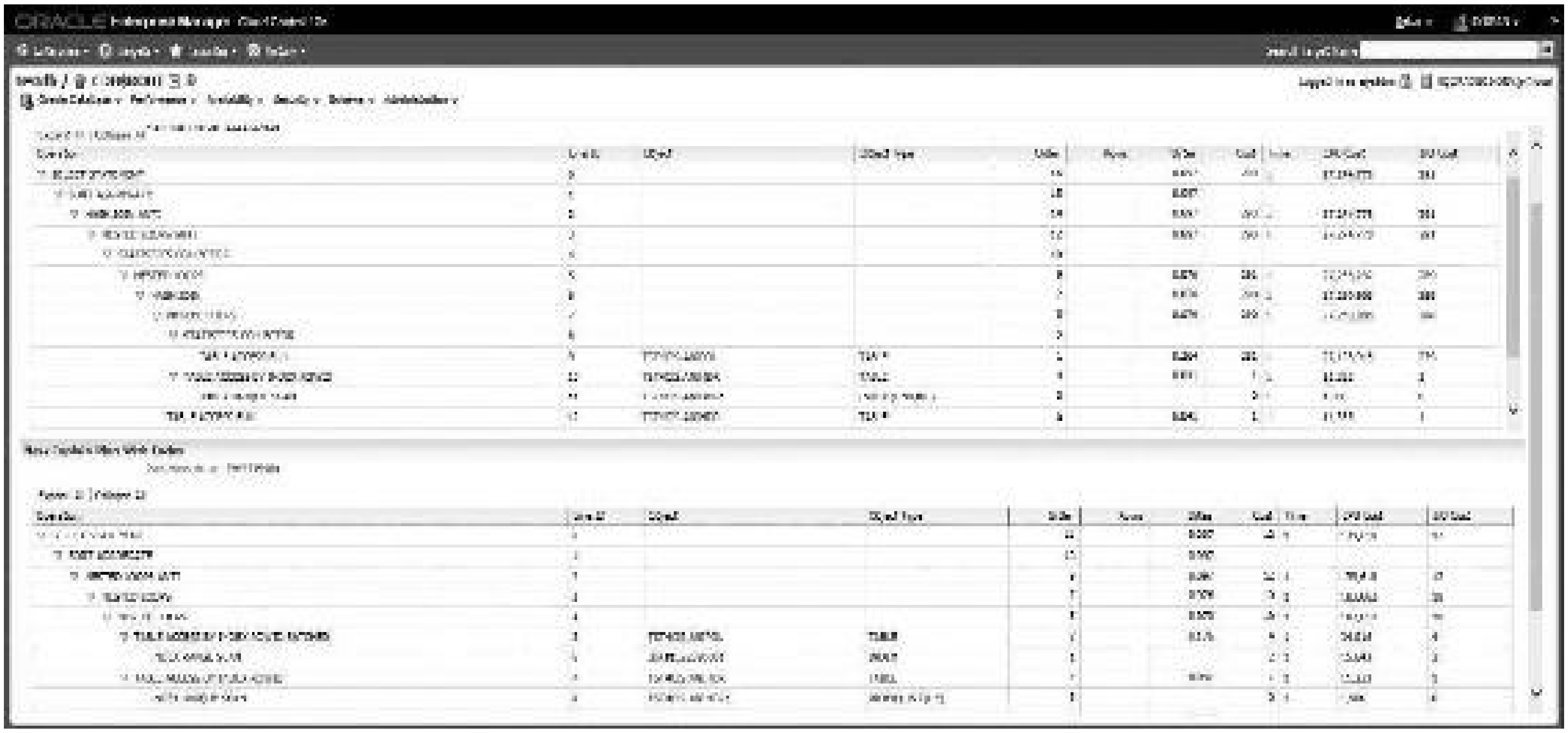


FIGURE 5-22. *Explain Plans comparison*

TIP

Compare Explain Plans is a great SQL Tuning Advisor tool built into OEM.

In Figure 5-23, it is evident from the Top Activity screen that the now-tuned SQL statement is no longer causing the negative impact (performance spike) that was previously felt earlier in the day (refer to Figure 5-17). The entire system is now running much better, with fewer users waiting in the queue.

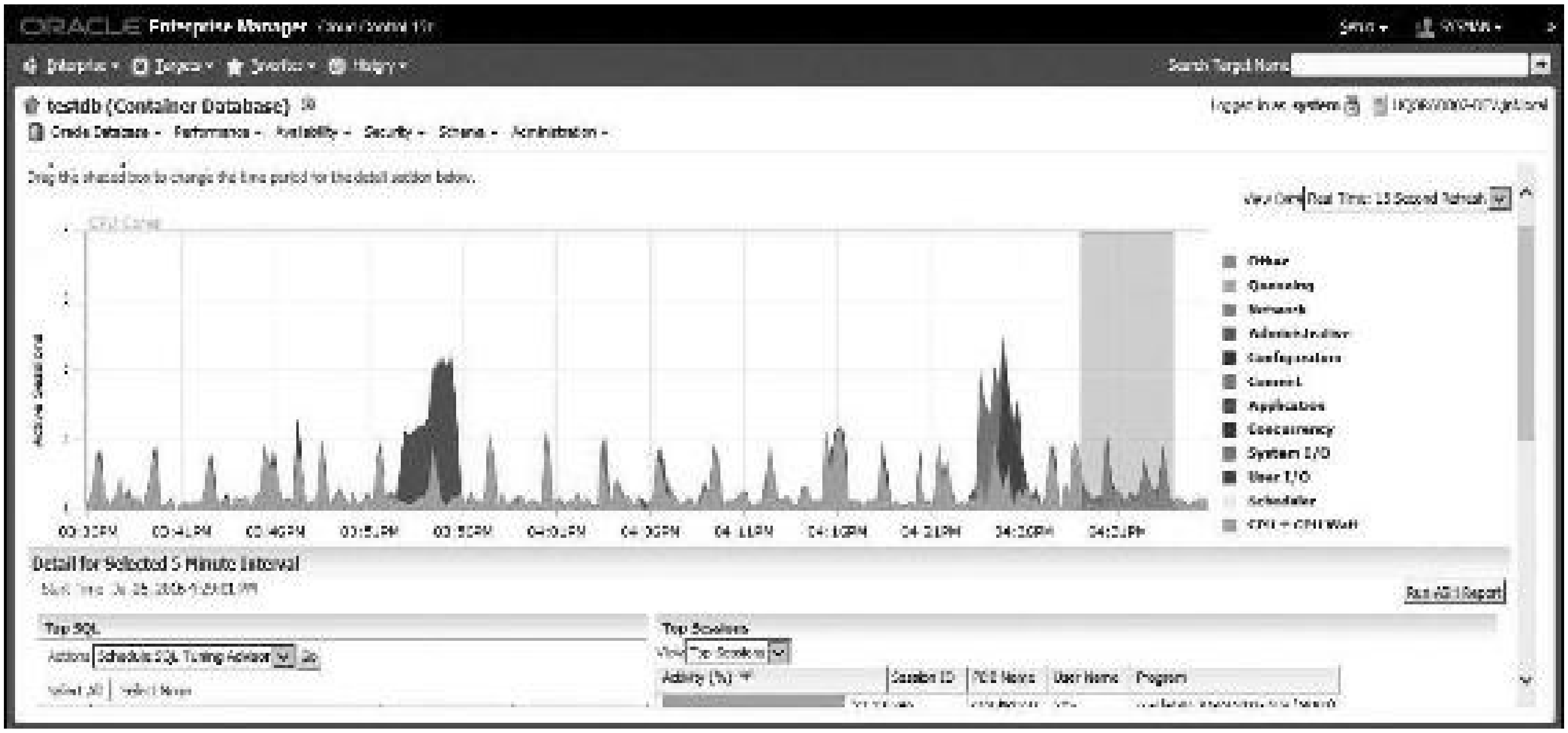
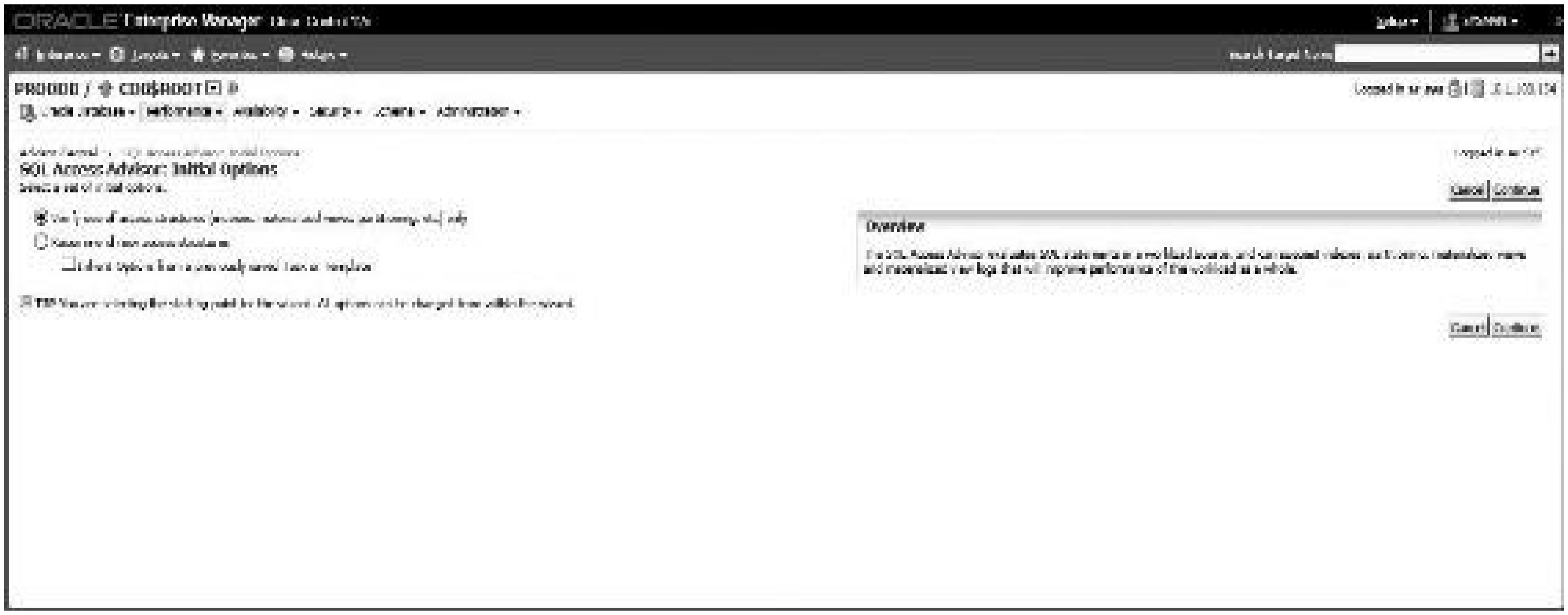

ORACLE Enterprise Manager Cloud Control 13c
testdb (Container Database)
Oracle Database Performance Availability Security Schema Administration
Drag the shaded box to change the time period for the detail section below.
View Data Real Time: 15 Second Refresh
Active Sessions
CPU Cores
Other
Queueing
Network
Administrative
Configuration
Commit
Application
Concurrency
System I/O
User I/O
Scheduler
CPU + CPU Wait
Detail for Selected 5 Minute Interval
Run ASH Report
Top SQL
Actions Schedule SQL Tuning Advisor Go
Top Sessions
View Top Sessions
Activity (%)
Session ID
User Name
Program

FIGURE 5-23. *Top Activity screen—much better after tuning*

Performance Tab: SQL | Access Advisor

Within the Tuning Pack, you will find a product called SQL Access Advisor (SAA). SAA can be used for tuning the entire workload (not just high-load SQL statements). Choose the option available from the Performance menu (Figure 5-9). To access the screen, choose Performance | SQL | Access Advisor, shown in Figure 5-24. SAA gives recommendations on how to improve performance of a workload through indexes (bitmap, b-Tree, functional, and concatenated), materialized views/logs, and a combination of these. SAA considers the cost of DML in terms of index maintenance and storage when it recommends additional access structure. SAA can also be used during the development phase to figure out what access structures are required before production deployment. You can use SQL Tuning Sets as input to SAA. Please check the Oracle documentation for additional information.


PRODDB / CDB$ROOT

SQL Access Advisor: Initial Options

[illegible]

- (●) [illegible]
- ( ) [illegible]
  - ☐ [illegible]

TIP [illegible]

Cancel | Continue

Overview

The SQL Access Advisor [illegible]

Cancel | Continue

FIGURE 5-24. *SQL Access Advisor screen*

Performance Tab: Manage Optimizer Statistics

Another option available from the Performance menu (Figure 5-9) is access to the Optimizer Statistics Console screen, shown in Figure 5-25. To access the screen, choose Performance | SQL | Optimizer Statistics. Keeping statistics up to date for dynamic tables can be a chore (worse if done for static tables too—don't do that). The Optimizer Statistics Console can help in this endeavor. Many different gathering options for optimizer statistics can be specified from this screen, as well as the scheduling and managing of specific jobs.

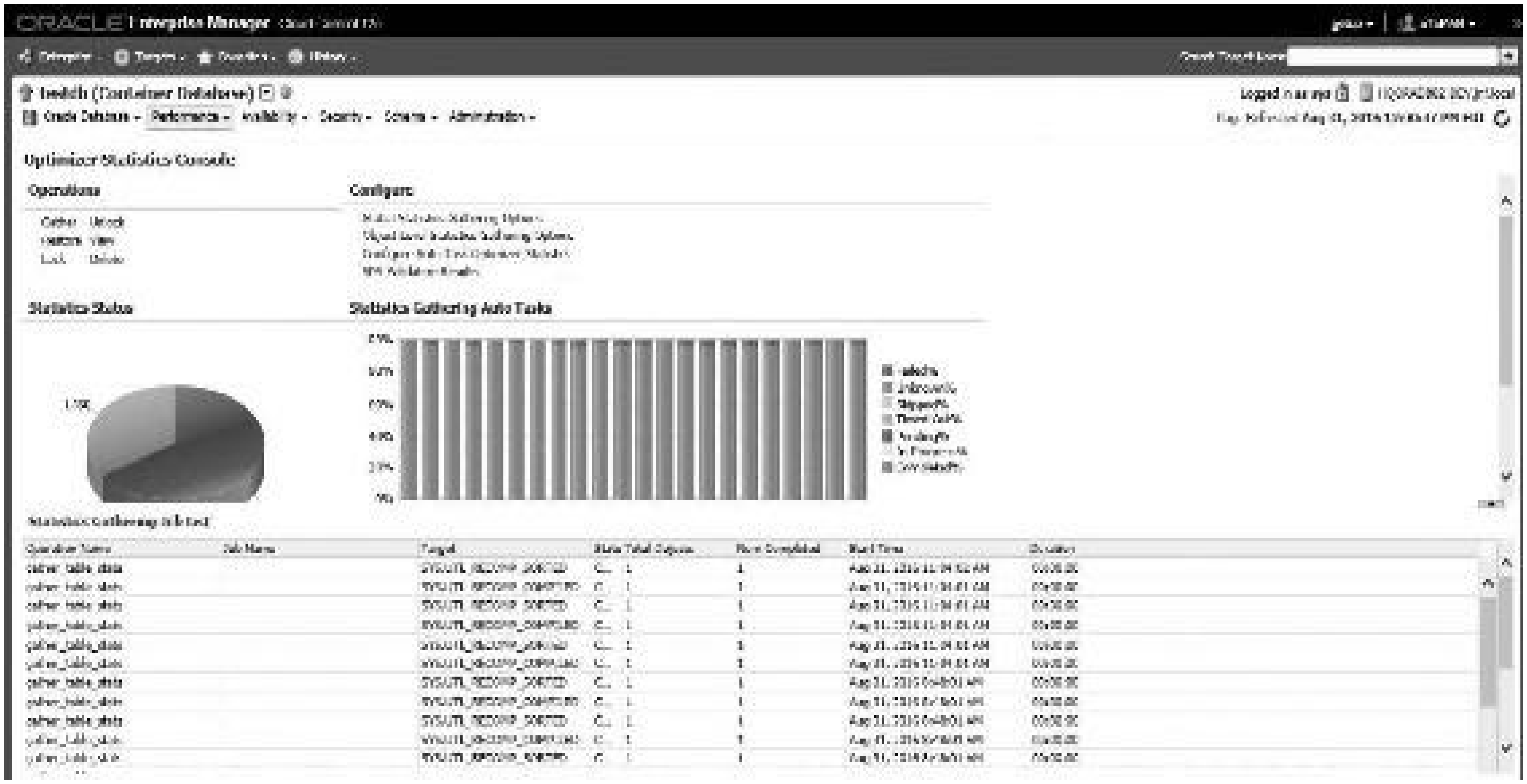
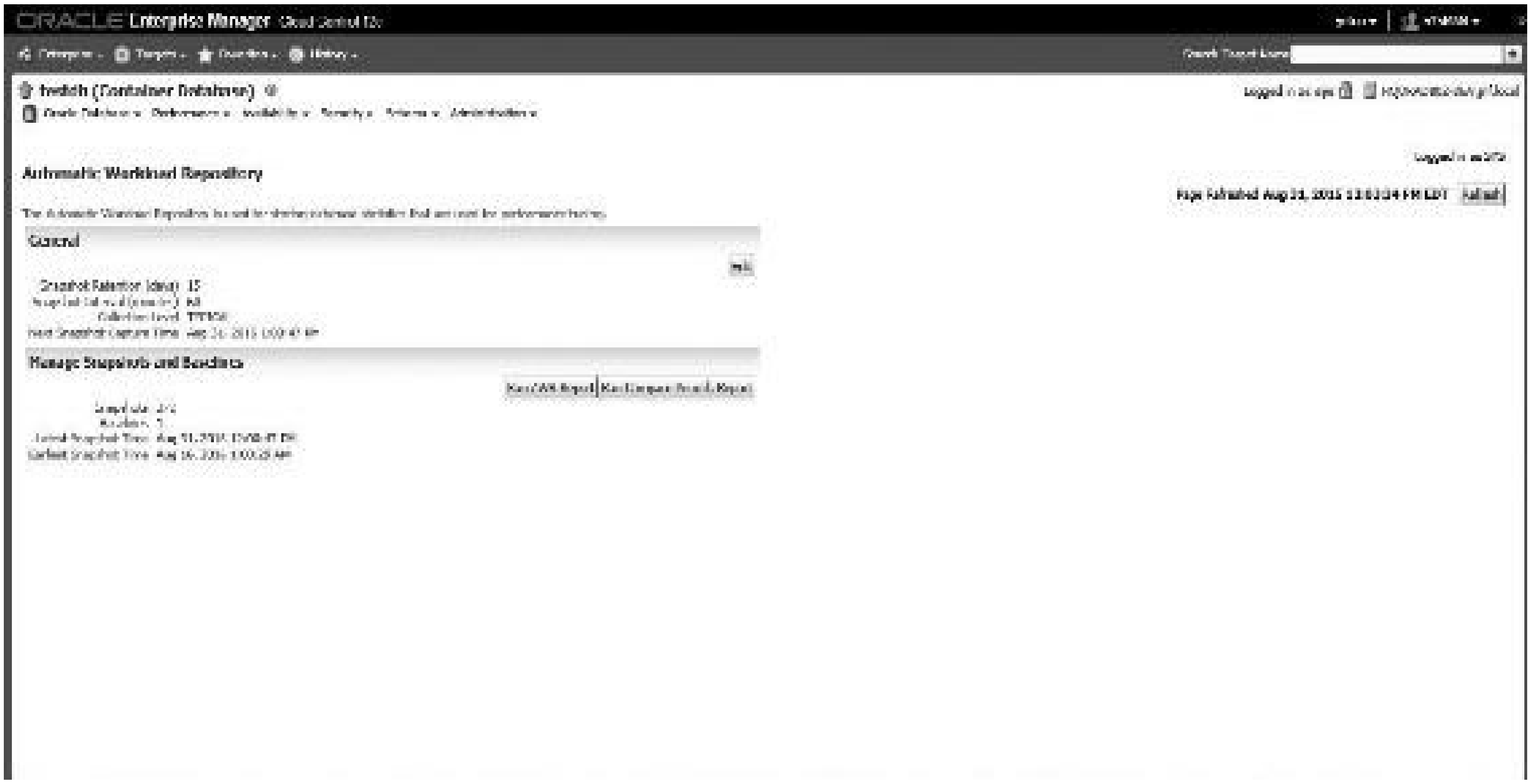

ORACLE Enterprise Manager
Performance
Optimizer Statistics Console
Operations
Configure
Statistics Status
Statistics Gathering Auto Tasks
Statistics Gathering Job List
Operation Name
Target
Start Time

FIGURE 5-25. *Optimizer Statistics Console screen*

Performance Tab: AWR | AWR Administration

You can access the Automatic Workload Repository (AWR) by choosing Performance | AWR | AWR Administration. The Automatic Workload Repository screen includes information on all snapshots and collection levels. (See Chapter 14 for more on AWR and how snapshots work.) In the example in Figure 5-26, there are 372 snapshots with a retention of 15 days and an interval of 60 minutes.


Automatic Workload Repository

General

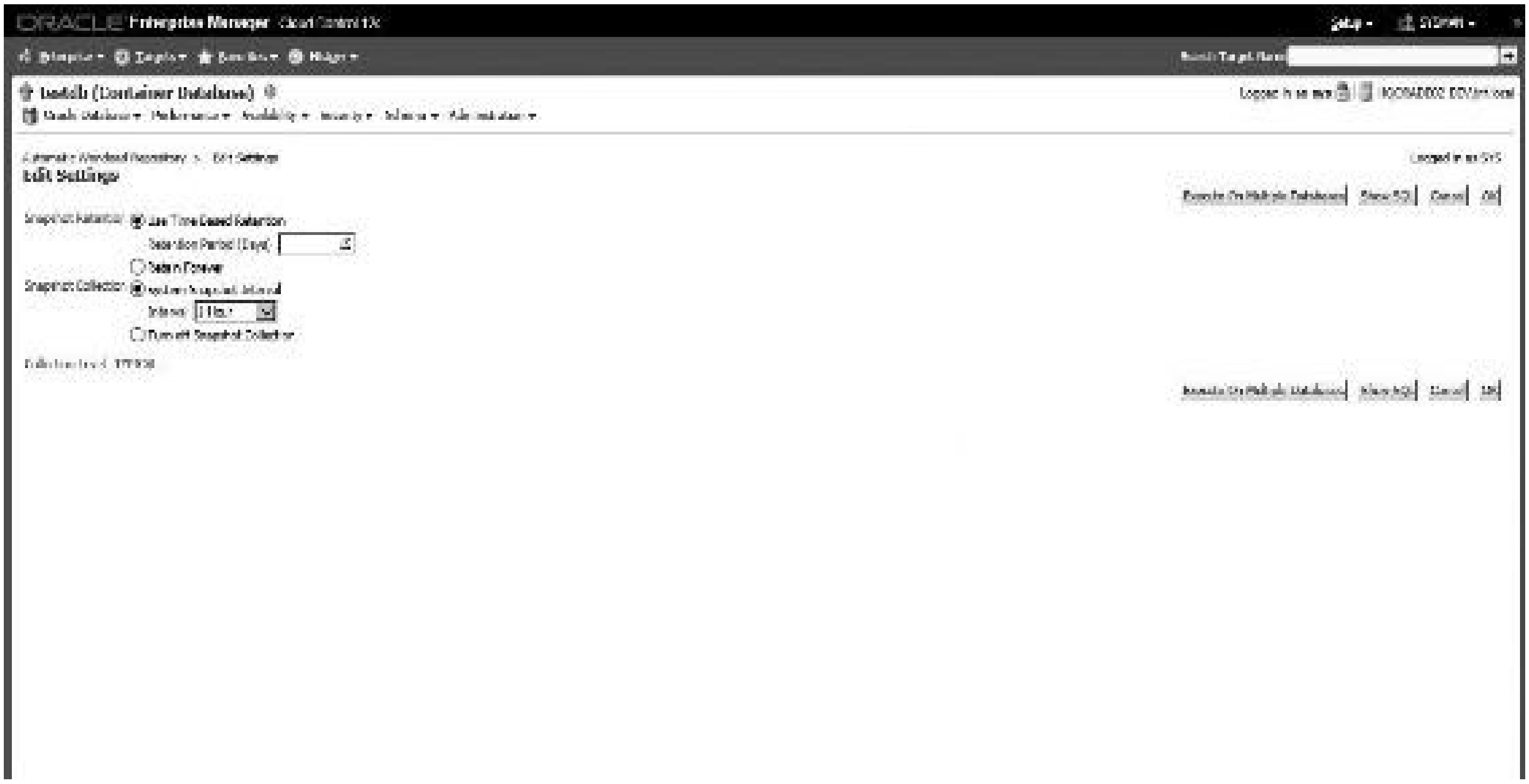
Snapshot Retention (days) 15
Snapshot Interval (minutes) 60
Collection Level TYPICAL
Next Snapshot Capture Time Aug 31, 2015 1:00:47 PM

Manage Snapshots and Baselines

Snapshots 372
Baselines 1
Latest Snapshot Time Aug 31, 2015 12:00:47 PM
Earliest Snapshot Time Aug 16, 2015 1:00:25 AM

FIGURE 5-26. *Automatic Workload Repository screen*

By clicking the Edit button, you can change the interval or retention period on the Edit Settings screen, shown in Figure 5-27. You can also edit the collection level.


Edit Settings

Snapshot Retention [✓ Use Time-Based Retention]
Retention Period (Days) 15
Retain Forever
Snapshot Collection [✓ System Snapshot Interval]
Interval 1 Hour
Turn off Snapshot Collection

Collection Level TYPICAL

FIGURE 5-27. *Automatic Workload Repository Edit Settings*

In Figure 5-26 you can also click the Run Compare Periods Report button and then enter any specific snapshot to begin and end with to generate some basic snapshot details, as shown in Figure 5-28 (like a very mini-Statspack).

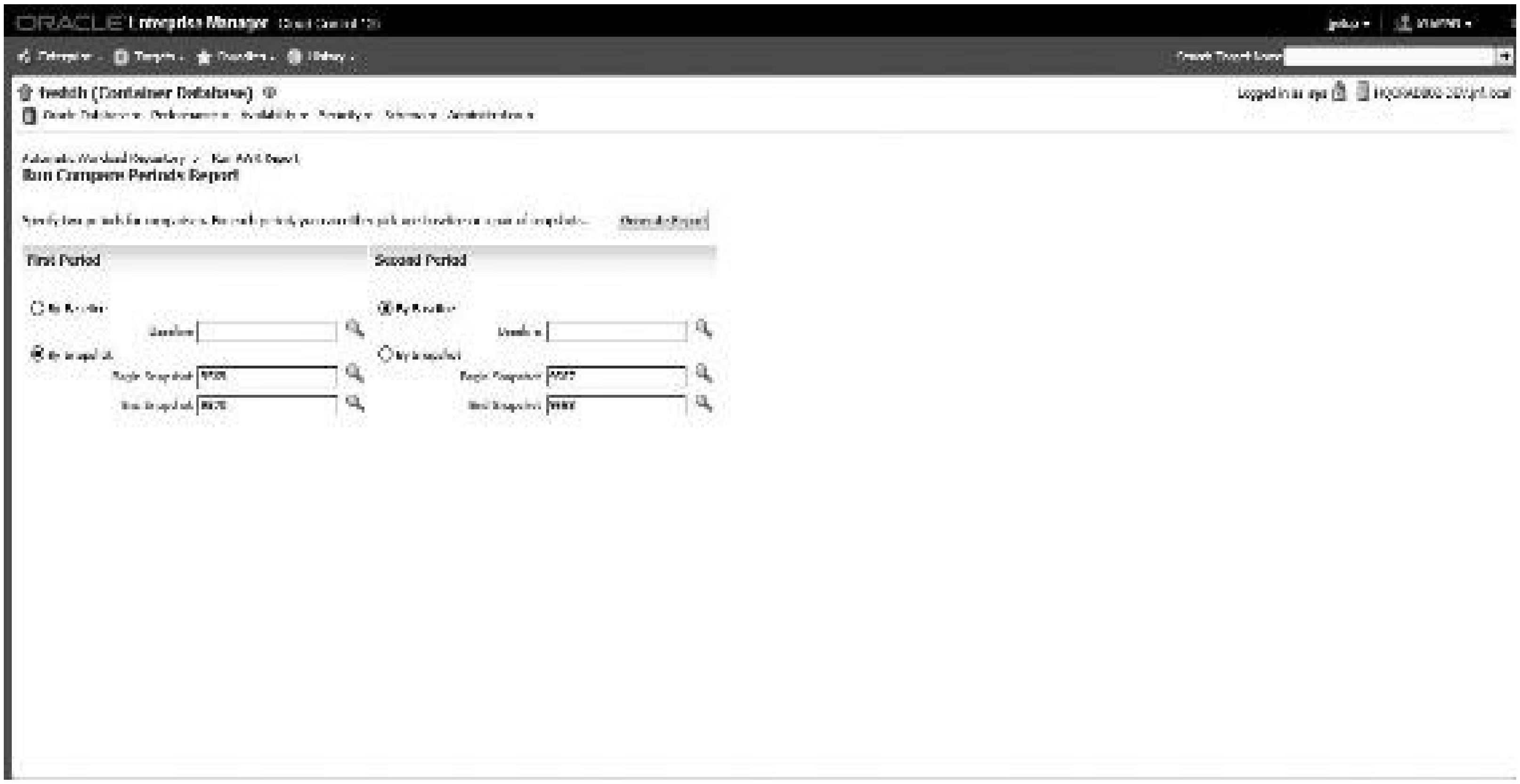
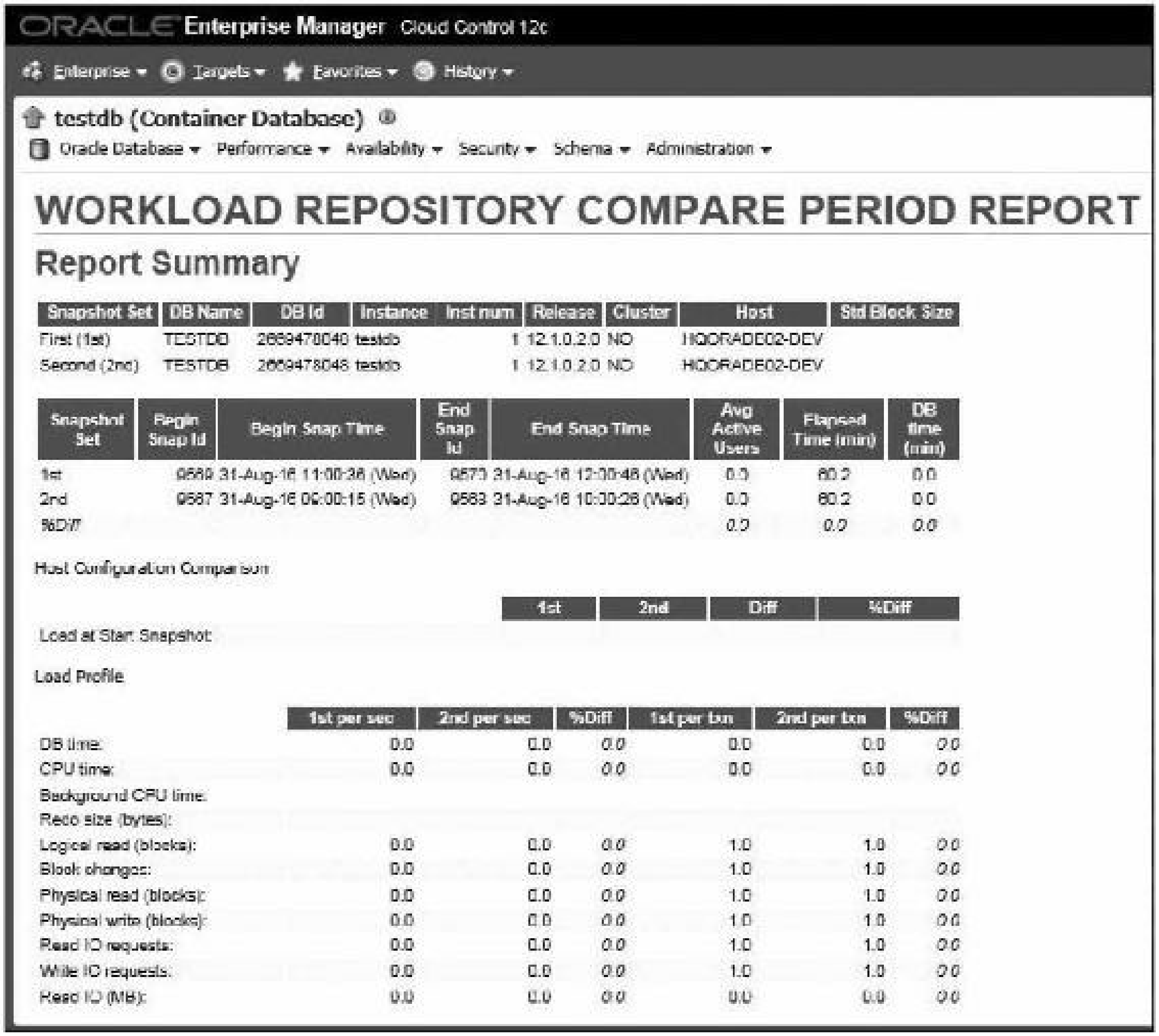


FIGURE 5-28. *AWR Run Compare Periods Report*

Alternatively, you can run and display the full AWR Report by clicking the Run AWR Report button (covered in detail in Chapter 14—see that chapter for full display sections). Once you have completed the Begin Snapshot and End Snapshot fields, click the Generate Report button to generate the report shown in Figure 5-29.


ORACLE Enterprise Manager Cloud Control 12c
Enterprise ▾ Targets ▾ Favorites ▾ History ▾
testdb (Container Database)
Oracle Database ▾ Performance ▾ Availability ▾ Security ▾ Schema ▾ Administration ▾

WORKLOAD REPOSITORY COMPARE PERIOD REPORT

Report Summary

Snapshot Set	DB Name	DB Id	Instance	Inst num	Release	Cluster	Host	Std Block Size
First (1st)	TESTDB	2669478040	testdb	1	12.1.0.2.0	NO	HQORADE02-DEV	
Second (2nd)	TESTDB	2669478046	testdb	1	12.1.0.2.0	NO	HQORADE02-DEV	

Snapshot Set	Begin Snap Id	Begin Snap Time	End Snap Id	End Snap Time	Avg Active Users	Elapsed Time (min)	DB time (min)
1st	9569	31-Aug-16 11:00:36 (Wed)	9573	31-Aug-16 12:00:46 (Wed)	0.0	60.2	0.0
2nd	9567	31-Aug-16 09:00:15 (Wed)	9583	31-Aug-16 10:00:26 (Wed)	0.0	60.2	0.0
%Diff					0.0	0.0	0.0

Host Configuration Comparison

	1st	2nd	Diff	%Diff
Load at Start Snapshot				

Load Profile

	1st per sec	2nd per sec	%Diff	1st per txn	2nd per txn	%Diff
DB time:	0.0	0.0	0.0	0.0	0.0	0.0
CPU time:	0.0	0.0	0.0	0.0	0.0	0.0
Background CPU time:						
Redo size (bytes):						
Logical read (blocks):	0.0	0.0	0.0	1.0	1.0	0.0
Block changes:	0.0	0.0	0.0	1.0	1.0	0.0
Physical read (blocks):	0.0	0.0	0.0	1.0	1.0	0.0
Physical write (blocks):	0.0	0.0	0.0	1.0	1.0	0.0
Read IO requests:	0.0	0.0	0.0	1.0	1.0	0.0
Write IO requests:	0.0	0.0	0.0	1.0	1.0	0.0
Read IO (MB):	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE 5-29. *The AWR Report*

Performance Tab: ASH Analytics

You can access the Active Session History (ASH) Analytics by choosing Performance | ASH Analytics (Figure 5-30). The best report, in my humble opinion, is the Automatic Workload Repository (AWR) Report (covered above). The next best report is a mini-AWR report (as I call it) or the Active Session History Report (ASH Report) found in the reporting sections of OEM. It shows in a very quick way the key sections found in a Statspack or AWR Report. In 12*c*, you now have near real-time ASH information from that report with ASH Analytics (Figure 5-30).

FIGURE 5-30. *Viewing the ASH (Active Session History) Analytics*

Some of the information in the ASH Report includes various Top Events and Load Profile, as in a Statspack or AWR Report. While the details of this report are beyond the scope of this chapter, please refer to Chapter 14 for tuning wait events and detailed information on the AWR Report, which includes much of the same information that will help in understanding the ASH Report.

TIP

The Active Session History (ASH) Analytics is a new and simple way to find and diagnose performance problems quickly.

Monitoring and Tuning Using the OEM Administration Menu

You'll find several tabs under the Database Instance Server or Cluster Database (depending on which one you select). Clicking the Administration menu will show a list of helpful options (Initialization Parameters, In-Memory Central, Storage, Resource Manager, and more). The scope of these options is well beyond this chapter, but you can get an idea from the screen shown in Figure 5-31 that some wonderful built-in tools are available to help the DBA work more effectively and efficiently. A couple of these frequently used options are described in this section.

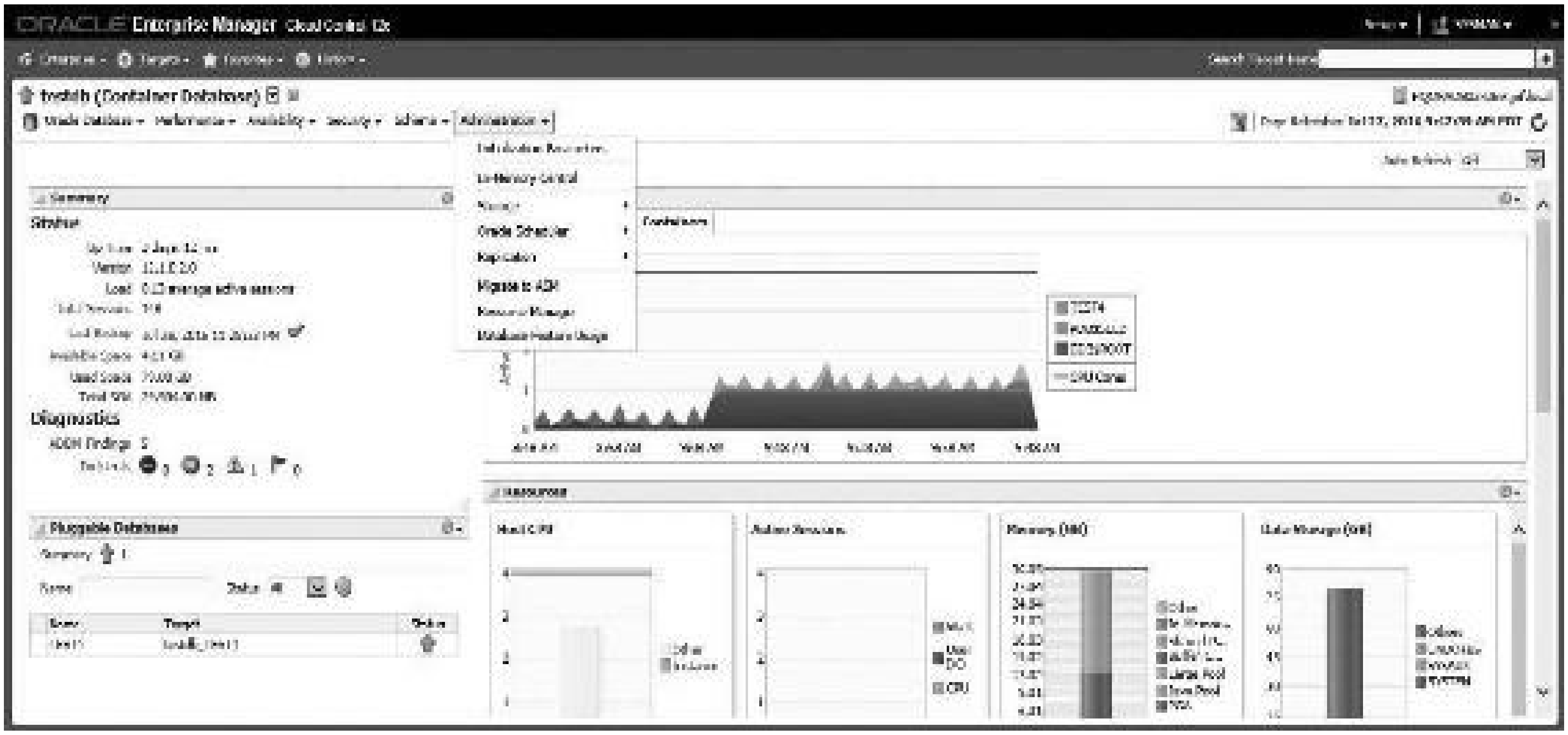
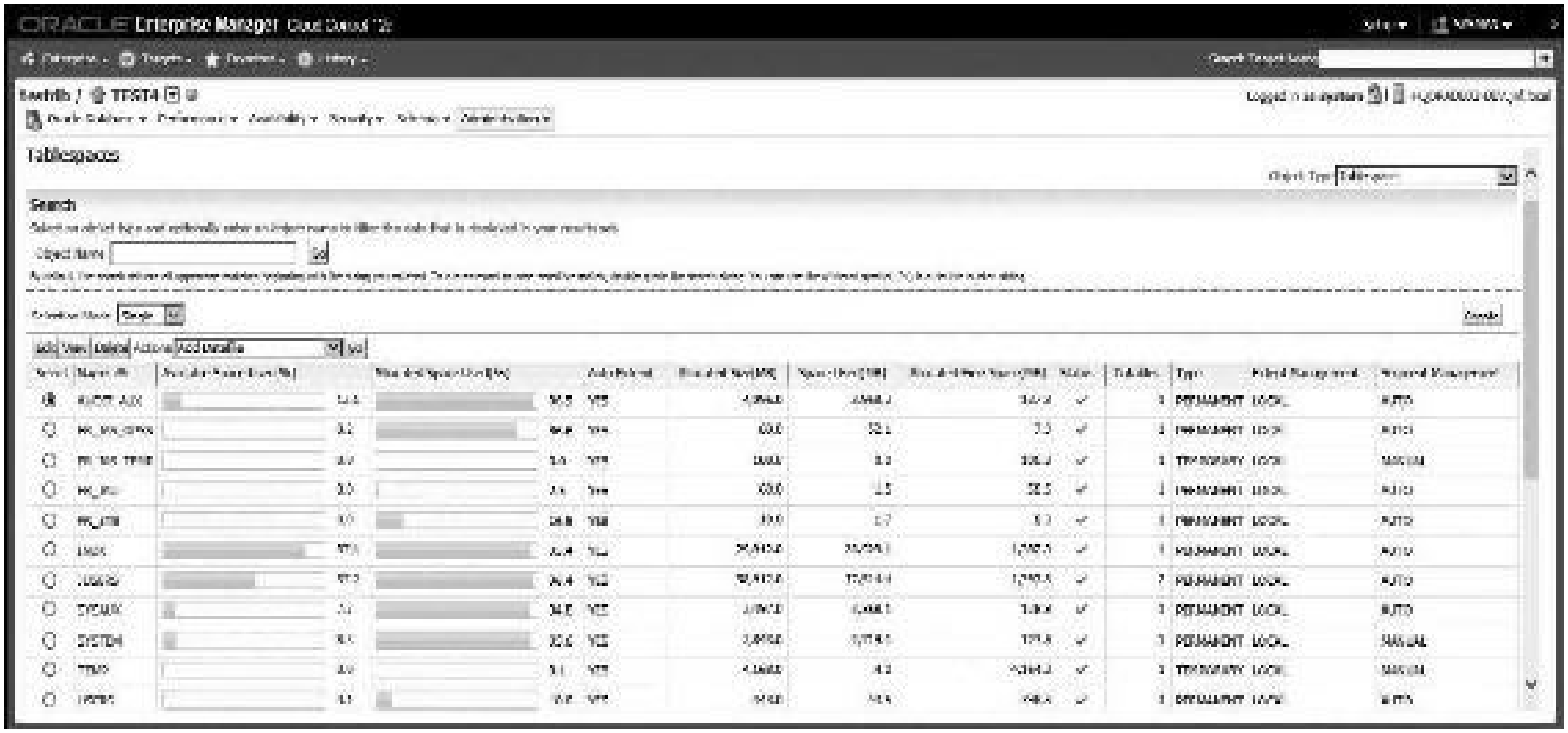


FIGURE 5-31. *The Administration menu*

Database Administration Tab: Storage|Tablespaces

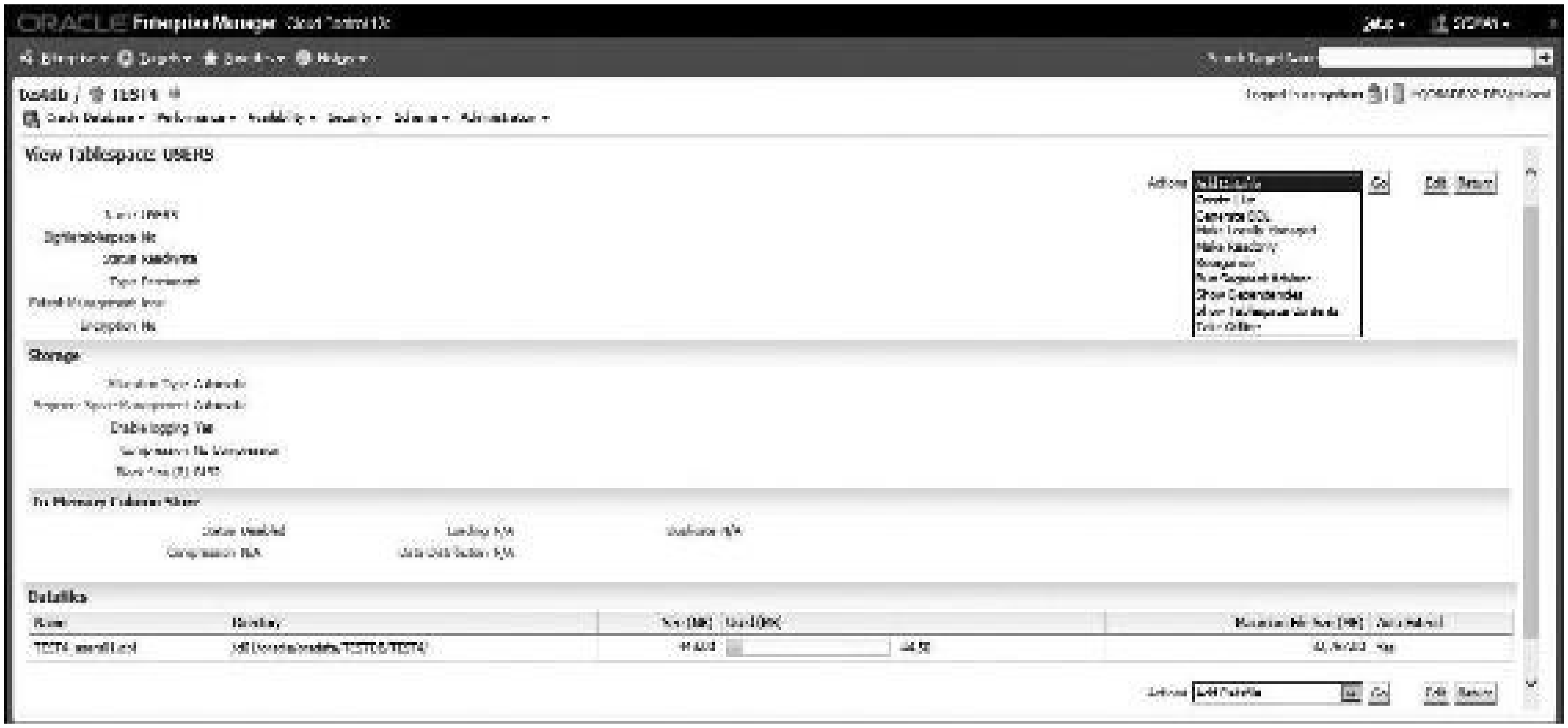
Choosing Administration | Storage | Tablespaces displays the Tablespaces screen, shown in Figure 5-32. This screen lists all of the tablespaces for this database, including information on allocated and used space, the type of tablespace, extent management, and segment management.



Select	Name	Available Space Used (%)	Allocated Space Used (%)	Auto Extend	Allocated Size (MB)	Space Used (MB)	Allocated Free Space (MB)	Status	Datafiles	Type	Extent Management	Segment Management
●	AUDIT_AUX	[illegible]	90.5	YES	[illegible]	[illegible]	[illegible]	✓	1	PERMANENT	LOCAL	AUTO
○	[illegible]	[illegible]	[illegible]	YES	60.0	52.1	7.9	✓	1	PERMANENT	LOCAL	AUTO
○	[illegible]	[illegible]	[illegible]	YES	[illegible]	[illegible]	[illegible]	✓	1	TEMPORARY	LOCAL	MANUAL
○	[illegible]	0.0	[illegible]	YES	60.0	1.5	[illegible]	✓	1	PERMANENT	LOCAL	AUTO
○	[illegible]	[illegible]	[illegible]	YES	[illegible]	[illegible]	[illegible]	✓	1	PERMANENT	LOCAL	AUTO
○	[illegible]	[illegible]	[illegible]	YES	[illegible]	[illegible]	[illegible]	✓	1	PERMANENT	LOCAL	AUTO
○	[illegible]	[illegible]	[illegible]	YES	[illegible]	[illegible]	[illegible]	✓	7	PERMANENT	LOCAL	AUTO
○	SYSAUX	[illegible]	[illegible]	YES	[illegible]	[illegible]	[illegible]	✓	1	PERMANENT	LOCAL	AUTO
○	SYSTEM	[illegible]	[illegible]	YES	[illegible]	[illegible]	[illegible]	✓	1	PERMANENT	LOCAL	MANUAL
○	TEMP	[illegible]	[illegible]	YES	[illegible]	4.0	[illegible]	✓	1	TEMPORARY	LOCAL	MANUAL
○	USERS	[illegible]	[illegible]	YES	[illegible]	[illegible]	[illegible]	✓	1	PERMANENT	LOCAL	AUTO

FIGURE 5-32. *Tablespaces screen, accessed via Administration | Storage*

By clicking a specific tablespace (USERS in this example), the View Tablespace screen in Figure 5-33 is displayed. This screen includes additional information, including the actual datafile(s) underlying the tablespace. Also notice all the available pull-down menu actions. Some of these are *very* powerful and huge time-savers.



View Tablespace: USERS

Actions [illegible] Go Edit Return

- Create Like
- Generate DDL
- [illegible]
- Make Readonly
- [illegible]
- [illegible]
- Show Dependencies
- Show Tablespace Contents
- Take Offline

Name USERS
Bigfile tablespace No
Status Readwrite
Type Permanent
Extent Management Local
Encryption No

Storage

Allocation Type Automatic
Segment Space Management Automatic
Enable logging Yes
Compression No Compression
Block Size (B) 8192

In Memory Column Store

Status Disabled
Loading N/A
Duplicate N/A
Compression N/A
Data Distribution N/A

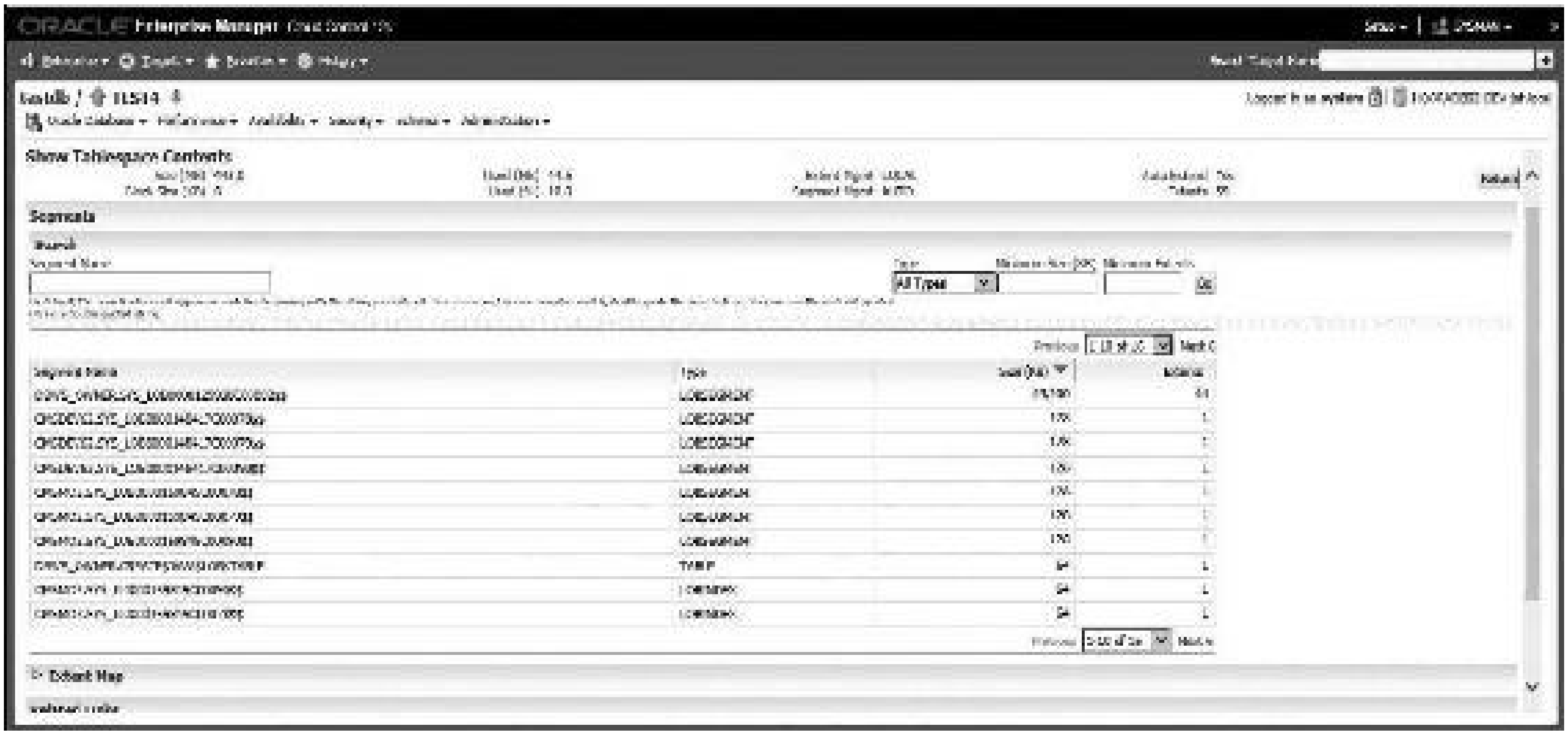
Datafiles

Name	Directory	Size (MB)	Used (MB)		Maximum File Size (MB)	Auto Extend
TEST4_users01.dbf	/u01/oracle/oradata/TESTCDB/TEST4/	[illegible]		[illegible]	[illegible]	Yes

Actions Add Datafile Go Edit Return

FIGURE 5-33. *View Tablespace screen for the USERS tablespace*

Choosing Show Tablespace Contents from the Actions pull-down menu displays the screen shown in Figure 5-34. This shows all of the segments that are contained in the given tablespace and is an excellent way to view objects that correspond to a heavily accessed tablespace.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Show Tablespace Contents

Segments

Search

Segment Name

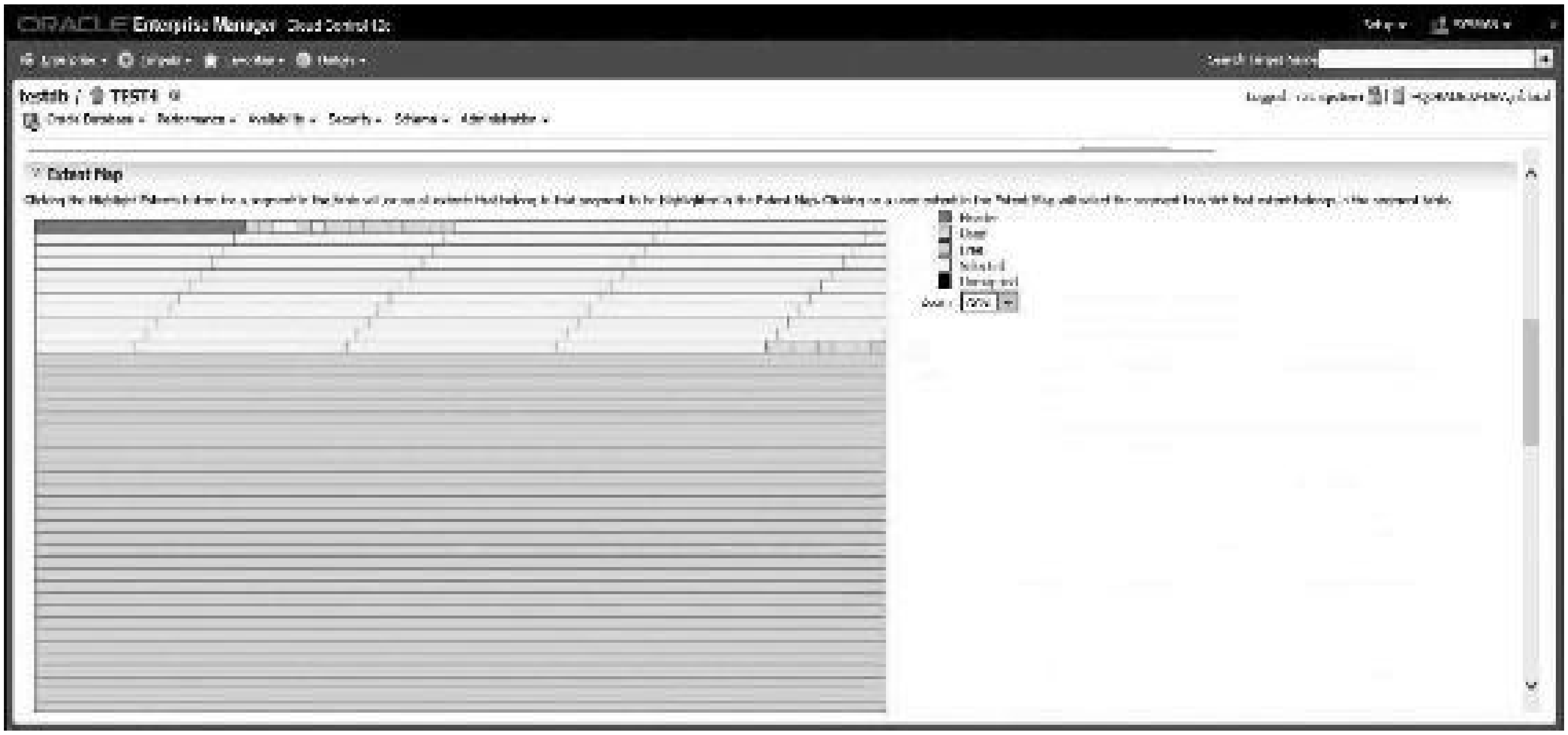
Type: All Types | Minimum Size (KB) | Minimum Extents | Go

Segment Name	Type	Size (KB)	Extents
[illegible]	LOBSEGMENT	[illegible]	[illegible]
[illegible]	LOBSEGMENT	128	1
[illegible]	LOBSEGMENT	128	1
[illegible]	LOBSEGMENT	128	1
[illegible]	LOBSEGMENT	128	1
[illegible]	LOBSEGMENT	128	1
[illegible]	LOBSEGMENT	128	1
[illegible]	TABLE	64	1
[illegible]	LOBINDEX	64	1
[illegible]	LOBINDEX	64	1

Extent Map

FIGURE 5-34. *Show Tablespace Contents screen*

Something more difficult to discover is the Extent Map. Clicking the arrow (>) next to Extent Map (shown at the bottom of Figure 5-34) expands the Show Tablespace Contents screen to display a *very cool* Extent Map, an example of which is shown in Figure 5-35. The Extent Map provides a graphical view of all tablespaces, datafiles, segments, total data blocks, free data blocks, and percentage of free blocks available in the tablespace's current storage allocation. The tool gives you the option of displaying all segments for a tablespace or all segments for a datafile. The Extent Map also provides additional information for each segment, including average free space per block, chained rows, and the last date that the object was analyzed.


ORACLE Enterprise Manager Cloud Control 12c

testdb / TEST4

Extent Map

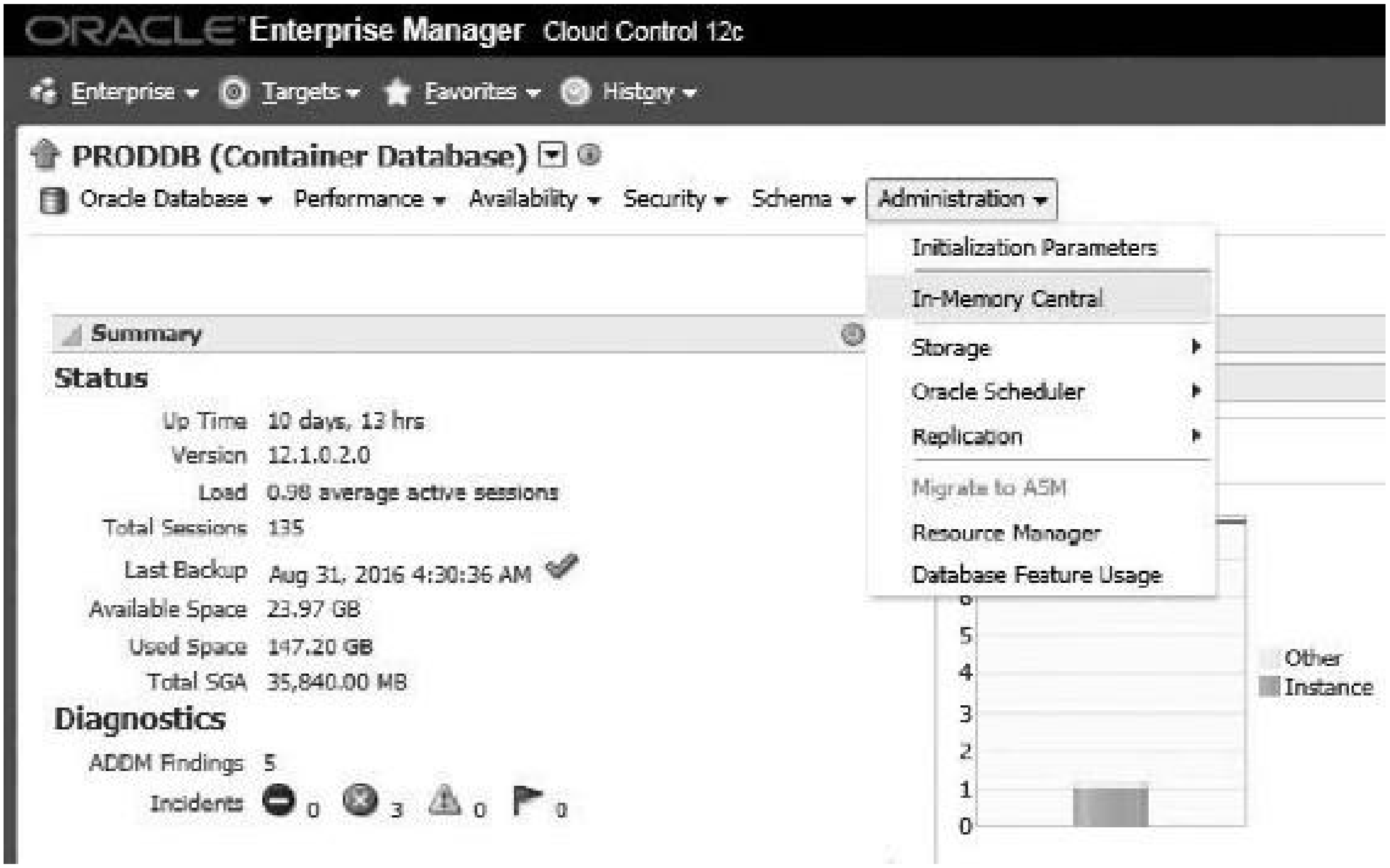
FIGURE 5-35. *Show Tablespace Contents screen with the Extent Map displayed*

TIP

The Extent Map, which displays the information in a tablespace block by block in a graphical manner, is a super-cool feature that's hard to discover in OEM.

Database Administration Tab: In-Memory Central and Initialization Parameters

The Administration menu is useful for getting to many areas that are easier to change using OEM instead of SQL. Items such as In-Memory Central (if you are using the In-Memory feature) and Initialization Parameters (shown at the container database level) are included under the Administration menu (Figure 5-36).



Status

Up Time	10 days, 13 hrs
Version	12.1.0.2.0
Load	0.98 average active sessions
Total Sessions	135
Last Backup	Aug 31, 2016 4:30:36 AM ✓
Available Space	23.97 GB
Used Space	147.20 GB
Total SGA	35,840.00 MB

Diagnostics

ADDM Findings	5
Incidents	0 3 0 0

FIGURE 5-36. *The Administration menu offers many useful options, including In-Memory Central.*

Database Administration Tab: All Initialization Parameters

Choose Administration | Initialization Parameters to open the screen shown in Figure 5-37. You can view and change the current initialization parameters from this screen. You can also group the parameters by category or sort out the dynamic parameters. Other databases and/or instances can be checked for any current values or recent changes.

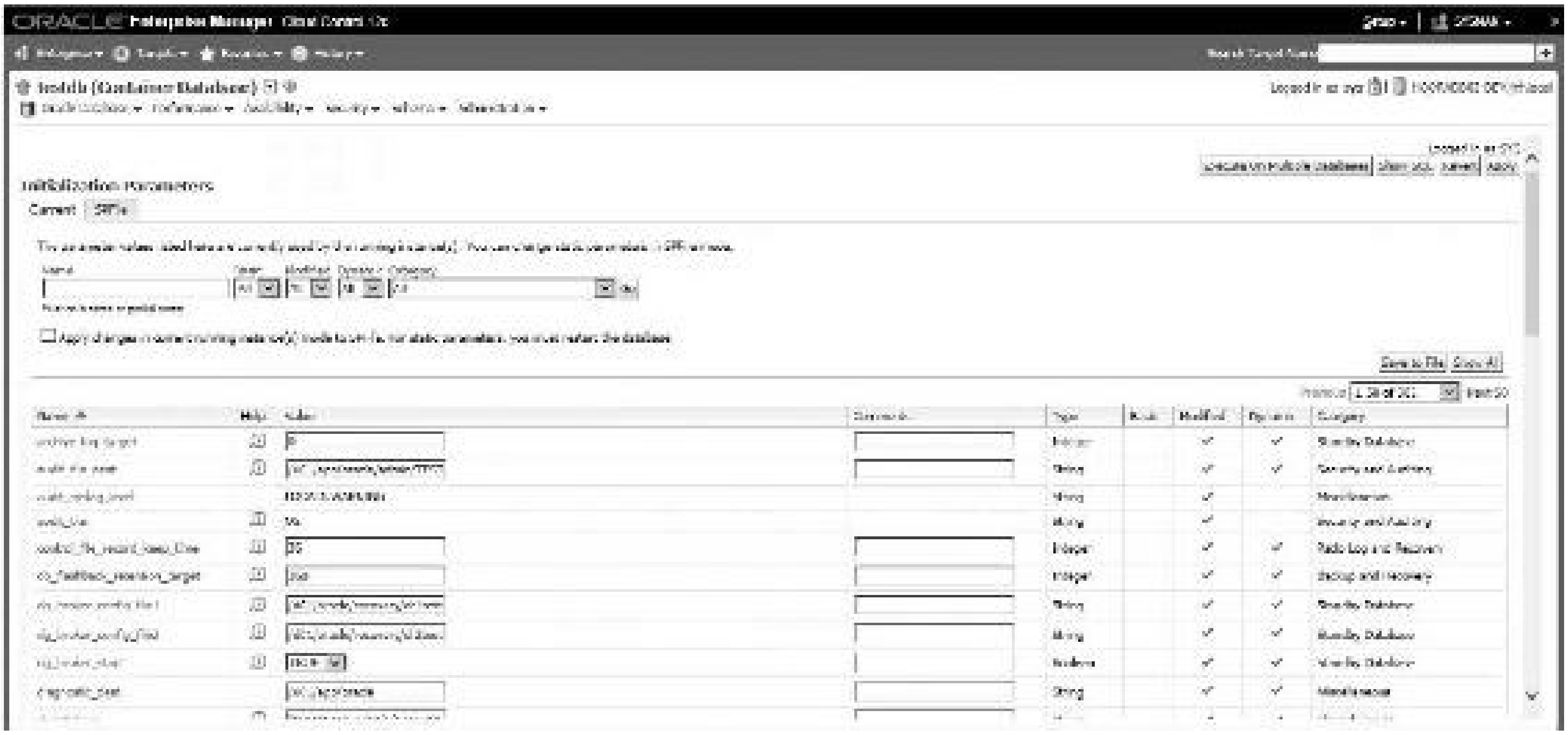
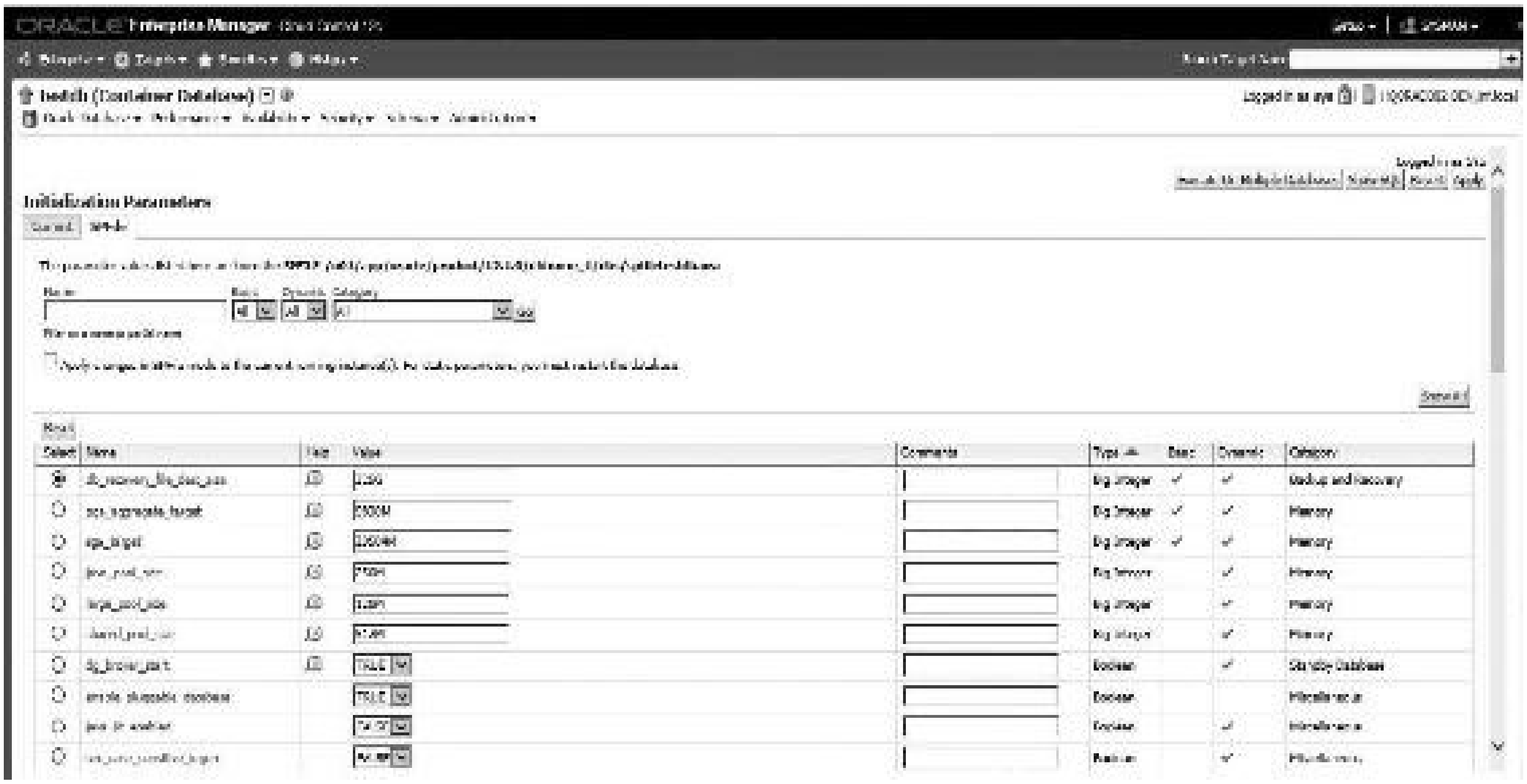


FIGURE 5-37. *Initialization Parameters screen, Current tab*

Clicking the SPFile tab displays the contents (see more information in Chapter 4) if the SPFILE is being used. Figure 5-38 shows an example of viewing the initialization parameters from the SPFILE; it also shows the location.



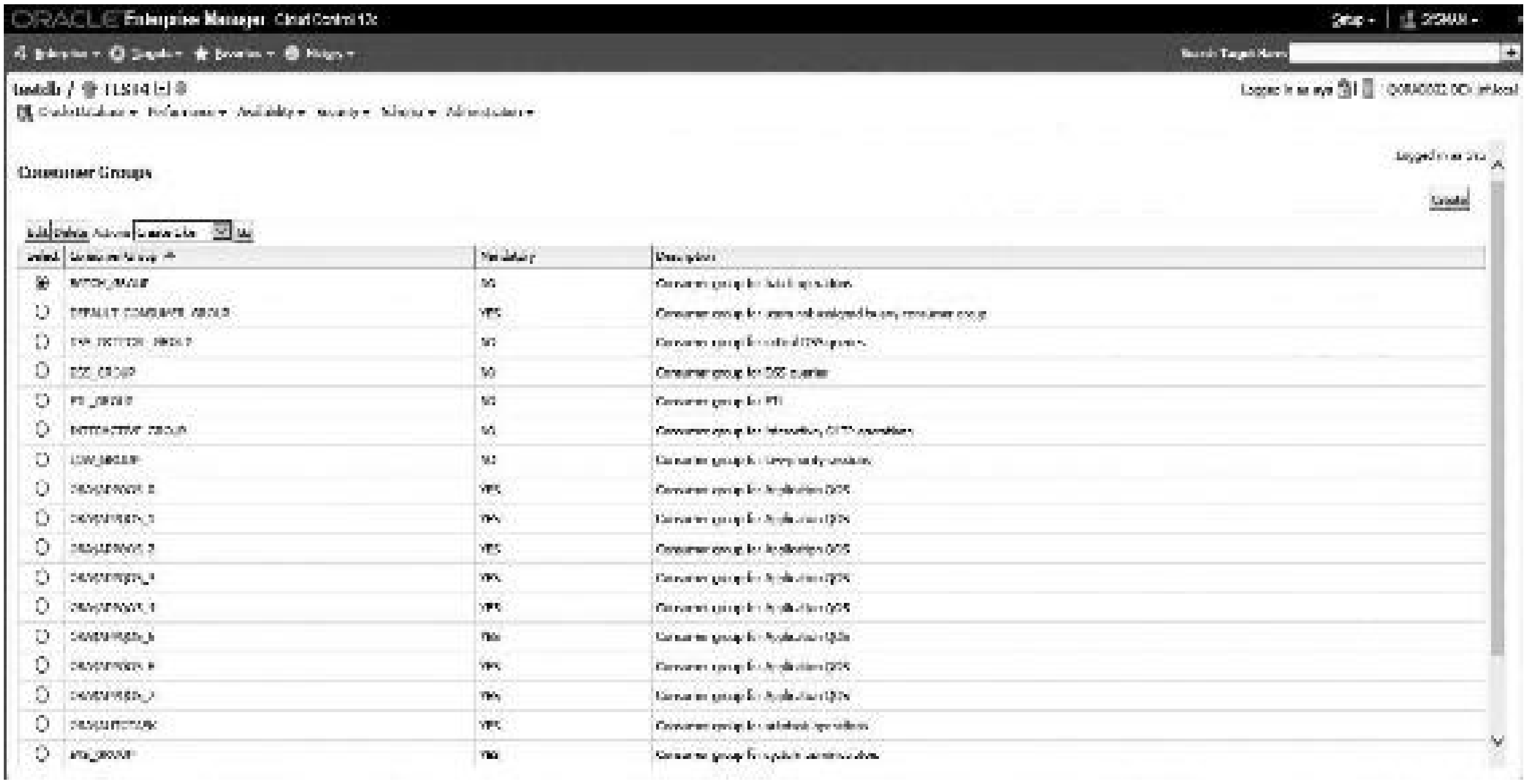
Initialization Parameters

Select	Name	Help	Value	Comments	Type	Basic	Dynamic	Category
●	db_recovery_file_dest_size		[illegible]		Big Integer	✓	✓	Backup and Recovery
○	pga_aggregate_target		[illegible]		Big Integer	✓	✓	Memory
○	sga_target		[illegible]		Big Integer	✓	✓	Memory
○	java_pool_size		[illegible]		Big Integer		✓	Memory
○	large_pool_size		[illegible]		Big Integer		✓	Memory
○	shared_pool_size		[illegible]		Big Integer		✓	Memory
○	dg_broker_start		TRUE		Boolean		✓	Standby Database
○	enable_pluggable_database		TRUE		Boolean			Miscellaneous
○	java_jit_enabled		[illegible]		Boolean		✓	Miscellaneous
○	[illegible]		[illegible]		[illegible]		✓	Miscellaneous

FIGURE 5-38. *Initialization Parameters screen, SPFile tab*

Database Administration Tab: Resource Manager (Consumer Groups)

Another option available from the Administration menu is Resource Manager, which enables you to monitor and tune using consumer groups. After choosing Administration | Resource Manager, click the highlighted Consumer Groups link to display the Consumer Groups screen, as shown in Figure 5-39. A system that includes users in AR (Accounts Receivable), CRM (Customer Relationship Management), and BI (Business Intelligence) can be better visualized when services are set up for each of them (now it's easy to see who is using all of the resources). In Figure 5-39, you see a Consumer Group BATCH_GROUP as the first listing.


Consumer Groups

Select	Consumer Group	Mandatory	Description
●	BATCH_GROUP	NO	Consumer group for batch operations
○	DEFAULT_CONSUMER_GROUP	YES	Consumer group for users not assigned to any consumer group
○	DSS_CRITICAL_GROUP	NO	Consumer group for critical DSS queries
○	DSS_GROUP	NO	Consumer group for DSS queries
○	ETL_GROUP	NO	Consumer group for ETL
○	INTERACTIVE_GROUP	NO	Consumer group for interactive, OLTP operations
○	LOW_GROUP	NO	Consumer group for low-priority sessions
○	ORA$APPQOS_0	YES	Consumer group for Application QOS
○	ORA$APPQOS_1	YES	Consumer group for Application QOS
○	ORA$APPQOS_2	YES	Consumer group for Application QOS
○	ORA$APPQOS_3	YES	Consumer group for Application QOS
○	ORA$APPQOS_4	YES	Consumer group for Application QOS
○	ORA$APPQOS_5	YES	Consumer group for Application QOS
○	ORA$APPQOS_6	YES	Consumer group for Application QOS
○	ORA$APPQOS_7	YES	Consumer group for Application QOS
○	ORA$AUTOTASK	YES	Consumer group for autotask operations
○	SYS_GROUP	YES	Consumer group for system administrators

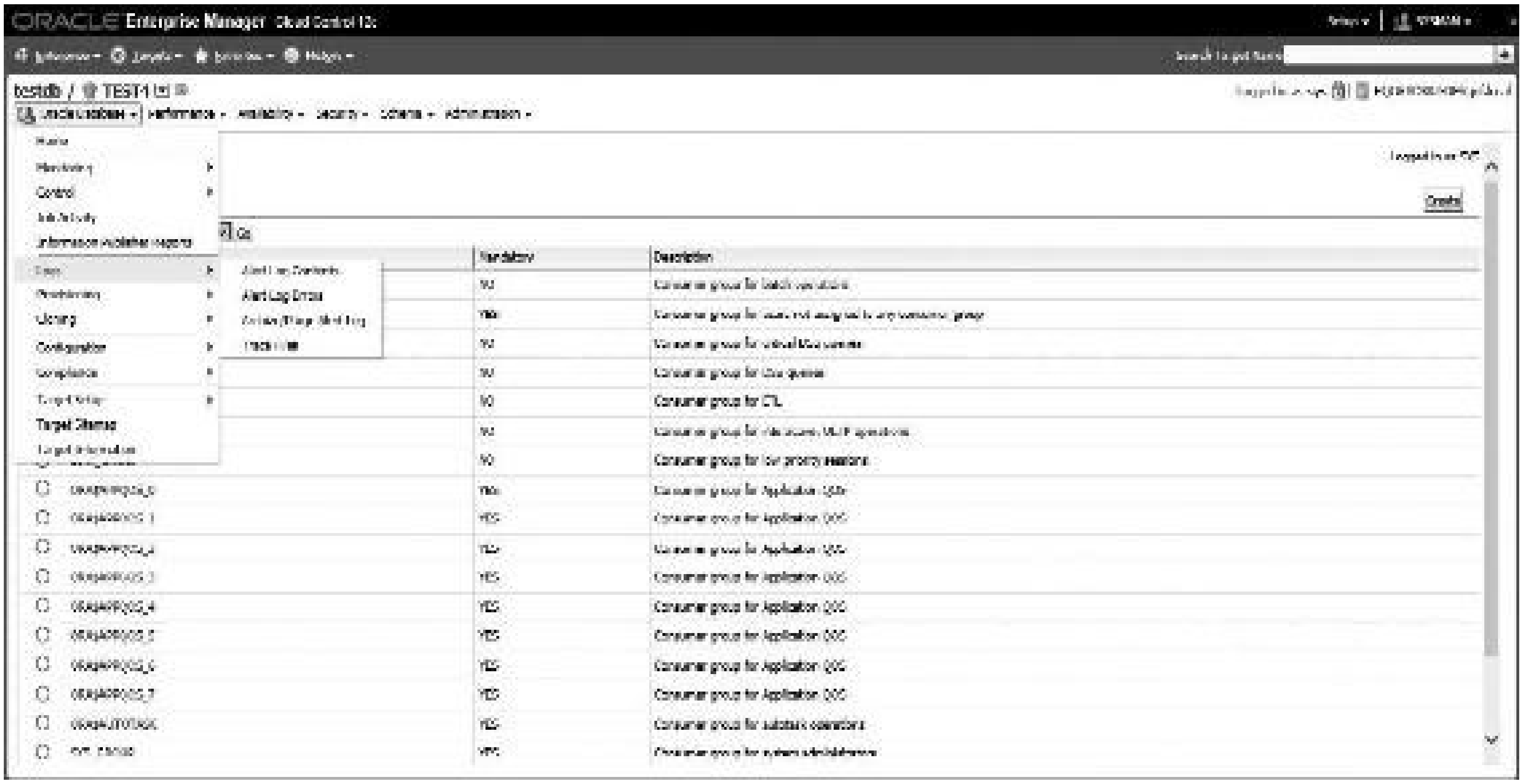
FIGURE 5-39. *Consumer Groups screen*

TIP

If you take the time to set up services, you can use the Top Consumers screen to see quickly which business areas are consuming the most resources.

Monitoring and Tuning Using the OEM Database or Cluster Database Menu

The Oracle Database menu, shown in Figure 5-40, also has several administration options, notably Logs (for accessing associated alert log and trace files, viewing alert log errors, and archiving and purging alert logs), Provisioning, and Cloning.

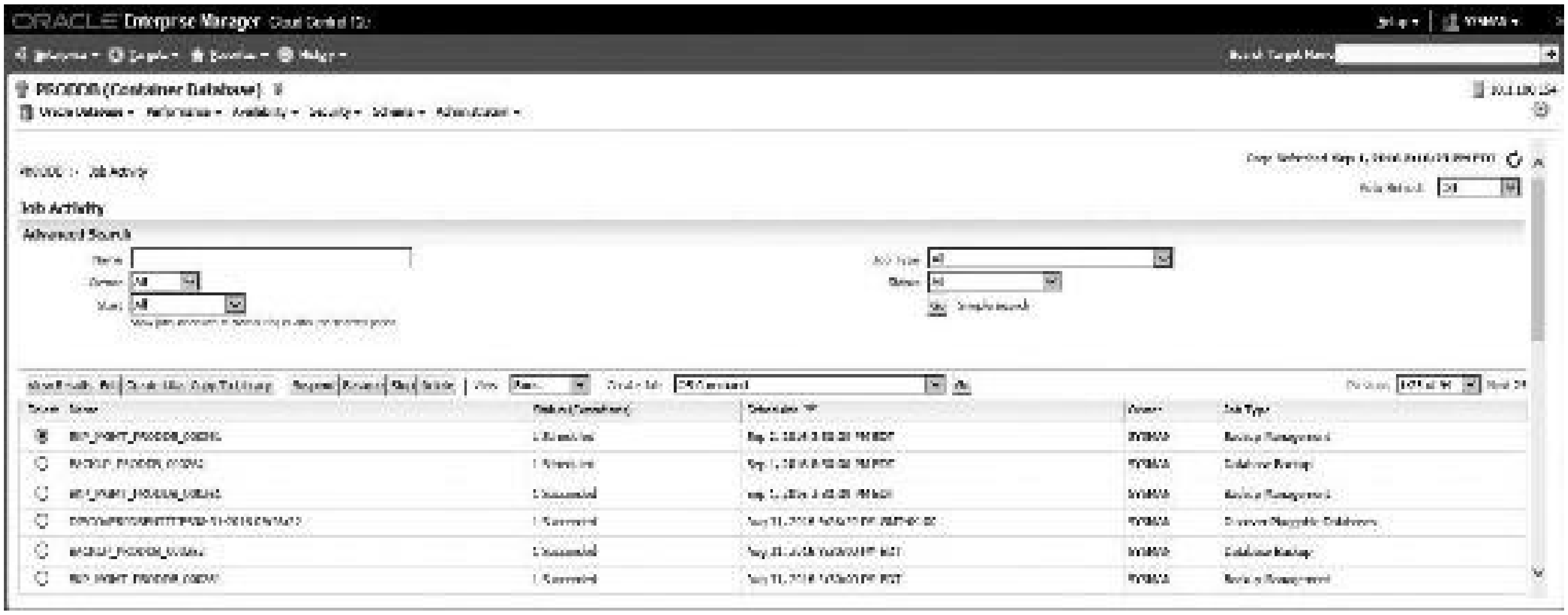


	Mandatory	Description
[illegible]	NO	Consumer group for batch operations
[illegible]	YES	Consumer group for users not assigned to any consumer group
[illegible]	NO	Consumer group for critical DBA sessions
[illegible]	NO	Consumer group for [illegible] queries
[illegible]	NO	Consumer group for ETL
[illegible]	NO	[illegible]
[illegible]	NO	Consumer group for low priority sessions
ORA$APPQOS_0	YES	Consumer group for Application QOS
ORA$APPQOS_1	YES	Consumer group for Application QOS
ORA$APPQOS_2	YES	Consumer group for Application QOS
ORA$APPQOS_3	YES	Consumer group for Application QOS
ORA$APPQOS_4	YES	Consumer group for Application QOS
ORA$APPQOS_5	YES	Consumer group for Application QOS
ORA$APPQOS_6	YES	Consumer group for Application QOS
ORA$APPQOS_7	YES	Consumer group for Application QOS
ORA$AUTOTASK	YES	Consumer group for autotask operations
[illegible]	YES	Consumer group for system administrators

FIGURE 5-40. *Accessing logs and trace files from the Oracle Database menu*

Database Tab: Job Activity

Scheduler Central contains all scheduled tasks. It also includes links for the Oracle Scheduler, Jobs, and Automated Maintenance tasks. Choosing Oracle Database | Job Activity opens the Job Activity screen, in which the job activity and all jobs are listed (Figure 5-41). It show the time that each job will execute, as well as the target system on which the job will execute. There is also information about the owner, status, and job type.



ORACLE Enterprise Manager Cloud Control 13c
PRODCDB (Container Database)
Job Activity
Advanced Search

Select	Name	Status (Executions)	Scheduled	Owner	Job Type
●	[illegible]	1 Scheduled	[illegible]	SYSMAN	Backup Management
○	[illegible]	1 Scheduled	[illegible]	SYSMAN	Database Backup
○	[illegible]	1 Succeeded	[illegible]	SYSMAN	Backup Management
○	[illegible]	1 Succeeded	[illegible]	SYSMAN	[illegible] Pluggable Databases
○	[illegible]	1 Succeeded	[illegible]	SYSMAN	Database Backup
○	[illegible]	1 Succeeded	[illegible]	SYSMAN	Backup Management

FIGURE 5-41. *Job Activity screen*

Cluster Database Tab: Configuration|Database Topology

The Configuration Topology screen (as shown in Figure 5-42) shows the topology for a 12*c* cluster database. Notice that details are shown on the right part of the screen. (Clicking the database from the graph would show details about the database, clicking the Listener from the graph would show details about the listener, etc.) Something nice is the information about the node, which pops up when the mouse rolls over one of the pictures in the graph.

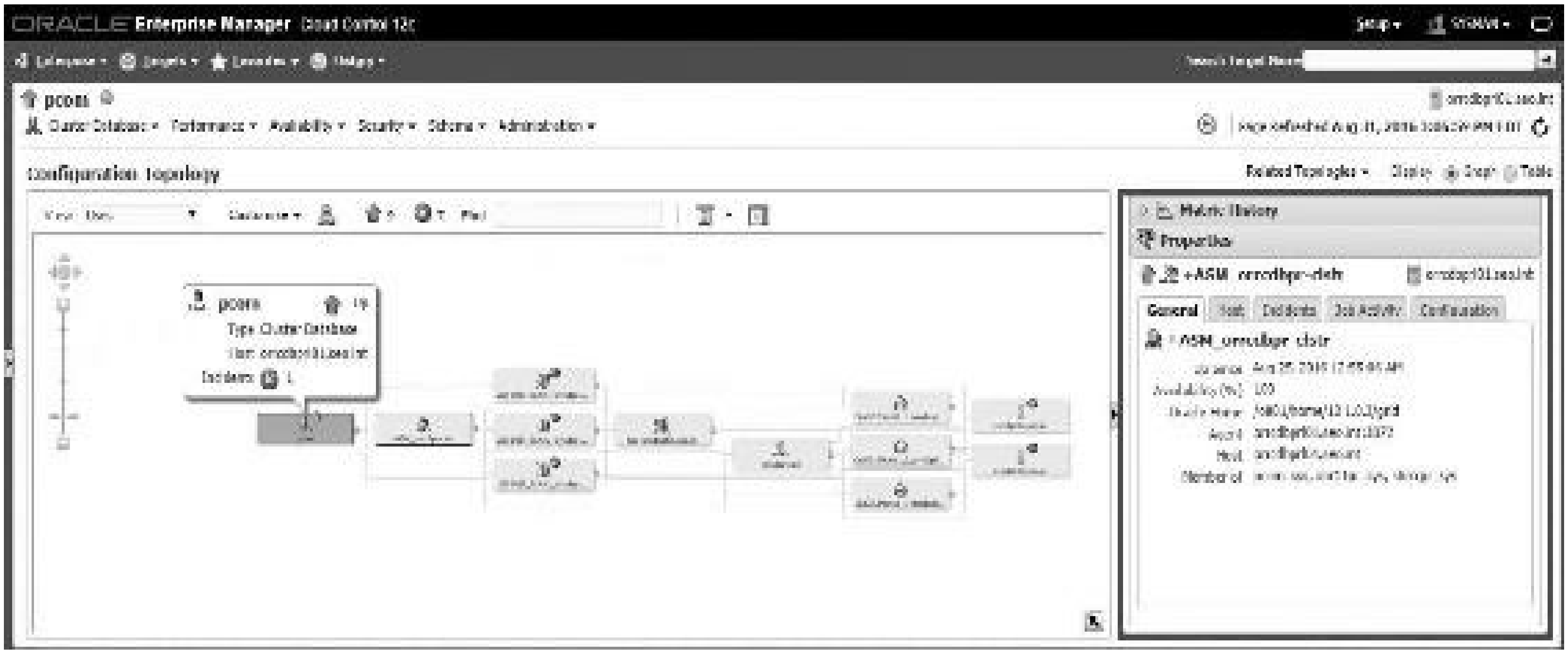
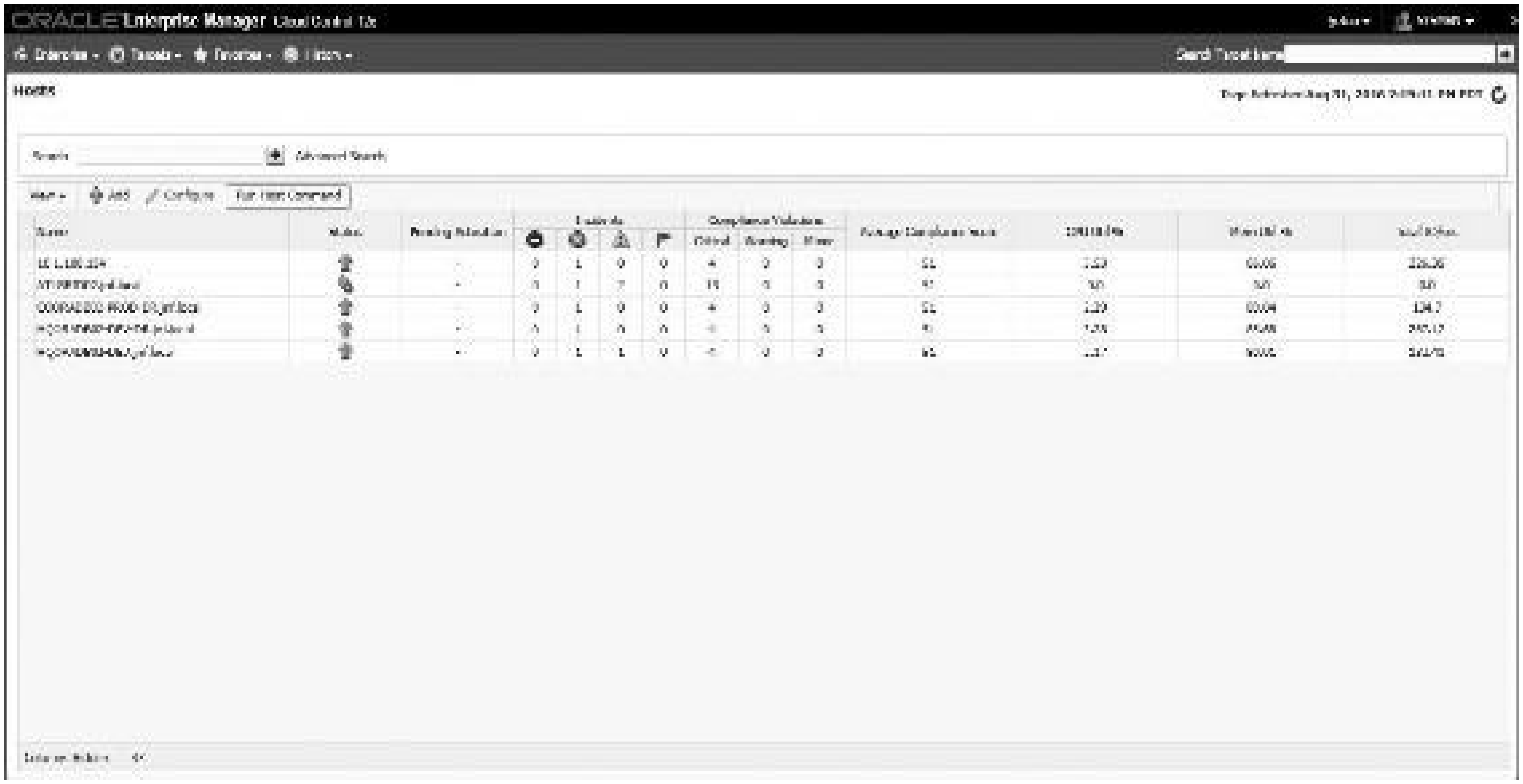


FIGURE 5-42. *Configuration Topology screen*

Monitoring the Hosts

While the Top SQL is usually the problem, digging into other areas of the infrastructure can quickly reveal issues. Choosing Targets (Figure 5-7) | Hosts displays all of the hosts out there. In the example shown in Figure 5-43, five hosts are listed.



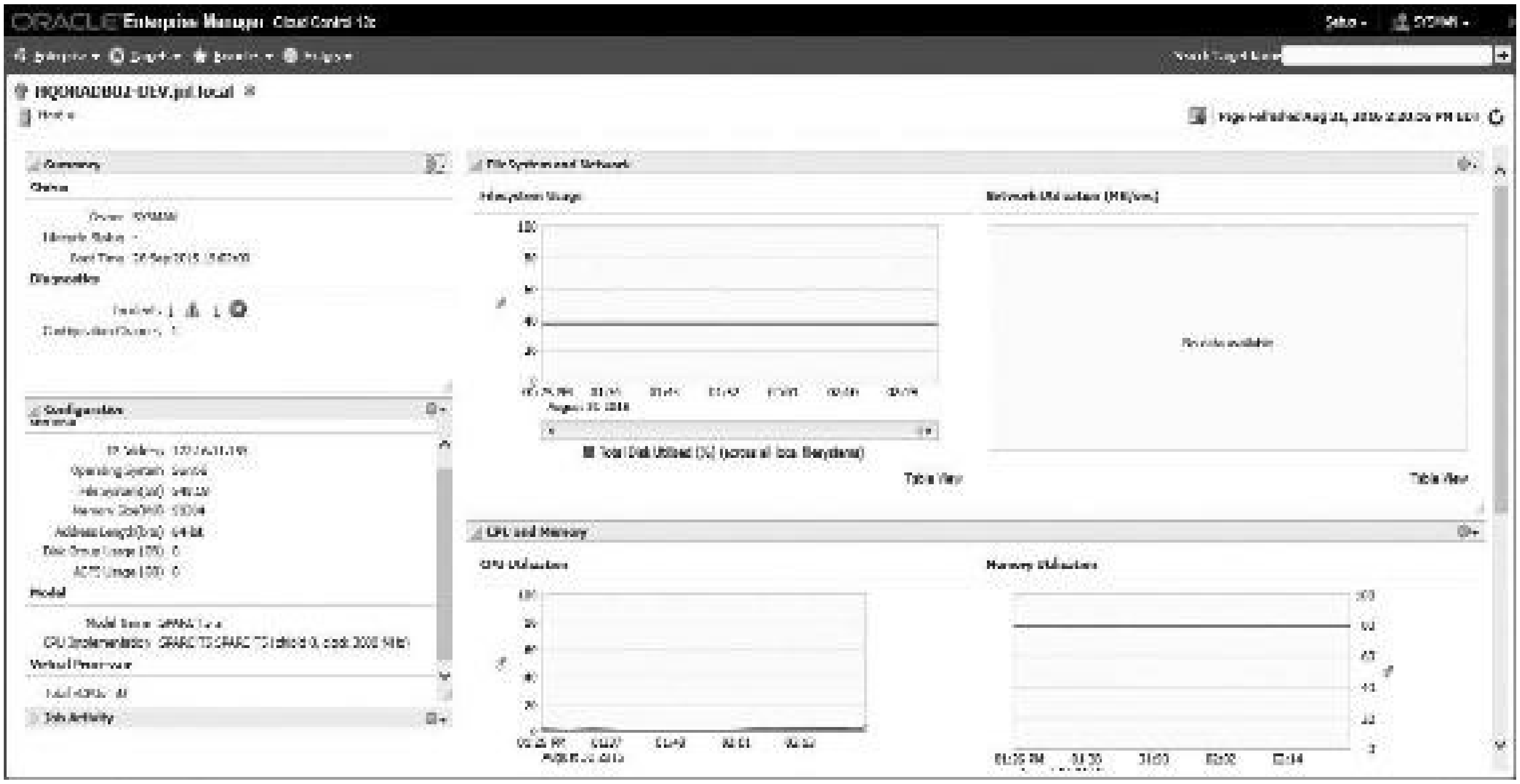
ORACLE Enterprise Manager Cloud Control 12c

Hosts

Name	Status	Pending Activation	Incidents				Compliance Violations			Average Compliance Score	CPU Util %	Mem Util %	Total IO/sec
							Critical	Warning	Minor				
[illegible]		-	0	1	0	0	4	0	0	51	[illegible]	[illegible]	[illegible]
[illegible]		-	0	1	7	0	15	0	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		-	0	1	0	0	4	0	0	51	[illegible]	[illegible]	134.7
[illegible]		-	0	1	0	0	[illegible]	0	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		-	0	1	1	0	[illegible]	0	0	[illegible]	[illegible]	[illegible]	[illegible]

FIGURE 5-43. *The Hosts screen*

Clicking just one of the hosts (HQORADB02) displays all of the detailed information about that host. This includes the IP address, the OS, the number of CPUs, the amount of memory, and the available disk space. It also shows any Alerts or Policy violations as it did at the database or instance level. Figure 5-44 shows that the host is currently up.



ORACLE Enterprise Manager Cloud Control 12c

HQORADB02-DEV.[illegible].local

Summary

Configuration

File System and Network

Filesystem Usage

Network Utilization (MB/sec)

Total Disk Utilized (%) (across all local filesystems)

Table View

CPU and Memory

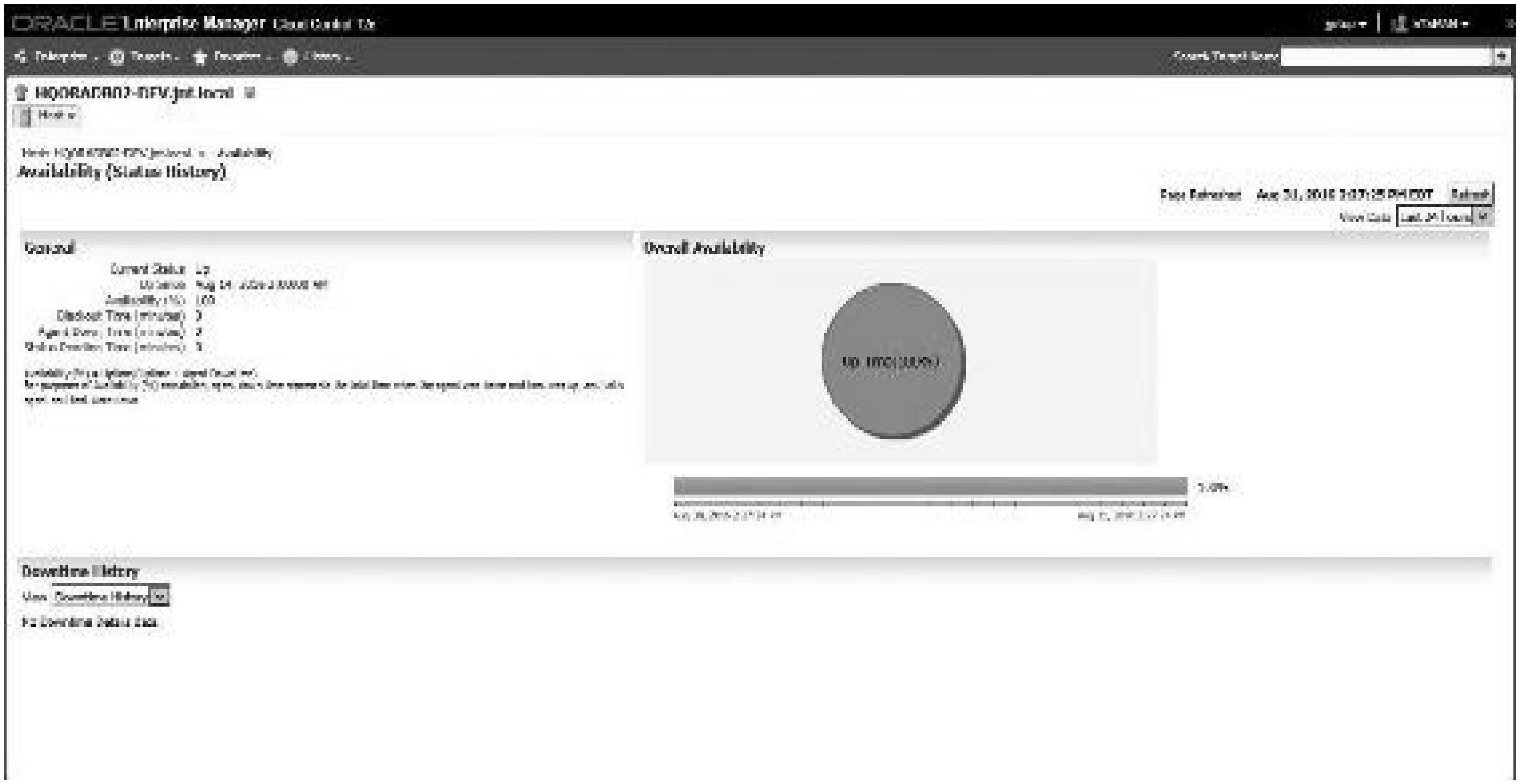
CPU Utilization

Memory Utilization

Job Activity

FIGURE 5-44. *Viewing information about a host*

By clicking the Host tab, hovering over the Monitoring tab from the drop-down menu, and then clicking the Status History button, the complete availability of this host is displayed over a period of time. In Figure 5-45, the host shown has been down 0 percent of the time.



Current Status: Up
Availability (%): 100
Blackout Time (minutes): 0
Agent Down Time (minutes): 0
Status Pending Time (minutes): 0

FIGURE 5-45. *Viewing information about host availability*

Monitoring the Application Servers and Web Applications

While database and host monitoring was crucial to the performance of client/server systems in the 1990s, the Internet and web applications have driven performance issues at the application-server level over the last decade. Finding issues at the application-server level (usually where the actual code is running) is critical to good performance. OEM offers several ways to monitor all application servers. The main way is by choosing it from the Targets in Figure 5-7 as we did for Hosts. The application server name as well as CPU and memory usage is displayed. As at the database and host levels, alerts and policy violations are also listed. One of the nicest aspects of OEM is that you can monitor a piece of the infrastructure or investigate a specific program that is causing performance issues.

In this section, viewing the web application itself will be discussed. Choosing Targets | Web Applications displays all of the information about a given web application. OEM shows whether the application is up or down, how long it's been up, its availability, related topology, alerts, and a variety of performance information. OEM also tests the performance of a given web application by allowing beacons to run at various times to measure its performance. These beacons are representative queries of what a user may be doing on a regular basis. Now the DBA knows when an application is slow because he or she will also be running a query that is similar to the user's query on a regular basis.

Oracle Cloud has added an even better tool for monitoring web applications and specific customer web pages. When you are running Oracle Cloud Services, you can look at the application performance in much more detail using the new Application Performance Monitoring (APM) tool. Figure 5-46 shows the topology of a RideShare application with response times for different tiers, including the AppServer and Database tiers.

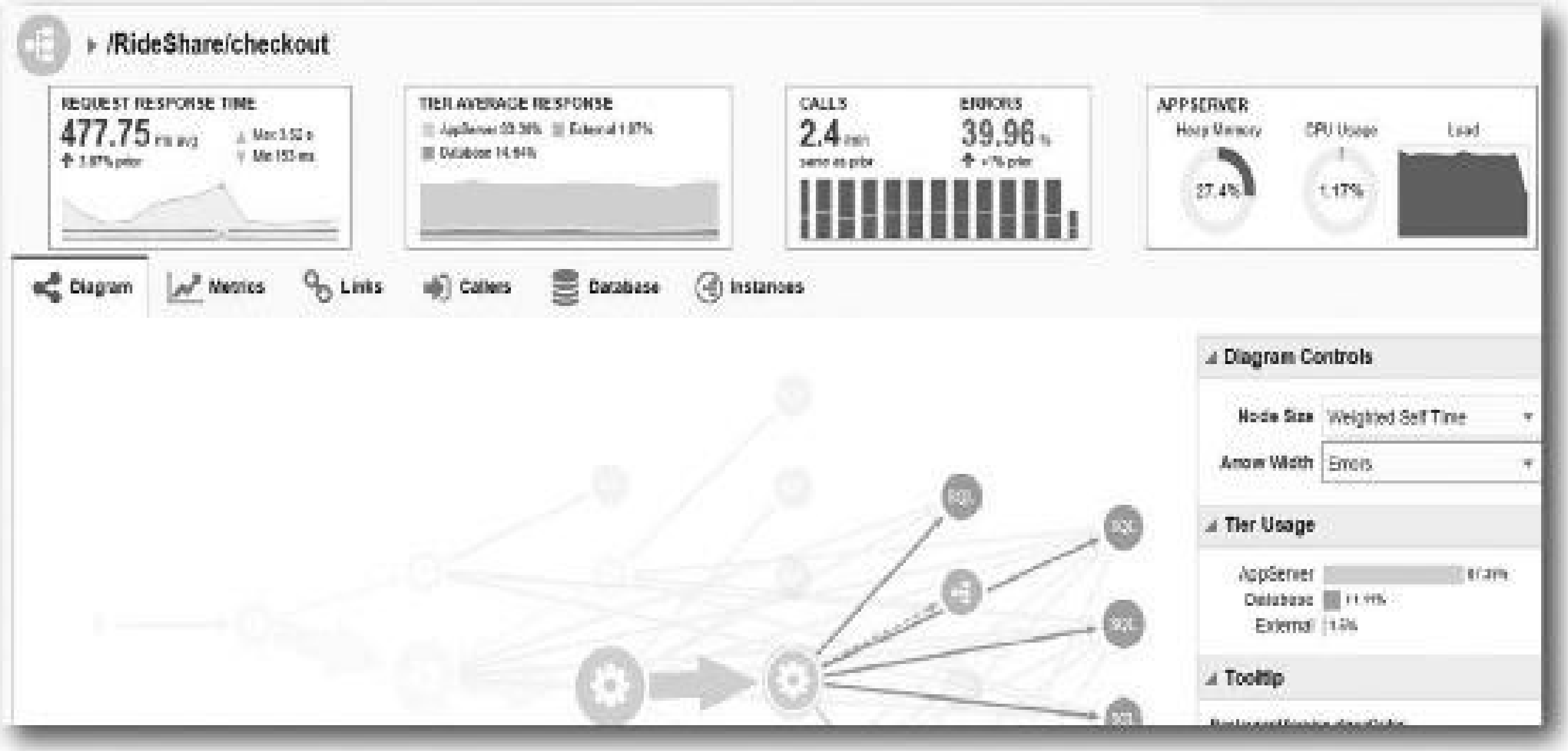
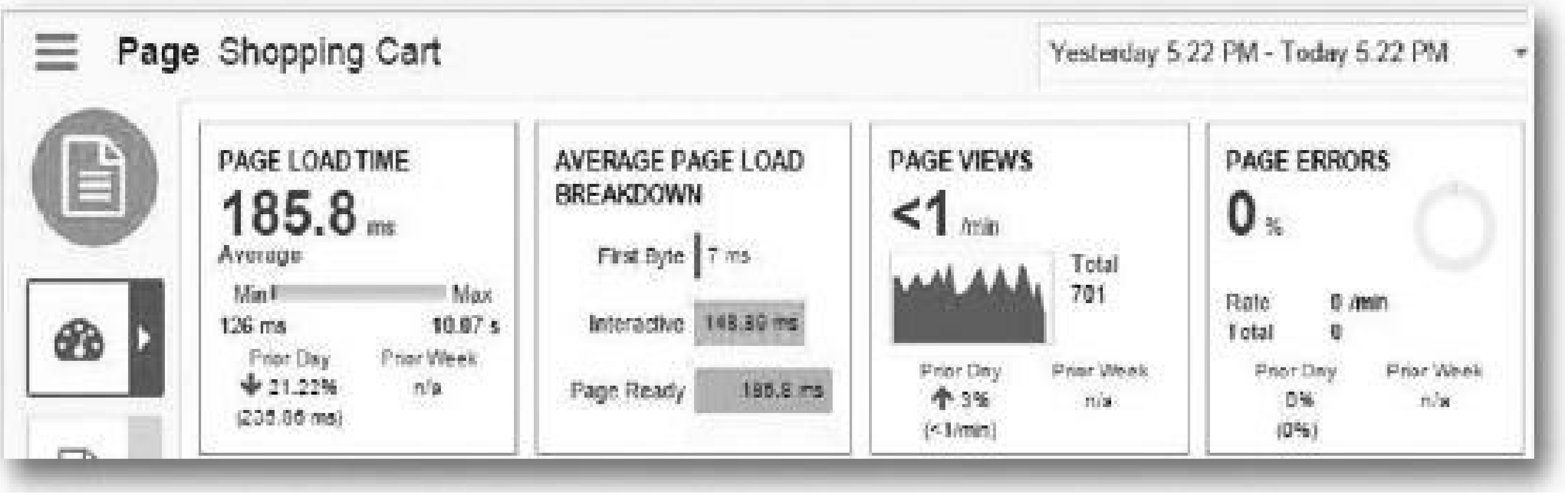


FIGURE 5-46. *Application Performance Monitoring tool application server monitoring*

You can also click a specific application being used by customers and see the breakdown of time spent loading the page, page views in less than a minute, errors, and other details (Figure 5-47). Thank you to Oracle for providing Figures 5-47 and 5-48 of this new product (late 2016).



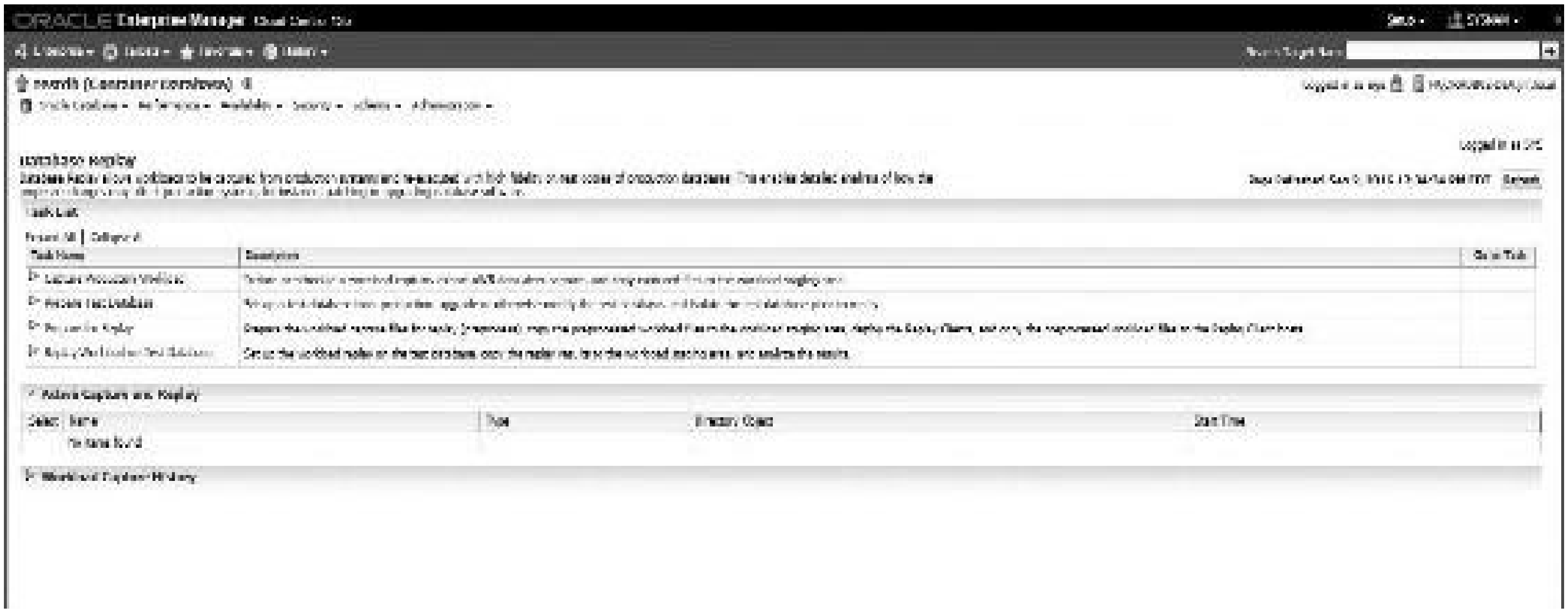
PAGE LOAD TIME
185.8 ms
Average
Min 126 ms
Max 10.87 s
Prior Day ↓ 21.22% (235.86 ms)
Prior Week n/a

AVERAGE PAGE LOAD BREAKDOWN
First Byte 7 ms
Interactive 148.80 ms
Page Ready 185.8 ms

PAGE VIEWS
<1 /min
Total 701
Prior Day ↑ 3% (<1/min)
Prior Week n/a

PAGE ERRORS
0 %
Rate 0 /min
Total 0
Prior Day 0% (0%)
Prior Week n/a

FIGURE 5-47. *Application Performance Monitoring tool customer performance*



Database Replay

[illegible]

Task List

Task Name	Description	Go to Task
Capture Production Workload	[illegible]	
Prepare Test Database	[illegible]	
Prepare for Replay	[illegible]	
Replay Workload on Test Database	[illegible]	

Active Capture and Replay

Select	Name	Type	Directory Object	Start Time
	No items found			

Workload Capture History

FIGURE 5-48. *Database Replay (the capture and replay tasks)*

TIP

You can use Enterprise Manager to monitor web servers and web applications. In Oracle Cloud 12c, Oracle provides a new tool for DevOps called Application Performance Monitoring (APM) to help monitor customer web pages in much greater detail.

Real Application Testing (Database Replay)

Real Application Testing, which captures the *database workload* on one system (usually your current system) and replays it later on a different system (your future system), is a great tool. It is under the Performance tab | Database Replay in Figure 5-9. This is helpful for testing upgrades to 12*c*—capture an 11*g* or 10g workload and then test it against 12*c*. I recommend taking a full Oracle class on this to understand it fully. The Database Replay option is shown in Figure 5-48.

Here are the steps in brief:

1. Capture the workload on a database.
2. Prepare the test database.
3. Prepare for replay.
4. Replay the workload on the test database.
5. Compare your results.

You can compare your results using a few different options. You can run a Synchronized Replay that replays everything with exact concurrency and commits with minimal data divergence. You can also perform an Unsynchronized Replay, which replays without the same concurrency or commits. Also, data divergence can be large depending on the load test performed. A report is created based on Data Divergence, Error Divergence, and Performance Divergence. The detail for the Capture task is shown in Figure 5-49.

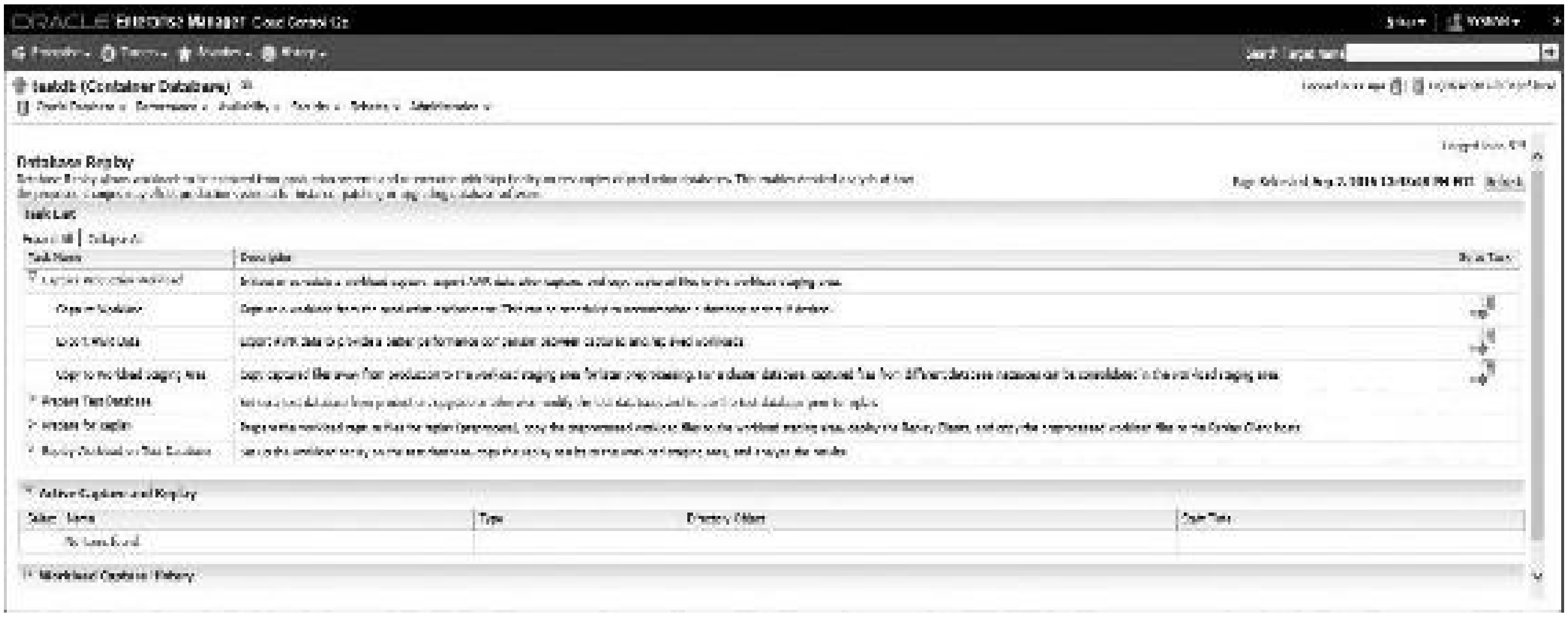


FIGURE 5-49. *Database Replay with Capture details*

TIP
A great way to test how your system will perform on new hardware or with a new version of Oracle is to use Oracle's Real Application Testing (Database Replay).

Summary

With OEM, DBAs are able to manage more databases and also manage systems more effectively using this versatile tool, which now extends into cloud computing, grid computing, and Exadata. This comprehensive knowledge of system health and performance also enables businesses to plan and trend out usage for future growth. Enterprise Manager is the most powerful Oracle utility available. It's not just for beginners; the better you are, the better this tool is. Keep in mind that OEM 13*c* is now available (shown in Figure 5-8), but it doesn't support Linux prior to Release 6 and requires use of a 12.1.0.2+ repository, which is why the functionally similar OEM 12*c* was the main focus of this chapter.

Tips Review

- In Oracle Enterprise Manager 12*c*, the online help is spectacular. Learn something every day by reading or searching for topics in the new Enterprise Manager Online Help button window.
- Use the SQL Tuning Advisor only to tune SQL statements, not conditions such as row locks.
- Compare Explain Plan is a great SQL Tuning Advisor tool built into OEM.
- The Extent Map, which displays the information in a tablespace block by block in a graphical manner, is a super-cool feature that's hard to discover in OEM.
- If you take the time to set up Services, you can use the Top Consumers screen to see quickly which business areas are consuming the most resources.
- You can use Enterprise Manager to monitor web servers and web applications. In Oracle Cloud 12*c*, Oracle provides a new tool for DevOps called Application Performance Monitoring (APM) to help monitor customer web pages in much greater detail.
- The Active Session History (ASH) report is a new and simple report that you can use to find and diagnose performance problems quickly.
- A great way to test how your system will perform on new hardware or with a new version of Oracle is to use Oracle's Real Application Testing (Database Replay).

References

Oracle Enterprise Manager Cloud Control Documentation (Oracle Corporation).
Using Oracle Application Performance Monitoring Cloud Service (Oracle Corporation).
Using Clusterware Administration and Deployment Guide (Oracle Corporation).
Rich Niemiec, *Tuning the Oracle Grid* (IOUG).
Rich Niemiec, "Tuning the Oracle Grid" (Oracle Open World).
Rich Niemiec, "Exadata 101" (Oracle Open World).
Oracle Learning Library
Tuning Pack 2.0 (Oracle White Paper).

Thanks to Asad Mohammed, who did most of the update for the chapter to 12*c*. Thanks to Steve Lemme for the screenshots for APM. Thanks to Anil Khilani, Prabhaker Gongloor (GP), Valerie K. Kane, and David LeRoy of Oracle, who contributed a couple of the screenshots and a bit of the

verbiage to this chapter previously. I want to also thank Ken Morse of Oracle, who contributed the majority of the screenshots and verbiage in the first tuning book on SQL Analyze, Oracle Expert, and Tuning Pack 2.0. Ken was a tremendous help in completing this chapter the first time around, while Valerie and David were instrumental the second time around.

CHAPTER 6

Using EXPLAIN, TRACE, and SQL Plan Management (Developer and DBA)

Finding and fixing problem queries has a lot to do with using the tools that are available. Different tools need to be used for different situations. The tools covered in this chapter are Oracle's provided utilities: SQL TRACE, TKPROF, EXPLAIN PLAN, DBMS_XPLAN, and STORED OUTLINES (previously used, and to convert to what is now used: SQL Plan Baselines/plan stability). These tools were enhanced, including the addition of the DBMS_MONITOR and DBMS_SESSION packages and TRCSESS, in 10*g*. The SQL tracing options have been centralized and extended using the DBMS_MONITOR package. Starting with Oracle 11*g*, SQL PLAN MANAGEMENT (SPM) has been added. STORED OUTLINES still work but are deprecated (discouraged) and will probably be gone for good in a future release. With 12*c*, Adaptive SQL Plan Management has been added.

The tips covered in this chapter include the following:

- Simple steps for using SQL TRACE/TKPROF
- Exploring sections of the SQL TRACE output
- Tracing a more complex query and what to look for to help performance
- Using DBMS_MONITOR
- Using TRCSESS
- Using EXPLAIN PLAN
- Reading EXPLAIN PLAN—top to bottom or bottom to top?
- Using DBMS_XPLAN (a much better way)
- Tracing in developer tools
- Important columns in the PLAN_TABLE table
- Tracing for errors and the undocumented initialization parameters
- Using SQL PLAN MANAGEMENT (SPM)
- Converting from STORED OUTLINES to SQL PLAN MANAGEMENT

- Using adaptive plans and SPM, a 12*c* new feature
- Using Adaptive SQL Plan Management, a 12*c* new feature

The Oracle SQL TRACE Utility

You use the Oracle SQL TRACE utility to measure timing statistics for a given query, a batch process, and an entire system. SQL TRACE is deprecated (discouraged and on the way out) in 11*g*, but it still works and is still used by many developers. It has been replaced with DBMS_MONITOR and DBMS_SESSION. I'm keeping this section because so many people still use SQL TRACE, but please start using the newer packages. SQL TRACE is a thorough method for finding potential bottlenecks on the system. SQL TRACE has the following functionality:

- SQL TRACE runs the query and generates statistics about an Oracle query (or series of queries) that is executed.
- SQL TRACE helps developers analyze every section of a query.

Generally, the Oracle SQL TRACE utility records all database activity (particularly queries) in a *trace* file. This trace file is very hard to read and should be changed into a readable format using the TKPROF utility (as described in the following section).

Simple Steps for SQL TRACE with a Simple Query

The steps for setting up and running Oracle's SQL TRACE utility are listed here:

1. Set the following `init.ora` parameters (SPFILE users will need to use the ALTER SYSTEM command to change these parameters):

```
TIMED_STATISTICS = TRUE
MAX_DUMP_FILE_SIZE = unlimited
```

The TIMED_STATISTICS parameter allows tracing to occur on the system. The MAX_DUMP_FILE_SIZE specifies the maximum file size in "minimum physical block size at device level" blocks. This is the largest size that the file will grow to; any further data to be recorded will be ignored, will not be written to the trace file, and might be missed. Both of these parameters may also be set via an ALTER SYSTEM command (for the entire system) and take effect when the next user logs in, but they will not affect those currently logged in to the system. You may also set the TIMED_STATISTICS and MAX_DUMP_FILE_SIZE parameters at the session level using the ALTER SESSION command (for an individual session). The output will be stored in the USER_DUMP_DEST (for Oracle 10.2 and earlier systems). After 11.1, the DIAGNOSTIC_DEST parameter is used instead, and its value is set automatically by Oracle. To determine the location of the files, run the following script:

NOTE
In addition to VALUE, you can also specify the instance (INST_ID) and container ID (CON_ID) for pluggable databases.

```
select value
from   v$diag_info
where  name = 'Diag Trace';

VALUE
-------------------------------------
/u01/app/oracle/diag/orcl/orcl/trace

The value returned is the path of the trace file.
```

2. Enable SQL TRACE for a SQL*Plus session (this starts tracing for an individual session):

   ```
   alter session set SQL_TRACE true;
   ```

   There are actually several different ways of starting and stopping trace sessions, which will be discussed later in this chapter.

3. Run the query to be traced:

   ```
   select table_name, owner, initial_extent, uniqueness
   from   ind2
   where  owner || '' = 'SCOTT' ; --Note: An index on "OWNER" is suppressed
   ```

4. Disable SQL TRACE for the SQL*Plus session:

   ```
   alter session set SQL_TRACE false;
   ```

   You do not actually have to stop the trace to examine the trace file, but it is a good idea. After running SQL TRACE, your output filename will look something like the following (the process ID is usually included in the trace filename):

   ```
   orcl_ora_19554.trc
   ```

TIP
Setting TIMED_STATISTICS = TRUE in the initialization file enables the collection of time statistics.

Finding the generated trace file may be the trickiest part of this whole process. The generated file should be named for the process ID of the trace session and include that number in the filename. Looking for the date and time of the file makes it easy to find if you are the only one tracing something. In the previous example, 19554 is the process ID of the session being traced. The trace filenames may vary between `ora%` and `ora_%`, depending on the operating system on which the trace was performed, and the file should appear in the location specified by running the script listed in Step 1. Another way of finding the file is to put a marker inside the file output (such as issuing a query like SELECT 'Rich1' FROM DUAL;), and then use a file search utility like `grep` in Linux or Windows

Search to find the text and the file that contains it.

You can use the following query, running from the same session, to obtain the number included in the trace filename (assuming you can access the V$ views):

```
select spid, s.sid,s.serial#, p.username, p.program
from   v$process p, v$session s
where  p.addr = s.paddr
and    s.sid = (select sid from v$mystat where rownum=1);
```

NOTE
Don't forget to grant SELECT on V_$PROCESS, V_$SESSION, and V_$MYSTAT to the user if not already granted.

Run TKPROF at the operating system prompt to convert the trace file into a readable format. The following command creates the file `rich2.prf` in the current directory from the `ora_19554.trc` trace file and also logs in to the database as system/manager to get the EXPLAIN PLAN output:

```
tkprof orcl ora_19554.trc rich2.prf explain=system/manager
```

The TKPROF utility translates the TRACE file generated by the SQL TRACE facility to a readable format. You can run TKPROF against a TRACE file that you have previously created, or you can run it while the program that is creating the TRACE file is still running. Table 6-1 lists options for TKPROF.

Variable	Definition
tracefile	This is the name of the SQL TRACE file containing the statistics by SQL_TRACE.
output_file	This is the name of the file where TKPROF writes its output.
print = number	This is the number of statements to include in the output. If this statement is not included, TKPROF lists all statements in the output.
explain = username/password	Run the EXPLAIN PLAN on the user's SQL statements in the TRACE file. This option creates a PLAN_TABLE of its own, so the user needs to have privileges to create the table and space in which to create it. When TKPROF is finished, this table is dropped. Ensure that you use the username/password of the user who parsed the cursor (ran the query) to ensure the EXPLAIN PLAN output is for the correct user. See Metalink Note 199081.1 for more information. In 12*c*, there is also the option `pdbtrace=username/password`.
insert = filename	This option creates a script to create a table and store the TRACE file statistics for each SQL statement traced.
record = filename	This option produces a file of all the user's SQL statements.
sys = yes|no	This option allows the user to request that the recursive SQL statements (issued by the SYS user) not be displayed in the output. The default is YES. Recursive SQL usually includes internal calls and any table maintenance, such as adding an extent to a table during an insert.
sort = parameters	A tremendous number of sorting options are available. My favorites are FCHCPU (CPU time of fetch), FCHDSK (disk reads for fetch), FCHCU and FCHQRY (memory reads for fetch), FCHROW (number of rows fetched), EXEDSK (disk reads during execute), EXECU and EXEQRY (memory reads during execute), EXEROW (rows processed during execute), EXECPU (execute CPU time), PRSCPU (parse CPU), and PRSCNT (times parsed).
waits = yes|no	Record summary for any wait events.
aggregate = yes|no	If NO, then TKPROF does not combine multiple users of the same SQL text.
table = schema.table	The table into which TKPROF temporarily puts execution plans before writing them to the output file.

TABLE 6-1. *Command-Line Options for TKPROF*

The syntax for TKPROF is as follows:

```
tkprof tracefile output_file [sort = parameters] [print=number]
[explain=username/password] [waits=yes|no]

[aggregate=yes|no] [insert=filename] [sys=yes|no] [table=schema.table]
[record=filename] [width=number]
```

The following are some quick examples using the options described in Table 6-1.

Run TKPROF and list only the top five CPU (fetch + execute + parse) results:

```
tkprof orcl_ora_19554 rich3 explain=system/manager sort=(FCHCPU,EXECPU,PRSCPU)
print=5
```

Run TKPROF and omit all recursive statements:

```
tkprof orcl ora 19554 rich4 explain=system/manager sys=no
```

Run TKPROF and create a file that shows your TRACE session:

```
tkprof orcl ora 19554.trc rich6.prf explain=system/manager record=record1.sql
```

TIP
The TKPROF utility puts traced output into a readable format. Without running TKPROF, reading the output of a TRACE would be difficult. By specifying `explain = username/password` *(as shown in the accompanying examples), you are able to get the EXPLAIN execution path, in addition to the execution statistics of the query.*

TIP
Run TKPROF from the command line without any parameter to get a list of all the parameters.

Now let’s run a quick example and see the output:

```
alter session set sql_trace true ;
select table_name, owner, initial_extent, uniqueness
from   ind2
where  owner || '' = 'SCOTT' ;
alter session set sql_trace false ;
```

Here’s the output:

```
select        TABLE_NAME, OWNER, INITIAL_EXTENT, UNIQUENESS
from          IND2
where         OWNER = 'SCOTT';

              count     cpu     elapsed disk     query     current     rows
Parse:            1     1.00       2.00    0         0           0
Execute:          1     0.00       0.00    0         0           2        0
Fetch:            2    69.00     113.00  142       430           0       36
```

Here is the execution plan (no index used):

```
TABLE ACCESS (FULL) OF 'IND2'
```

The preceding output shows 142 disk reads (physical reads) and 430 total reads (query + current). The number of memory reads is the total reads less the disk reads, or 288 memory reads (430 – 142). Having such a high number of disk reads compared to query reads is certainly a potential problem unless you are running a data warehouse or queries that often do require full table scans. The execution path shows a full table scan, confirming that you may have a potential problem.

TIP
A traced query with a large number of physical reads may indicate a missing index. The DISK column indicates the physical reads (usually when an index is not used), and the QUERY column added to the current column is the total number of block reads (the physical reads are included in this number). A query with a large number of query reads and a low number of disk reads may indicate the use of an index, but if the query reads are overly high, it could indicate a bad index or bad join order of tables. A query with a large number of current reads usually indicates a large DML (UPDATE, INSERT, DELETE) query.

The next listing shows what happens when you rerun the query (after restarting the system) to be traced, but now using an index on the OWNER column:

```
select     table_name, owner, initial_extent, uniqueness
from       ind2
where      owner = 'SCOTT' ;   (The index on "OWNER" is not suppressed)
```

The following listing shows the output of the file `rich2.prf`. Often you'll see zero (0) disk reads for queries that have frequently accessed data. The first time a query is run, there will always be disk reads.

```
select     table_name, owner, initial_extent, uniqueness
from       ind2
where      owner = 'SCOTT' ;

               count     cpu     elapsed disk     query     current     rows
Parse:             2     0.00       0.00    0         0           0        0
Execute:           2     0.00       0.00    0         0           0        0
Fetch:             4     6.00       6.00    0       148           0       72
```

Note that the number of total reads went from 430 to 148 by using an index. The following listing (abbreviated) shows the execution plan (index used):

```
TABLE ACCESS (BY ROWID) OF 'IND2'
  INDEX (RANGE SCAN) OF 'IND2_1' (NON-UNIQUE)
```

The Sections of a TRACE Output

The TRACE utility has multiple sections, including the SQL statement, statistics, information, and EXPLAIN PLAN. Each of these is discussed in the following text sections.

The SQL Statement

The first section of a TKPROF statement (yes, still works in 12.2) is the *SQL statement*. This statement will be exactly the same as the executed statement. If any hints or comments were in the statement, they are retained in this output. This can be helpful when you are reviewing the output from multiple sessions. If you find a statement that is causing problems, you can search for the exact statement. Remember, some of the statements from Oracle Forms are generated dynamically, so parts of the query (particularly WHERE clause predicates) may be displayed as bind variables (:1) and not actual text.

The Statistics Section

The *statistics* section contains all the statistics for this SQL statement and all the recursive SQL statements generated to satisfy this statement. This section has eight columns, the first being the type of call to the database. There are three types of calls: Parse, Execute, and Fetch. Each call type generates a separate line of statistics. The Parse is where the SQL statement itself is put into memory (library cache of the shared pool), or it can also reuse an exact cursor. The Execute is where the statement is actually executed, and the Fetch is where the data is retrieved. The other seven columns are the statistics for each type of call. Table 6-2 explains each column and its definition.

Column	Definition
COUNT	The number of times this type of call was made.
CPU	The total CPU time for all of the calls of this type for this statement. If the TIMED_STATISTICS initialization parameter file is not set to TRUE, this statistic and the elapsed statistic will be 0.
ELAPSED	The total elapsed time for this call.
DISK	The total number of data blocks retrieved from disk to satisfy this call. This is the number of physical reads.
QUERY	The total number of data buffers retrieved from memory for this type of call. SELECT statements usually retrieve buffers in this mode. This is the number of consistent gets.
CURRENT	The total number of data buffers retrieved from memory for this type of call. UPDATE, INSERT, or DELETE usually accesses buffers in this mode, although SELECT statements may use a small number of buffers in this mode also. This is the number of db block gets.
ROWS	The total number of rows processed by this statement. The rows processed for SELECT statements appear in the row of Fetch statistics. INSERTs, UPDATEs, and DELETEs appear in the Execute row.

TABLE 6-2. *Statistics for Each Type of Call*

The Information Section

The *information* section contains information about the number of library cache misses from parse and execute calls. If the number of misses is high, you may have a problem with the size of the shared pool. You should check the hit ratio and the reload rate of the library cache. This section also shows the username of the last user to parse this statement. You'll also find information about the current optimizer mode setting.

The Row Source Operation Section

The *row source operation* section lists the number of rows cross-referenced with the operation that used the rows.

TIP
The trace file is a point-in-time picture of what happened on the system at the time that the trace was run (includes the row source operation). In contrast, the EXPLAIN PLAN (detailed next) is generated when the TKPROF listing is created, which could be some time later. The row source operation listing is generated as part of the trace file and can be used to see if the database objects have changed since the trace was performed.

The EXPLAIN PLAN (Execution Plan)

I find this section of the TKPROF output to be the most useful. The first column of this section is the number of rows processed by each line of the execution plan. Here, you are able to see how slow a statement is. If the total number of rows in the Fetch statistics is low compared to the number of rows being processed by each line of the EXPLAIN PLAN, you may want to review the statement. This plan is generated when you use the EXPLAIN OPTION of the TKPROF command and is the plan that would be generated if the SQL was executed at the time that the TKPROF command was run. If you want the plan that was generated at the time that SQL was originally run, then use the row source operation plan command.

It is also possible that only one line of the execution plan is processing a large number of rows compared to the rest of the statement. This situation can be caused by full table scans or the use of a bad index.

Table 6-3 lists some of the problems to look for in the TKPROF output.

Problem	Solution
The parsing numbers are high.	The SHARED_POOL_SIZE may need to be increased or use bind variables more.
The disk reads are very high.	Indexes are not being used or may not exist.
The query and/or current (memory reads) are very high.	Indexes may be on columns with low cardinality (columns where an individual value generally makes up a large percentage of the table; like a YES|NO field). Removing/suppressing the index or using histograms or a bitmap index may increase performance. A poor join order of tables or bad order in a concatenated index may also cause this.
The parse elapse time is high.	There may be a problem with the number of open cursors.
The number of rows processed by a row in the EXPLAIN PLAN is high compared to the other rows.	This could be a sign of an index with a poor distribution of distinct keys (unique values for a column). This could also be a sign of a poorly written SQL statement.
The number of misses in the library cache during parse is greater than 1.	This indicates the statement had to be reloaded. You may need to increase the SHARED_POOL_SIZE in the `init.ora` file or do a better job of sharing SQL by using bind variables.

TABLE 6-3. *Problems to Look for in the TKPROF Output*

Digging into the TKPROF Output

When you compare the TKPROF output to the actual object's physical characteristics, you start to see how Oracle really works. Consider a CUSTOMER table with over 100,000 records contained in over 1000 blocks. By querying DBA_TABLES and DBA_EXTENTS, you can see the blocks that are both allocated (1536) and being used (1382), as shown in the following listing:

```
select  sum(blocks)
from    dba_segments
where   segment_name = 'CUSTOMER';

SUM(BLOCKS)
-----------
       1536
```

```
select blocks, empty_blocks
from   dba_tables
where  table_name = 'CUSTOMER';

    BLOCKS EMPTY_BLOCKS
---------- ------------
      1382          153
```

If you look at the TKPROF output of a query that counts all records in the CUSTOMER table (shown in the next listing), you see that it performs a full table scan because this is the first access after a startup. Also note that the number of blocks accessed (mostly physical disk access) is slightly higher than the total number of blocks in the physical table (seen in the previous queries). All but 4 of the 1387 query blocks read are disk reads. (Disk reads are a subset of the query, which is the sum of disk and memory reads in consistent mode.)

```
select count(*)
from   customer;

call     count       cpu    elapsed       disk      query    current        rows
------- ------  -------- ---------- ---------- ---------- ----------  ----------
Parse        1   3505.04    3700.00          0          0          0           0
Execute      1      0.00       0.00          0          0          0           0
Fetch        2   1101.59   18130.00       1383       1387         15           1
------- ------  -------- ---------- ---------- ---------- ----------  ----------
total        4   4606.63   21830.00       1383       1387         15           1

Misses in library cache during parse: 1
Optimizer goal: ALL_ROWS
Parsing user id (OE): 85
Number of plan statistics captured: 1

Rows         Execution Plan
0            SELECT STATEMENT  MODE: ALL_ROWS
1              SORT (AGGREGATE)
114688           TABLE ACCESS  MODE: ANALYZED (FULL) OF 'CUSTOMER' (TABLE)
```

If you run this query a second time (shown in the following listing), a big change occurs. Looking at the TKPROF output of a query that counts all records in the CUSTOMER table, this time you see that it still performs a full table scan, but now there are many fewer disk reads because most of the blocks needed are already cached in memory. Most of the 1387 query blocks read are memory reads. (Only 121 are disk reads.)

```
select count(*)
from   customer;

call     count       cpu    elapsed       disk      query    current       rows
------- ------  -------- ---------- ---------- ---------- ----------  -------
Parse        1      0.00       0.00          0          0          0        0
Execute      1      0.00       0.00          0          0          0        0
Fetch        2    901.29    2710.00        121       1387         15        1
------- ------  -------- ---------- ---------- ---------- ----------  -------
total        4    901.29    2710.00        121       1387         15        1

Misses in library cache during parse: 0
Optimizer goal: ALL_ROWS
Parsing user id (OE): 85
Number of plan statistics captured: 1
Rows          Execution Plan
0            SELECT STATEMENT     MODE: ALL_ROWS
1              SORT (AGGREGATE)
114688          TABLE ACCESS      MODE: ANALYZED (FULL) OF 'CUSTOMER' (TABLE)
```

TIP

Full table scans are one of the first things Oracle pushes out of memory (becoming least recently used as soon as you run them) because they are so inefficient, generally using a lot of memory.

Using DBMS_MONITOR

In a multitier environment with connection pooling or a shared server, a session can span multiple processes and even multiple instances. DBMS_MONITOR is a built-in package introduced in Oracle 10*g* that allows any user's session to be traced from client machine to middle tier to the backend database. This makes it easier to identify the specific user who is creating a large workload. DBMS_MONITOR replaces trace tools such as DBMS_SUPPORT. The DBA role is required to use DBMS_MONITOR.

End-to-end application tracing can be based on the following:

- **Session** Based on session ID (SID) and serial number on the local instance.
- **Client identifier** Allows trace to be set across multiple sessions. Specifies the end user based on the logon ID. Set this using the DBMS_SESSION.SET_IDENTIFIER procedure.
- **Instance** Specifies a given instance based on the instance name.
- **Service name** Specifies a group of related applications. Set using the DBMS_SERVICE.CREATE_SERVICE procedure (which creates a DB service).
- **Module name** Set by developers in their application code using procedure

DBMS_APPLICATION_INFO.SET_MODULE. This name is used to represent the module or code being executed.

- **Action name** Set by developers in their application code using procedure DBMS_APPLICATION_INFO.SET_ACTION. This name is used to represent the action being performed by the module.

End-to-end application tracing can generate the following details:

- **Waits** If TRUE, then wait information is written to the trace file.
- **Binds** If TRUE, then bind information is written to the trace file.
- **Instance name** The name of the instance being traced if this parameter is set.
- **Plan stat** (new in 11*g*) Frequency that row source statistics are written to trace file (possible values include NEVER, FIRST_EXECUTION [default], or ALL_EXECUTIONS).

Service name, module name, and action name are associated hierarchically; you can't specify an action name without specifying the module name and the service name, but you can specify only the service name, or only the service name and module name.

Oracle 11*g* introduced an important parameter called *plan stat*. If you want to guarantee that a *row source plan* is present in the trace file for each SQL statement, then use a value of ALL_EXECUTIONS for the parameter.

TIP
Using a value of ALL_EXECUTIONS for the PLAN_STAT ensures that information regarding the execution plans is always contained in the trace file.

Setting Trace Based on Session ID and Serial Number

To set the trace based on session ID and serial number, first determine the SID and serial number of the session you want to trace:

```
select sid,serial#,username
from   v$session;

       SID    SERIAL# USERNAME
---------- ---------- ------------------------------
       156       3588 SCOTT
       142       1054 SYS
```

To enable the trace using DBMS_MONITOR:

```
SQL> exec dbms monitor.session trace enable(156,3588,TRUE,FALSE);
```

The third parameter is for waits (default is TRUE), and the fourth parameter is for bind variables (default is FALSE).

To turn off the trace:

```
SQL> exec dbms monitor.session trace disable(156,3588);
```

To trace the current session, set the SID and SERIAL# to NULL:

```
SQL> exec dbms monitor.session trace enable(null,null);
```

(or exit the session).

Setting Trace Based on Client Identifier

To set the trace based on a client identifier as the user, first set the identifier for the current session by running the following:

```
SQL> exec dbms session.set identifier('bryan id');
```

To verify the client identifier:

```
select sid,serial#,username, client_identifier
from   v$session
where  client_identifier is not null;

       SID    SERIAL# USERNAME                       CLIENT_IDENTIFIER
---------- ---------- ------------------------------ ------------------
       156       3588 SCOTT                          bryan id
```

Now you can set the trace for this client identifier:

```
SQL> exec dbms_monitor.client_id_trace_enable(client_id=>'bryan
id',waits=>true,binds=>false);
```

The second parameter is for waits (default is TRUE), and the third parameter is for bind variables (default is FALSE). The benefit of using CLIENT_ID traces is that tracing is enabled for all instances and is persistent across restarts. Whatever shared process or session ID the client with the identifier `bryan id` uses, this user's activities will be written to one or more trace files. For a multitier environment, the connection between the end client and database is nonstatic; that is, the end client makes a request and can be routed to different database sessions from the middle tier. In older versions, you had no way to keep track of clients across many database sessions, whereas now you can use end-to-end tracing to get the CLIENT_IDENTIFIER attribute. This column can also be found in V$SESSION.

To disable this client identifier trace:

```
SQL> exec dbms monitor.client id trace disable('bryan id');
```

Setting Trace for the Service Name/Module Name/Action Name

In order to use the action name, you must include the module name and the service name. In order to use the module name, the service name must be present. Tracing is enabled for a given combination of service name, module name, and action name globally for a database unless an instance name is specified for a procedure. The service name is determined by the connect string used to connect to a service.

An Oracle database is represented to clients as a service; that is, the database performs work on behalf of clients. A database can have one or more services associated with it. For example, you could have one database with two different services for web clients: book.us.acme.com for clients making book purchases and soft.us.acme.com for clients making software purchases. In this example, the database name is SALES.ACME.COM, so the name isn't even based on the database name. The service name is specified by the SERVICE_NAMES parameter in the initialization parameter file. A default service name is created automatically for the database with the same name as the global database name, a name comprising the database name (DB_NAME parameter) and the domain name (DB_DOMAIN parameter).

To enable tracing for a service name (assuming the service ebk2 has been created):

```
SQL> exec dbms monitor.serv mod act trace enable(service name=>'ebk2');
```

This traces all sessions that connect to the database using a service with the name of ebk2.

To enable tracing for a combination of service, module, and action:

```
SQL> exec dbms_monitor.serv_mod_act_trace_enable(service_name=>'ebk2', -module_name=>
'salary update', action name=>'insert item');
```

To disable tracing in the preceding code, use the procedure SERV_MOD_ACT_TRACE_DISABLE, as shown here:

```
SQL> exec dbms monitor.serv mod act trace disable(service name=>'ebk2', -module name=>
'salary update', action name=>'insert item');
```

To trace for the entire database or instance (not recommended):

```
SQL> execute DBMS_MONITOR.DATABASE_TRACE_ENABLE(waits => TRUE, binds => FALSE,
instance name => 'ebk1');
```

TIP
When using DBMS_MONITOR, disable tracing when you are done; otherwise, every session that meets the criteria specified will be traced.

Enabled Tracing Views

DBA_ENABLED_TRACES and DBA_ENABLED_AGGREGATIONS are the views to look at to see what enabled tracing and statistics gathering is in place. You can use these views to make sure all the tracing options have been disabled. The following example shows the output from the DBA_ENABLED_TRACES view:

```
select trace_type, primary_id, instance_name
from   dba_enabled_traces;

TRACE_TYPE  PRIMARY_ID INSTANCE_NAME
----------- ---------- ------------
SERVICE     ebk2
DATABASE               ebk1
```

TRCSESS Multiple Trace Files into One File

The TRCSESS utility allows trace data to be selectively extracted from multiple trace files and saved into a single trace file based on criteria such as session ID or module name. This command-line utility is especially useful in connection pooling and shared server configurations, where each user request could end up in a separate trace file. TRCSESS lets you obtain consolidated trace information pertaining to a single user session.

This consolidated trace file can be created according to several criteria:

- Session ID
- Client ID
- Service name
- Action name
- Module name

The command syntax for TRCSESS is as follows:

```
trcsess [output=] [session=] [clientid=] [service=] [action=] [module=]
[trace file names]

output= output destination default being standard output.
session= The SID and Serial# of the session to be traced, in the format SID.
SERIAL#.
clientid= clientid to be traced.
service= service to be traced.
action= action to be traced.
module= module to be traced.

trace_file_names - list of trace file names, separated by spaces, which need
to searched by the trcsess command. If no files are listed, then all the files
in the current directory will be searched. The wild card character, *, may be
used in the file names.
```

Example 1

This is from one of the examples in the earlier section "Using DBMS_MONITOR," where SERVICE_NAME = EBK2, MODULE= SALARY_UPDATE, and ACTION = INSERT_ITEM. Go to the DIAGNOSTIC_DEST directory or ADR_HOME, the location is `<DIAGNOSTIC_DEST dir>/rdbms/DB_NAME/SID/trace`, and run the following command:

```
trcsess output combo.trc service "ebk2" module "salary_update" action "insert_item"
```

This searches all the trace files that meet the preceding criteria and creates a consolidated trace file named `combo.trc`.

Now TKPROF can be run against `combo.trc`:

```
tkprof combo.trc output=combo_report sort=fchela
```

Example 2

Set the client ID:

```
SQL> exec dbms_session.set_identifier('ebk3');
```

Enable tracing for the client ID:

```
SQL> EXECUTE DBMS_MONITOR.CLIENT_ID_TRACE_ENABLE('ebk3');
```

Trace by this client ID, and then issue this command (from the directory as before):

```
trcsess output=combo2.trc clientid=ebk3   *.trc
```

TRCSESS checks all the trace files for the specified client ID. Now TKPROF can be run against `combo2.trc` (the combined trace file).

Example 3

In the first case, all the trace files in the current directory are used as input, and a single trace file (`combo3.trc`) is created, with all session=17.1988 trace information. (Note that 17.1988 is the `<SID>.<Serial#>`.)

```
trcsess output=combo3.trc session=17.1988
trcsess output=combo4.trc session=17.1988 ebk2_ora_0607.trc ebk2_ora_0125.trc
```

In the second case, only the two trace files listed are used as input and a single trace file (`combo4.trc`) is created, with all session=17.1988 trace information from the two trace files listed.

Using EXPLAIN PLAN Alone

The EXPLAIN PLAN command allows developers to view the query execution plan that the Oracle optimizer uses to execute a SQL statement. This command is very helpful in improving the performance of SQL statements because it does not actually execute the SQL statement—it only outlines the plan and inserts this execution plan in an Oracle table. Prior to using the EXPLAIN PLAN command, a file called `utlxplan.sql` (located in the same directory as `catalog.sql`, typically `ORACLE_HOME/rdbms/admin`) must be executed under the Oracle account that will be executing the EXPLAIN PLAN command.

The script creates a table called PLAN_TABLE that the EXPLAIN PLAN command uses to insert the query execution plan in the form of records. This table can then be queried and viewed to determine if the SQL statement needs to be modified to force a different execution plan. Oracle supplies queries to use against the PLAN_TABLE table, too: `utlxpls.sql` and `utlxplp.sql`. Either will work, but `utlxplp.sql` is geared toward parallel queries. An EXPLAIN PLAN example is shown next (executed in SQL*Plus).

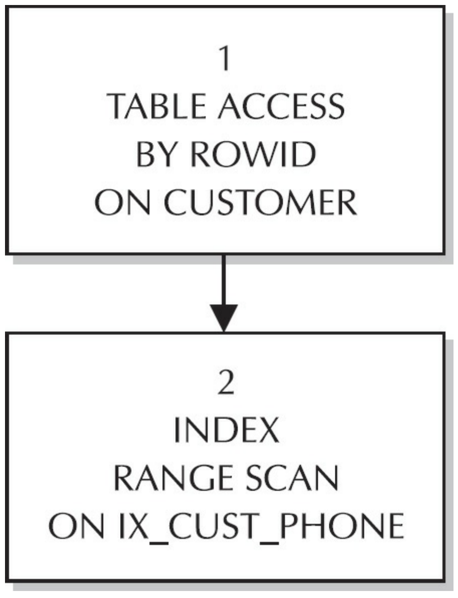
Q. Why use EXPLAIN without TRACE?

A. The statement is *not* executed; it only shows what will happen if the statement is executed.

Q. When do you use EXPLAIN without TRACE?

A. When the query will take an exceptionally long time to run.

The procedures for running TRACE vs. EXPLAIN are demonstrated here:



Q. How do I use EXPLAIN by itself?

A. Follow these steps:

1. Find the script; it is usually in the `ORACLE_HOME/rdbms/admin` directory:

```
utlxplan.sql
```

2. Execute the script `utlxplan.sql` in SQL*Plus:

```
@utlxplan (run this as the user who will be running the EXPLAIN plan)
```

This script creates the PLAN_TABLE for the user executing the script. You can create your own PLAN_TABLE, but use Oracle's syntax—or else!

3. Run EXPLAIN PLAN for the query to be optimized (the SQL statement is placed after the FOR clause of the EXPLAIN PLAN statement):

```
explain plan for
select      CUSTOMER_NUMBER
from        CUSTOMER
where       CUSTOMER_NUMBER = 111;
Explained.
```

4. Optionally, you can also run EXPLAIN PLAN for the query to be optimized using a tag for the statement:

```
explain plan
set statement_id = 'CUSTOMER' for
select      CUSTOMER_NUMBER
from        CUSTOMER
where       CUSTOMER_NUMBER = 111;
```

TIP

Use the SET STATEMENT_ID = 'your_identifier' when the PLAN_TABLE will be populated by many different developers. I rarely use the SET STATEMENT_ID statement. Instead, I explain a query, look at the output, and then delete from the PLAN_TABLE table. I continue to do this (making changes to the query) until I see an execution plan that I think is favorable. I then run the query to see if performance has improved. If multiple developers/DBAs are using the same PLAN_TABLE, the SET STATEMENT_ID (case sensitive) is essential to identifying a statement.

5. Select the output from the PLAN_TABLE:

```
select     operation, options, object_name, id, parent_id
from       plan table
where      statement id = 'CUSTOMER';

Operation              Options      Object Name        ID          Parent
select statement                                        0
Table Access           By ROWID     Customer            1
Index                  Range Scan   CUST IDX            2               1
```

TIP
Use EXPLAIN instead of TRACE so you don't have to wait for the query to run. EXPLAIN shows the path of a query without actually running the query. Use TRACE only for multiquery batch jobs to find out which of the many queries in the batch job are slow.

TIP
You can use the `utlxpls.sql` *and* `utlxplp.sql` *queries provided by Oracle to query the plan table without having to write your own query and without having to format the output.*

An Additional EXPLAIN Example for a Simple Query

This section walks you through a simple process of running a query and then checking the EXPLAIN PLAN for the information about how the query will be processed.

1. Run the query with the EXPLAIN syntax embedded prior to the query:

```
explain plan
set statement_id = 'query 1' for
select    customer_number, name
from      customer
where     customer_number = '111';
```

2. Retrieve the output of EXPLAIN by querying the PLAN_TABLE.

   To retrieve the information for viewing, you must execute a SQL statement. Two scripts provided in the Oracle documentation are displayed in Steps 2 and 3, along with the results of each based on the previous EXPLAIN PLAN command. Note that this example varies from the last example. The CUSTOMER_NUMBER column is an indexed number field, which, in the second example, is suppressed because of a datatype mismatch (111 is in quotes, forcing a TO_CHAR operation). In the first example, I treated the CUSTOMER_NUMBER column correctly as a number field (111 is not in quotes). At times, the optimizer is smart enough *not* to do this to you, but when you use Pro*C or other similar coding, the optimizer may not be able to translate this for you.

```
select    operation, options, object_name, id, parent_id
from      plan_table
where     statement_id = 'query 1'
order by  id;

Operation              Options    Object Name          ID     Parent ID
select Statement                                        0
Table Access           Full   Customer Information      1             0
```

Alternatively, you could just run the `utlxpls.sql` script.

3. Retrieve more intuitive and easy-to-read output for EXPLAIN:

```
select    lpad(' ', 2*(level-1)) || operation || ' ' || options || ' ' ||
          object_name || ' ' || decode(id, 0, 'Cost = ' || position) "Query Plan"
from      plan_table
start     with id = 0
and       statement_id = 'query 1'
connect by prior id = parent_id
and       statement_id = 'query 1';
```

Here is the output:

```
Query Plan
select statement    Cost=220
   Table Access Full Customer
```

EXPLAIN PLAN—Read It Top to Bottom or Bottom to Top?

Whether you should read from top to bottom or bottom to top depends on how you write the query that retrieves the information from the PLAN_TABLE table. This is probably why many people disagree about which way to read the result. (All methods may be correct.) The following listing shows the order of execution based on the query that retrieves the information. In this example, the output is read top to bottom, with one caveat: you must read it from the innermost to the outermost. This listing shows a method that should clear up any questions:

```
delete     from plan_table;
explain plan
set        statement_id = 'SQL1' for
select     to_char(sysdate, 'MM/DD/YY HH:MI AM'), to_char((trunc((sysdate -4 -1),
           'day') +1), 'DD-MON-YY')
from       bk, ee
where      bk_shift_date >= to_char((trunc(( sysdate - 4 - 1), 'day') + 1), 'DD-
           MON-YY')
and        bk_shift_date <= to_char((sysdate - 4), 'DD-MON-YY')
and        bk_empno = ee_empno(+)
and        substr(ee_hierarchy_code, 1, 3) in ('PNA', 'PNB', 'PNC', 'PND', 'PNE',
           'PNF')
order by   ee_job_group, bk_empno, bk_shift_date
/
select     LPad(' ', 2*(Level-1)) || Level || '.' || Nvl(Position,0)|| ' ' ||
           Operation || ' ' || Options || ' ' || Object_Name || ' ' || Object_Type
           || ' ' || Decode(id, 0, Statement_Id ||' Cost = ' || Position) || cost
           || ' ' || Object_Node "Query Plan"
from       plan_table
start      with id = 0 And statement_id = 'SQL1'
connect by prior id = parent_id
and        statement_id = 'SQL1'
/
Query Plan
1.0 SELECT STATEMENT    SQL1  Cost =
    2.1 SORT ORDER BY (7th)
        3.1 FILTER (6th)
            4.1 NESTED LOOPS OUTER (5th)
                5.1 TABLE ACCESS BY ROWID BK (2nd)
                    6.1 INDEX RANGE SCAN I_BK_06 NON-UNIQUE (1st)
                5.2 TABLE ACCESS BY ROWID EE (4th)
                    6.2 INDEX UNIQUE SCAN I_EE_01 UNIQUE (3rd)
```

Reading the EXPLAIN PLAN

Using the previous EXPLAIN PLAN, I will elucidate the steps. The numbers in the left column in Table 6-4 identify each step. They are listed in the order in which they are executed.

Step	Action
6.1	This is the index range scan of I_BK_06. This is the first step. This index is on the BK_SHIFT_DATE column. This step performs a scan of this index to produce a list of ROWIDs that fall between the two dates.
5.1	This retrieves the rows from the BK table.
6.2	This scans the I_EE_01 index. This index is on the EE_EMPNO column. Using the BK_EMPNO retrieved from the previous step, this index is scanned to retrieve the ROWIDs to produce a list of the EE_EMPNOs that match the BK_EMPNOs.
5.2	This retrieves the rows from the EE table.
4.1	This is a nested loop. The two lists are joined, producing one list.
3.1	This is a filter. The rest of the conditions of the WHERE clause are applied.
2.1	This is SORT_ORDER_BY. The remaining rows are sorted according to the ORDER BY clause.
1.0	This tells which type of statement it is.

TABLE 6-4. *Reading the EXPLAIN PLAN*

TIP
Whether the EXPLAIN PLAN is read from top to bottom or from bottom to top depends entirely on the query used to select information from the PLAN_TABLE. Both methods of reading the query may be correct, given that the query selecting the information is correctly structured.

Setting AUTOTRACE ON

There is also an easier method available for generating an EXPLAIN PLAN and statistics about the performance of a query with SQL*Plus. The main difference between AUTOTRACE and EXPLAIN PLAN is that AUTOTRACE actually executes the query (in the way TRACE does) and automatically queries the plan table, whereas EXPLAIN PLAN does neither. The AUTOTRACE command generates similar information, as shown in the next listing. To use AUTOTRACE, the user must possess the PLUSTRACE role (by running `plustrce.sql`, which is usually located in the `ORACLE_HOME/sqlplus/admin` directory).

```
SET AUTOTRACE ON
select     count(last_name)
from       emp
where      name = 'branches';
```

The output is as follows:

```
COUNT(LAST_NAME)
----------------
               0

Execution Plan
----------------------------------------------------------
Plan hash value: 141239332
----------------------------------------------------------------------

| Id  | Operation          | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |             |     1 |     8 |     1   (0)| 00:00:01|
|   1 |  SORT AGGREGATE    |             |     1 |     8 |            |         |
|*  2 |   INDEX RANGE SCAN| EMP_NAME_IX |     1 |     8 |     1   (0)| 00:00:01|
-------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------
   2 - access("LAST_NAME"='BRANCHES')

Note:
- dynamic sampling used for this statement (level=2)
Statistics
----------------------------------------------------------
9      recursive calls
0      db block gets
9      consistent gets
1      physical reads
0      redo size
529    bytes sent via SQL*Net to client
519    bytes received via SQL*Net from client
2      SQL*Net roundtrips to/from client
0      sorts (memory)
0      sorts (disk)
1      rows processed
```

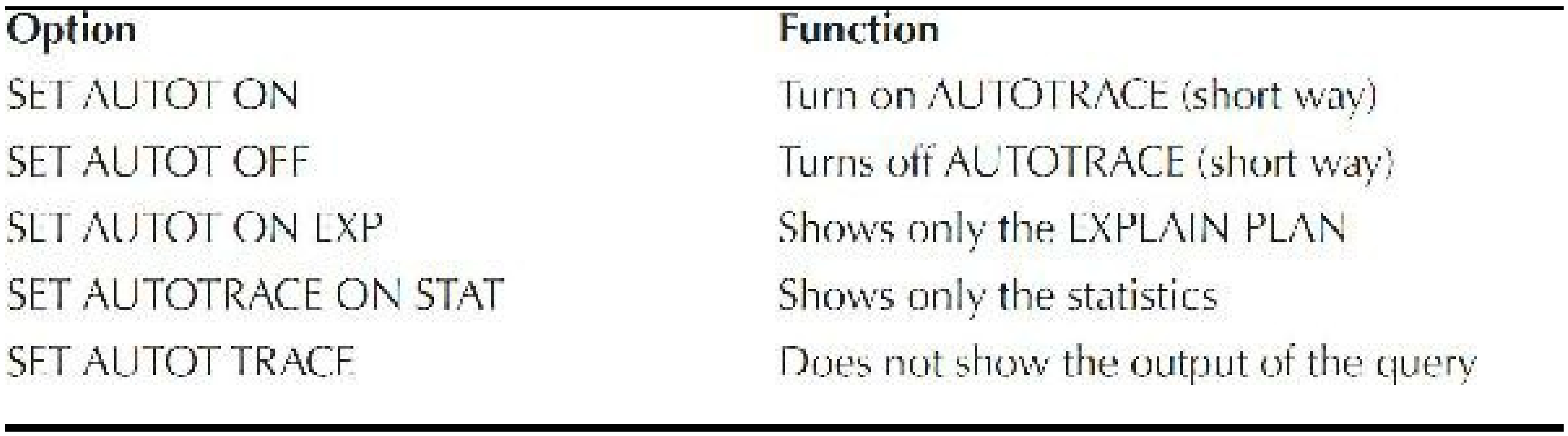
The AUTOTRACE option provides an EXPLAIN PLAN and statistics for a query. AUTOTRACE provides many of the TRACE and TKPROF statistics such as disk reads (physical reads) and total reads (consistent reads + db block gets).

TIP

If the error "Unable to verify plan table format or existence" occurs when enabling AUTOTRACE, you must create a plan table using the `utlxplan.sql` *script.*

CAUTION
AUTOTRACE may fail when querying system views because the user may not have permission to view underlying objects.

Table 6-5 shows other AUTOTRACE options.



Option	Function
SET AUTOT ON	Turn on AUTOTRACE (short way)
SET AUTOT OFF	Turns off AUTOTRACE (short way)
SET AUTOT ON EXP	Shows only the EXPLAIN PLAN
SET AUTOTRACE ON STAT	Shows only the statistics
SET AUTOT TRACE	Does not show the output of the query

TABLE 6-5. *AUTOTRACE Options*

EXPLAIN PLAN When Using Partitions

Table partitions yield different outputs for their EXPLAIN PLANs (as shown in the following listing). Here, I've created a table with three partitions and a partitioned index. Broadly speaking, partitions are tables stored in multiple places in the database. For more information on partitioning tables, refer to Chapter 3.

```
create table dept1
      (deptno    number(2),
       dept_name     varchar2(30))
       partition by range(deptno)
      (partition d1 values     less than (10),
       partition d2 values     less than (20),
       partition d3 values     less than (maxvalue));

insert into dept1 values (1, 'DEPT 1');
insert into dept1 values (7, 'DEPT 7');
insert into dept1 values (10, 'DEPT 10');
insert into dept1 values (15, 'DEPT 15');
insert into dept1 values (22, 'DEPT 22');

create index dept_index
      on dept1 (deptno)
      local
      (partition d1,
       partition  d2 ,
       partition  d3 );
```

I now generate an EXPLAIN PLAN that forces a full table scan to access the first two partitions:

```
explain plan for
select       dept_name
from         dept1
where        deptno  || '' = 1
or           deptno || '' = 15;
```

When selecting from the plan table, you must select the additional columns PARTITION_START (starting partition) and PARTITION_STOP (ending partition). For a full table scan, all partitions will be accessed:

```
select     operation, options, id, object_name, partition_start,
           partition_stop
from       plan_table;
```

The output (for the full table scan) is shown here:

```
OPERATION         OPTIONS        ID  OBJECT NAME  PARTITION START    PARTITION STOP
SELECT STATEMENT
PARTITION         CONCATENATED    0               1                  3
PARTITION RANGE   FULL            1   DEPT1       1                  3
```

The preceding example shows that a full table scan on the DEPT1 table is performed. All three partitions are scanned. The starting partition is 1, and the ending partition is 3.

Next, an EXPLAIN PLAN is generated in the following listing for an index range scan of partition 2 only (ensure that you delete from the plan table to clear it):

```
explain plan for select dept_name
from      dept1
where     deptno    = 15;
Explained.
```

Now I generate an EXPLAIN PLAN for an index range scan accessing only the second partition:

```
select      operation, options, id, object_name, partition_start,
            partition_stop
from        plan_table;
```

The output (for the index range scan) is shown here:

```
OPERATION                 OPTIONS           ID OBJECT_NAME PARTITION_START PARTITION_STOP
SELECT STATEMENT                                0
PARTITION RANGE           SINGLE               1                      2                2
TABLE ACCESS BY LOCAL INDEX ROWID              2   DEPT1              2                2
INDEX                     RANGE SCAN           3   DEPT_INDEX         2                2
```

This output shows that the only partition of the table *or* index that is accessed is the second partition. This is because the value for DEPTNO = 15 is within the second partition of the DEPT1 table. The DEPTNO column is also indexed, and this value is also within the second partition of the index.

TIP
Partitions can also be viewed by the EXPLAIN PLAN by accessing the columns PARTITION_START and PARTITION_STOP in the PLAN_TABLE table.

Finding High Disk and/or Memory Reads Without Using TRACE

Is there another method for retrieving problem disk and memory read information without tracing everything? Yes! By using V$SQLAREA, you can find the problem queries on your system. This next listing shows how to find the problem queries. In this query, you are searching for queries where the disk reads are greater than 10,000 (missing or suppressed index potentials). If your system is much larger, you may need to set this number higher.

```
select      disk_reads, sql_text
from        v$sqlarea
where       disk_reads > 10000
order by    disk_reads desc;

DISK_READS        SQL_TEXT
    12987         select    order#,columns,types from orders
                  where     substr(orderid,1,2)=:1
    11131         select    custid, city from customer
                  where     city = 'CHICAGO'
```

This output suggests that there are two problem queries causing heavy disk reads. The first has the index on ORDERID suppressed by the SUBSTR function; the second shows that there is a missing index on CITY.

In the query in the following listing, you are searching for queries where the memory reads are greater than 200,000 (over-indexed query potentials). If your system is much larger, you may need to set this number higher.

```
select     buffer_gets, sql_text
from       v$sqlarea
where      buffer_gets > 200000
order by   buffer_gets desc;

BUFFER_GETS     SQL_TEXT
    300219     select order#,cust_no, from orders
               where division = '1'
```

The output suggests that one problem query is causing substantially heavy memory reads (300,219 blocks of data read into memory). The index on DIVISION appears to have a cardinality of 1 because this table has only a single division. What's happening here is that the entire index is being read and then the entire table is being read. The index should be suppressed for this statement to improve performance (and perhaps should be removed permanently if additional divisions will not be added).

TIP

Accessing the V$SQLAREA table can give statistics that are often found when tracing a query. See Chapter 12 for additional information on accessing V$SQLAREA.

Tracing/Explaining Problem Queries in Developer Products

Although you can issue the ALTER SESSION SET SQL_TRACE TRUE command on the SQL*Plus command line to TRACE SQL statements, doing this is tough when it comes to using developer products. One drawback to this option is that you are not able to trace a form or report; you need to cut the code out of the form or report and run it from SQL*Plus. This process can be very time-consuming if you do not know which statements you need to trace.

There is another way to create a trace of the execution of a form. If you are using Forms (versions 6*i*, 10*g*, and 11*g*), you can include `statistics = yes` on the command line. This way, you are able to trace individual forms. Later versions of Oracle Forms and Oracle Reports (all part of Fusion Middleware) allow tracing from inside a form or report. Please refer to the Forms and/or Reports (Fusion Middleware) documentation for an explanation of how to use these options. Oracle Applications often has a menu item to do this as well. You could also use DBMS_MONITOR to trace these products. Lastly, some methods for tracing PL/SQL programs are available: DBMS_PROFILER, DBMS_TRACE, and DBMS_HPROF.

TIP

You can also use TRACE within the Fusion Middleware (Developer) products. You simply need to set `statistics = yes` *on the command line for some products, or you may embed the tracing within an actual trigger to turn tracing on and off.*

Important Columns in the PLAN_TABLE Table

The descriptions for *some* of the more important columns available in the PLAN_TABLE table are as follows:

- **STATEMENT_ID** The value of the option STATEMENT_ID parameter specified in the EXPLAIN PLAN statement.
- **TIMESTAMP** The date and time when the EXPLAIN PLAN statement was issued.
- **REMARKS** Any comment (up to 80 bytes) you wish to associate with each step of the EXPLAIN PLAN. If you need to add or change a remark on any row of the PLAN_TABLE table, use the UPDATE statement to modify the rows of the PLAN_TABLE table.
- **OPERATION** The name of the internal operation performed in this step. In the first row generated for a statement, the column contains one of four values: DELETE, INSERT, SELECT, or UPDATE, depending on the type of statement.
- **OPTIONS** A variation on the operation described in the OPERATION column. See Chapter 7

of *Oracle Database SQL Tuning Guide 12*c for information on the contents of this column.

TIP
The OPERATION and OPTIONS columns of the PLAN_TABLE are the most important columns for tuning a query. The OPERATION column shows the actual operation performed (including type of join), and the OPTIONS column tells you when a full table scan is being performed (that may need an index).

- **OBJECT_NODE** The name of the database link used to reference the object (a table name or view name). For local queries using the parallel query option, this column describes the order in which output from operations is consumed.
- **OBJECT_OWNER** The name of the user who owns the schema containing the table or index.
- **OBJECT_NAME** The name of the table or index.
- **OBJECT_INSTANCE** A number corresponding to the ordinal position of the object as it appears in the original statement. The numbering proceeds from left to right, outer to inner, with respect to the original statement text. Note that view expansion results in unpredictable numbers.
- **OBJECT_TYPE** A modifier that provides descriptive information about the object, for example, NON-UNIQUE for indexes.
- **OPTIMIZER** The current optimizer mode.
- **ID** A number assigned to each step in the execution plan.
- **PARENT_ID** The ID of the next execution step that operates on the output of the ID step.

TIP
The PARENT_ID column is very important because it shows the dependencies of two steps in an EXPLAIN PLAN. If a step in the EXPLAIN PLAN has a PARENT_ID, it implies that this statement must run prior to the PARENT_ID that is specified.

- **POSITION** The order of processing for steps that all have the same PARENT_ID.
- **OTHER** Other information that is specific to the execution step that a user may find helpful.
- **OTHER_TAG** The contents of the OTHER column.
- **COST** The cost of the operation as *estimated* by the optimizer's cost-based approach. The value of this column does not have any particular unit of measurement; it is merely a weight value used to compare costs of execution plans.

- **CARDINALITY** The cost-based approach's *estimate* of the number of rows accessed by the operation.
- **BYTES** The cost-based approach's *estimate* of the number of bytes accessed by the operation.
- **OTHER_XML** This column can be queried to find out extra information that the optimizer used to determine the execution plan.

TIP

The BYTES column is extremely important when evaluating how to tune a query. When an index is used and the number of bytes is great, it implies that doing a full table scan would perhaps be more efficient (i.e., reading the index and data is more costly than just reading the data in a full table scan). Also, the number of bytes helps you determine which table should be accessed first in the query (driving table) because one table may limit the number of bytes needed from another. See Chapter 9 for tips on choosing the driving table.

TIP

Remember that both the COST and BYTES values in a query are estimates; it is quite possible for a version of a query with a higher estimated cost or bytes to run faster than another with a lower value.

Using DBMS_XPLAN

DBMS_XPLAN is one of the most common and best ways to query the execution plan of a query quickly. It automatically queries the last plan in PLAN_TABLE when you use the DBMS_XPLAN.DISPLAY procedure. There are a couple of other options as well to display it in different ways, but most people like it because it's a quick way to see the *last* execution plan as they are tuning a query. It will also give additional information after the execution plan. It will highlight filter versus join conditions and let you know if the plan table is current. It will also display a warning message if an old version of the plan table is being used. Keep in mind that OPERATION column text truncation might be a problem if you don't set the LINESIZE as shown in the following example. The DBMS_XPLAN package has the following table functions:

- **DISPLAY** Display the last query plan
- **DISPLAY_CURSOR** Display contents and execution plan of any loaded cursor (can specify SQL_ID)
- **DISPLAY_AWR** Display contents and execution plan of stored SQL statement in AWR

- **DISPLAY_SQLSET** Display contents and execution plan of statements in a SQL Tuning Set

The following is a DBMS_XPLAN example (run this *after* you run an EXPLAIN PLAN on a query):

```
SET LINESIZE 130
SET PAGESIZE 0

select * from table (dbms_xplan.display);

PLAN_TABLE_OUTPUT
----------------------------------------------------------------------------------------

----------------------------------------------------------------------------------------
| Id  | Operation              | Name          | Rows  | Bytes | Cost  | Pstart| Pstop |
----------------------------------------------------------------------------------------
|   0 | UPDATE STATEMENT       |               |   328 |  2296 |     2 |       |       |
|   1 |  UPDATE                | JOURNAL_LINE  |       |       |       |       |       |
|   2 |   PARTITION RANGE ALL  |               |       |       |       |     1 |     4 |
|   3 |    TABLE ACCESS FULL   | JOURNAL_LINE  |   328 |  2296 |     2 |     1 |     4 |
----------------------------------------------------------------------------------------
Note: cpu costing is off, 'PLAN_TABLE' is old version
11 rows selected
```

There is an additional procedure to display the plan stored in AWR (AWR is covered in Chapter 14) or in a Tuning Set (more on this in Chapter 8). The following are queries to look at SQL Plan Baselines (covered in Chapter 8) and a quick query to display a cursor (query V$SQL or other V$ views to get the cursor; Chapter 12 covers V$ views):

```
DBMS_XPLAN.DISPLAY_SQL_PLAN_BASELINE
        sql_handle IN VARCHAR2 := NULL,
        plan_name  IN VARCHAR2 := NULL,

        format     IN VARCHAR2 := 'TYPICAL')   <'BASIC'/'ALL'>
RETURN dbms_xplan_type_table;

select * from table (dbms_xplan.display_cursor('ahvccymgw92jw'));
```

There are many options for different levels of statistics, specific child numbers of a cursor, and the ability to use your own plan table. Please check the Oracle docs for additional information. A few more quick examples are listed here:

```
select * from table (dbms_xplan.display(null,null,'basic'));
select * from table (dbms_xplan.display(null,null,'typical'));
select * from table (dbms_xplan.display(null,null,'all'));
```

Initialization Parameters for Undocumented TRACE

One area that the experts can investigate is the X$KSPPI table. A brief listing for undocumented TRACE parameters in `init.ora` is shown here (see Appendix A for additional information). Note that Oracle does not support use of undocumented features of the product.

```
select ksppinm "Parameter Name", ksppstvl "Value",ksppstdf "Default"
from   x$ksppi x, x$ksppcv y
where  x.indx = y.indx
and    ksppinm like '/ %trace%' escape '/';
```

TIP

The X$KSPPI table can be accessed only by the SYS user. See Chapter 13 for tips on accessing the X$ tables and using some of these parameters. Do not use any undocumented parameters without consulting My Oracle Support. Also, the layout and column names of these views have been known to change between Oracle releases.

Tracing Errors Within Oracle for More Information

This section explains the use of one of the undocumented features of TRACE. Before using undocumented `initialization` parameters, please contact My Oracle Support. To TRACE errors for a session, you can set an event in the `initialization` parameters file (see Chapter 13 for more information). You can also trace sessions for errors by running the query shown next (used to TRACE a 4031 error). These queries build a TRACE file in your USER_DUMP_DEST that will contain a dump of the full error text.

Use the following command to trace sessions for errors:

```
alter session set events='4031 trace name errorstack level 4';
```

TIP

Tracing queries can help performance, but using the TRACE facility built into the undocumented TRACE `init.ora` parameters (discussed previously) can give you great insight into solving errors within Oracle.

Tracing by Enabling Events

Trace sessions can also be initiated by using this command:

```
SQL> Alter session set events '10046 trace name context forever, level 1';
Session altered.
```

The value of the level (1 in the previous command) can be 1 (*regular trace*), 4 (*trace bind variables*), 8 (*trace wait states*), or 12 (*regular trace, plus bind variables and wait states*). Information about bind variables and wait states can then appear in the trace file but will be ignored by TKPROF when formatting the report. The trace file output for the previous command looks like this:

```
SELECT SYSDATE   FROM DUAL  WHERE SYSDATE IN ( :b1  )
END OF STMT
PARSE #4:c=0,e=0,p=0,cr=0,cu=0,mis=0,r=0,dep=1,og=4,tim=0
BINDS #4:
 bind 0: dty=12 mxl=07(07) mal=00 scl=00 pre=00 oacflg=03 oacfl2=1 size=8 offset=0
   bfp 0ddcc774 bln 07 avl 07 flg 05
   value="11/19/2000 19:25:47"
WAIT #1: nam='SQL*Net message to client' ela= 0 p1=1413697536 p2=1 p3=0
```

To turn event tracing off, use the following command:

```
SQL> Alter session set events '10046 trace name context off';
Session altered.
```

Oracle 11*g* introduced a new syntax for setting events that makes it easier to trace processes without knowing the SID or SERIAL# (see My Oracle Support Note 813737.1 for additional information). You can now use the following command instead:

```
alter system set events 'sql trace {process : ospid = 2345} level=12';
```

Using Stored Outlines

Oracle8*i* introduced a facility called *STORED OUTLINES* that allows a query to use a predetermined execution plan every time that query is run, no matter where the query is run from. While the use of STORED OUTLINES was deprecated (discouraged) in 11*g*, they are still used and thus covered here briefly (sections following this will cover converting STORED OUTLINES to SQL Plan Management and SQL Plan Baselines). People sometimes speak of the STORED OUTLINES as storing an execution plan, but this is not really what happens. Instead, Oracle stores a series of *hints*—instructions to the database to execute a query in a precise way—to duplicate the execution plan as saved during a recording session.

Oracle can replicate execution plans for queries using STORED OUTLINES through a process similar to using the EXPLAIN PLAN functionality in SQL*Plus. First, you set up the STORED OUTLINE session by telling Oracle to save outlines for queries you are about to run using the ALTER SESSION command. Next, you execute the query for which you want the outline stored. (You generally do this on a session-only basis so as not to affect other users.) Finally, if the execution plan is acceptable, you can save it to the database so it can be used by everyone everywhere. STORED OUTLINES have been largely replaced by SPM (SQL Plan Management).

Dropping Stored Outlines

How do you get rid of STORED OUTLINES when you don't want them anymore or when they impact performance negatively? Use the DROP_UNUSED procedure in the DBMS_OUTLN package.

To drop all unused outlines:

```
execute dbms_outln.drop_unused
```

To remove outlines that *have* been used, first apply the DBMS_OUTLN.CLEAR_USED procedure, which accepts an outline name (available from the USER_OUTLINES view) and can be run against only one outline at a time. You could write a short PL/SQL program to clear outlines en masse.

To determine whether an outline is actually being used, examine the USED column in USER_OUTLINES. You can also query the OUTLINE_CATEGORY column in the V$SQL view to see things that are still in the cache.

```
SELECT OUTLINE_CATEGORY, OUTLINE_SID
FROM   V$SQL
WHERE  SQL_TEXT = 'portion of query%'
```

Using SQL Plan Management (SPM) and SPM Example

SQL Plan Management has been added to help preserve the performance of SQL statements by only allowing execution plans that improve the performance of the statement being executed. SPM is similar to, yet different from, STORED OUTLINES. Like STORED OUTLINES, SPM's goal is to stabilize the execution plan of a SQL statement. STORED OUTLINES freeze an execution plan for a SQL statement, whereas SPM allows a new execution plan to be selected as long as it improves the performance of the SQL statement. Some of the reasons that you would need SPM include:

- New version of Oracle (new optimizer version—use capture/replay to test effect)
- Changes to optimizer statistics or data changes
- Schema, application, or metadata changes (use SQL Advisor to get suggestions)
- System settings changes (use SQL Replay to find what works)
- SQL Profile (statistics—data skews and correlated columns) creation

TIP
STORED OUTLINES freeze an execution plan whereas SPM allows a new execution plan as long as the plan improves the performance of the SQL statement. If both a stored outline and an SPM plan exist for a SQL statement, the stored outline takes precedence.

SPM Terms

The following are terms related to the SMB hierarchy.

- **Main components of SPM**:
  - **Plan capture** Creation of the SQL Plan Baseline that stores accepted execution plans.
  - **Plan selection** Any new execution plans for an accepted statement are initially stored as unaccepted plans in the SQL Plan Baseline.
  - **Plan evolution** Evaluation of all unaccepted plans and only plans which increase performance by a certain threshold are changed to accepted and used.
- **SQL Management Base (SMB)** SQL Plan History and SQL Plan Baseline are located within the SMB. The SMB is located in the SYSAUX tablespace and also contains SQL profiles.
- **SQL Plan History** A subset of SMB that includes both *accepted* and *not accepted* plans generated for a SQL statement.
- **SQL Plan Baseline** A subset of SQL Plan History that includes only the set of accepted plans generated for a SQL statement.
- **Flags** Used to indicate the status of an execution plan in the SMB:
  - **Enabled** The default value for an execution plan in Plan History or Plan Baseline is ENABLED.
  - **Accepted** The plan needs to be accepted before it can be considered to be used.
  - **Fixed** The plan takes precedence over other execution plans.
  - **Reproduced** Automatically set to YES when the CBO (Cost-Based Optimizer) is able to

reproduce the plan for the given SQL statement and set to NO when that is not possible.

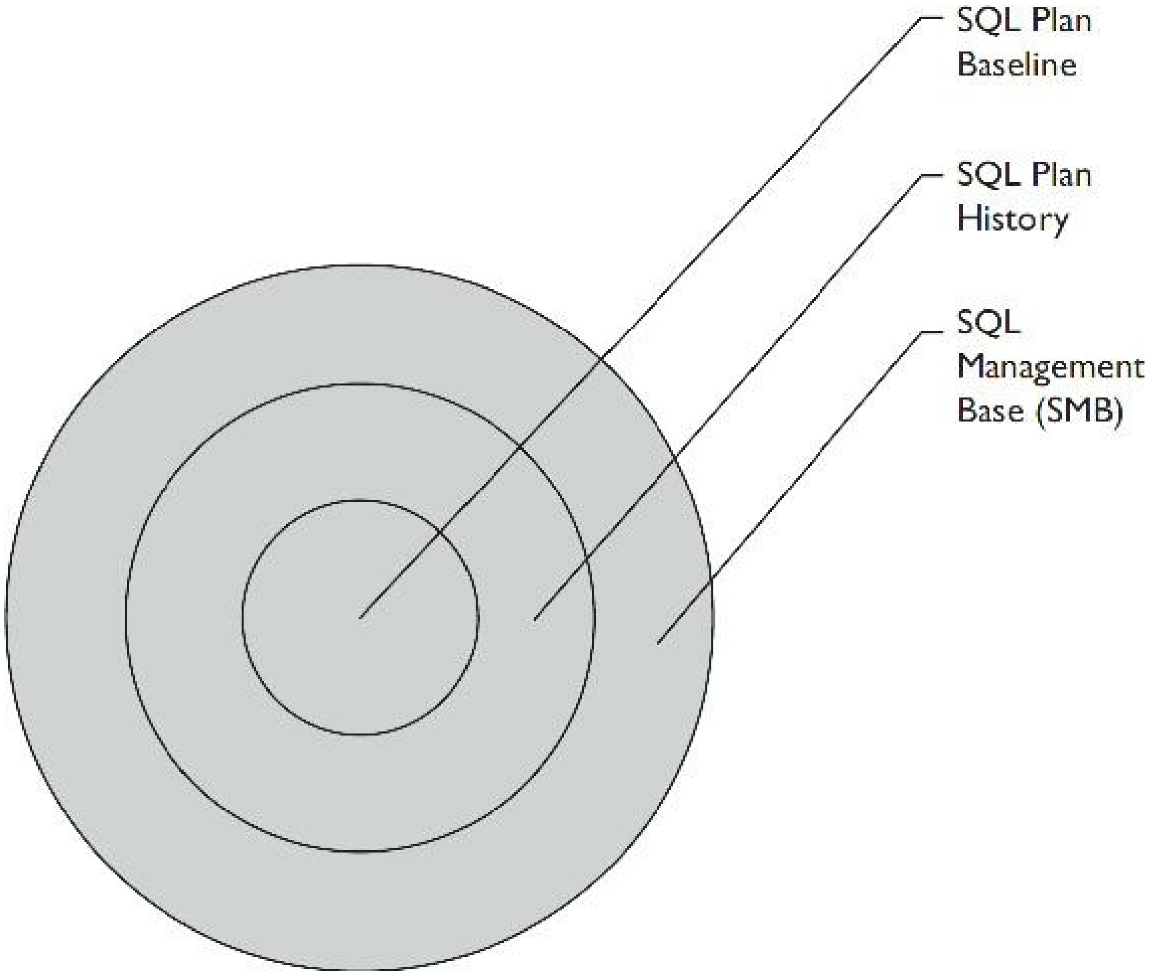
- **Adaptive (new in 12*c*)** The plan has been determined to be an adaptive plan and not accepted; once the plan is accepted, the adaptive flag will be set to NO.

The illustration on the next page shows a target chart of how this hierarchy looks.
The following are terms related to the status of plans:

- **Accepted plan** A plan must be both ENABLED and ACCEPTED in order to be considered by the optimizer.
- **Enabled plan** The default value for an execution plan in Plan History or Plan Baseline is ENABLED. A plan must be both ENABLED and ACCEPTED to be considered by the optimizer.
- **Fixed plan** This execution plan gets priority over other plans for a SQL statement unless there are other FIXED plans, in which case the FIXED plan with the best performance is selected.

Some other terms associated with SPM include

- **AUTOPURGE** A plan is automatically purged from Plan History if it has not been used for 53 weeks (based on the LAST_EXECUTED date in DBA_SQL_PLAN_BASELINES). This date can be modified using the DBMS_SPM.CONFIGURE package.



- **OPTIMIZER_USE_SQL_PLAN_BASELINES** The database parameter that determines if the Plan Baseline will be used if it is present for a SQL statement. The default is TRUE.

- **OPTIMIZER_CAPTURE_PLAN_BASELINES** Any SQL statements executed while this parameter is set to TRUE are added to the Plan Baseline (but not necessarily ACCEPTED). The default is FALSE.
- **DBA_SQL_PLAN_BASELINES** A view for gathering information about Plan Baselines that have been created.

TIP
A SQL Plan Baseline must be both ENABLED and ACCEPTED to be considered by the optimizer.

Using SPM

SPM is enabled and SQL statements are stored in the SQL Management Base using the following method:

1. Set the OPTIMIZER_CAPTURE_PLAN_BASELINES parameter to TRUE at the system or session level.
2. Use the SQL Tuning Set (see Chapter 29 of the *Oracle Database 12*c *SQL Tuning Guide* for details).
3. Extract the statement from the shared pool using the DBMS_SPM.LOAD_PLANS_FROM_CURSOR_CACHE function (see the *Oracle Database 12*c *SQL Tuning Guide*, Chapter 29, for details).

Note that only repeatable SQL statements (that is, statements that have been parsed or executed more than once) are considered by SPM.

SPM is helpful for

- Database upgrades
- System and/or data changes
- Deployment of new application modules

SPM Example

Here is an example of how SPM works:

1. Turn capture on and run the SQL statement more than once so SPM can determine if the statement is repeatable, and then turn capture off:

```
alter session set optimizer_capture_sql_plan_baselines=true;
select * /* ebk1 */ from emp where job='PRESIDENT';
select * /* ebk1 */ from emp where job='PRESIDENT';
alter session set optimizer capture sql plan baselines=false;
```

2. Query DBA_SQL_PLAN_BASELINES to determine the status of the SQL statement in SPM:

```
select  plan_name,  sql_handle,  enabled,  accepted,  fixed,
        module,  sql_text
from    dba_sql_plan_baselines;

PLAN_NAME                      SQL_HANDLE                     ENA ACC FIX MODULE
SQL TEXT
-----------------------------------------------------------------------------------------
SQL_PLAN_1r9f32bakc2qmd8a279cc SQL_1ba5c312d5260ad3           YES YES NO  SQL*Plus
select * /* ebk1 */ from emp where job='PRESIDENT';
```

Note that ENABLED is YES, ACCEPTED is YES, and FIXED is NO. Also note the module that was used to add this plan (SQL*Plus).

3. Now make a change to the environment (index added) and run the SQL statement again:

```
create index ellen on emp(job);
alter session set optimizer capture sql plan baselines=true;
select * /* ebk1 */ from emp where job='PRESIDENT';
select * /* ebk1 */ from emp where job='PRESIDENT';
alter session set optimizer capture sql plan baselines=false;
```

4. Query DBA_SQL_PLAN_BASELINES to determine the status of the SQL statement in SPM:

```
PLAN_NAME                      SQL_HANDLE                     ENA ACC FIX MODULE
------------------------------ ------------------------------ --- --- --- -------
SQL TEXT
---------------------------------------------------------------------------------
SQL PLAN 1r9f32bakc2qmc581a482 SYS SQL 1ba5c312d5260ad3       YES NO  NO  SQL*Plus
select * /* ebk1 */ from emp where job='PRESIDENT'

SQL_PLAN_1r9f32bakc2qmd8a279cc SYS_SQL_1ba5c312d5260ad3       YES YES NO  SQL*Plus
select * /* ebk1 */ from emp where job='PRESIDENT'
```

Note that another PLAN NAME was added (with the same SQL_HANDLE) that has an ACCEPTED value of NO, which means the optimizer will not consider this plan.

Now I'm going to set OPTIMIZER_USE_SQL_PLAN_BASELINE to FALSE and allow the optimizer to choose a plan (not necessarily in the Plan Baseline). Then I will set the OPTIMIZER_USE_SQL_PLAN_BASELINE to TRUE and force the optimizer to choose only an accepted plan in the Plan Baseline.

```
alter system set optimizer_use_sql_plan_baselines=false;

explain plan for
select * /* ebk1 */ from emp where job='PRESIDENT';

select * from table(dbms_xplan.display(null,null,'basic'));

PLAN_TABLE_OUTPUT
------------------------------------------------
| Id  | Operation                    | Name  |
------------------------------------------------
|   0 | SELECT STATEMENT             |       |
|   1 |  TABLE ACCESS BY INDEX ROWID| EMP   |
|   2 |   INDEX RANGE SCAN           | ELLEN |
------------------------------------------------

alter system set optimizer_use_sql_plan_baselines=true;

explain plan for
select * /* ebk1 */ from emp where job='PRESIDENT';

select * from table(dbms_xplan.display(null,null,'basic'));

PLAN_TABLE_OUTPUT
---------------------------------------------------------------------------
Plan hash value: 3956160932

----------------------------------
| Id  | Operation         | Name |
----------------------------------
|   0 | SELECT STATEMENT  |      |
|   1 |  TABLE ACCESS FULL| EMP  |
----------------------------------
```

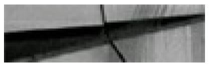
Using DBMS_XPLAN tells you what actually happened versus an EXPLAIN PLAN, which tells you what's intended (by comparing the two, you can see if something changed from what execution plan was intended/started and what execution plan was eventually used/ended with). Note that in the first case, the optimizer chooses a plan that makes use of the index, but, in the second case, it did not because that plan was not an ACCEPTED plan.

The next step is to evolve a SQL plan to allow a plan with an ACCEPTED status of NO to be changed to YES if the plan performs better than plans that already have an ACCEPTED value of YES:

```
set serveroutput on
set long 10000
DECLARE
```

```
  report clob;
BEGIN
  report := DBMS_SPM.EVOLVE_SQL_PLAN_BASELINE(
               sql_handle => 'SYS_SQL_1ba5c312d5260ad3');
  DBMS_OUTPUT.PUT_LINE(report);
END;
/
```

Here is the output:



```
                          Evolve SQL Plan Baseline
Report
-------------------------------------------------------------------------------

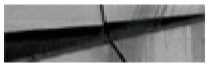
Inputs:
-------
  SQL_HANDLE = SQL_1ba5c312d5260ad3
  PLAN_NAME  =
TIME_LIMIT = DBMS_SPM.AUTO_LIMIT
  VERIFY     = YES
  COMMIT     = YES
Plan:
SQL_PLAN_1r9f32bakc2qmc581a482
--------------------------------------
  Plan was verified: Time used .03 seconds.
  Plan passed performance criterion: 3.5 times better than baseline plan.
  Plan was changed to an accepted plan.

                               Baseline Plan      Test Plan     Stats Ratio
                               -------------      ---------     -----------
  Execution Status:                 COMPLETE       COMPLETE
  Rows Processed:                      1              1
  Elapsed Time(ms):                 .066           .052            1.27

CPU Time(ms):                          0              0
  Buffer Gets:                         7              2             3.5
  Physical Read Requests:              0              0
  Physical Write Requests:             0              0
  Physical Read
Bytes:                                 0              0
  Physical Write Bytes:                0              0
  Executions:                          1              1

-------------------------------------------------------------------------------
                                 Report Summary
-------------------------------------------------------------------------------
Number of plans verified: 1
Number of plans accepted: 1
PL/SQL procedure successfully completed.
```

Note that the plan, which was previously not ACCEPTED, is now ACCEPTED:



```
PLAN_NAME                      SQL_HANDLE                     ENA ACC FIX MODULE
------------------------------ ------------------------------ --- --- --- ----------
SQL_TEXT
--------------------------------------------------------------------------------
SQL_PLAN_1r9f32bakc2qmcb81a482 SYS_SQL_1babc312d5260ad3       YES YES NO  SQL*Plus
select * /* ebk1 */ from emp where job='PRESIDENT'

SQL_PLAN_1r9f32bakc2qmd8a279cc SYS_SQL_1babc312d5260ad3       YES YES NO  SQL*Plus
select * /* ebk1 */ from emp where job='PRESIDENT'
```

Now when I run the SQL statement with OPTIMIZER_USE_SQL_PLAN_BASELINE set to TRUE, this newly ACCEPTED plan is chosen because it performs better than other ACCEPTED plans for this SQL statement:

```
alter system set optimizer_use_sql_plan_baselines=true;

explain plan for
select * /* ebk1 */ from emp where job='PRESIDENT';

select * from table(dbms_xplan.display(null,null,'basic'));

PLAN_TABLE_OUTPUT
--------------------------------------------------------------------------------
Plan hash value: 3484773650

--------------------------------------------
| Id  | Operation                    | Name  |
--------------------------------------------
|   0 | SELECT STATEMENT             |       |
|   1 |  TABLE ACCESS BY INDEX ROWID | EMP   |
|   2 |   INDEX RANGE SCAN           | ELLEN |
```

& Using Fixed SQL Plan Baselines

Fixed plans (if present) are used instead of any other plans in the Plan Baseline for a SQL statement. If more than one Fixed plan exists for a SQL statement, then the Fixed plan with the best performance is used. Here is an example of how to set a plan to FIXED:

```
DECLARE
  l_plans_altered  PLS_INTEGER;
BEGIN
  l_plans_altered := DBMS_SPM.alter_sql_plan_baseline(
    sql_handle      => 'SYS_SQL_976227df3c76f615',
    plan_name       => NULL,
    attribute_name  => 'fixed',
    attribute_value => 'YES');
END;
/

select plan_name, sql_handle, enabled, accepted, fixed, module, sql_text
from   dba_sql_plan_baselines;

PLAN_NAME                      SQL_HANDLE                     ENA ACC FIX MODULE
------------------------------ ------------------------------ --- --- --- ----------
SQL_TEXT
--------------------------------------------------------------------------------
SQL_PLAN_9fsj7vwy7dxhpb59fb1c2 SYS_SQL_976227df3c76f615       YES NO  YES SQL*Plus
select * /* ebk20 */ from emp where job='PRESIDENT'

SQL_PLAN_9fsj7vwy7dxhpd8a279cc SYS_SQL_976227df3c76f615       YES YES YES SQL*Plus
select * /* ebk20 */ from emp where job='PRESIDENT'
```

Dropping a Plan

Here is an example of how to drop a plan using the SQL_HANDLE:

```
set serveroutput on
declare
l_plan_dropped pls_integer; begin
l_plan_dropped := dbms_spm.drop_sql_plan_baseline
(sql_handle => 'SYS_SQL_976227df3c76f615', plan_name => NULL);end;
/
```

Converting from Stored Outlines to SQL Plan Management

Now I will walk you through an example of how to convert a SQL statement from using STORED OUTLINES to using SQL Plan Management.

To create a stored outline:

```
alter session set query_rewrite_enabled = true;
alter session set create_stored_outlines = true;
create or replace outline kev_outline on select * /* ebk2 */ from emp where
job='PRESIDENT';
Session altered.
Session altered.
Outline created
```

To use the stored outline:

```
alter session set query_rewrite_enabled = true;
alter session set use_stored_outlines = true;
select * /* ebk2 */ from emp where job='PRESIDENT';
```

The following shows the status of the stored outline:

```
select *
from   user_outlines;

NAME
--------------------
CATEGORY
----------------------------------------------------------------------------
USED   TIMESTAMP
------ ---------

VERSION
------------------------------------------------------------

SQL_TEXT
----------------------------------------------------------------------------
SIGNATURE                        COMPATIBLE   ENABLED  FORMAT MIGRATED
-------------------------------- ------------ -------- ------ ------------

KEV_OUTLINE
DEFAULT
USED   26-JUN-16
12.2.0.0.2
select * /* ebk2 */ from emp where job 'PRESIDENT'
A4D018768BB006A28CB8430DBA307BDC COMPATIBLE   ENABLED  NORMAL NOT-MIGRATED
```

Note that the MIGRATED status field shows it to be NOT-MIGRATED and the USED status field shows it to be USED.

To migrate this stored outline to a Plan Baseline:

```
set serveroutput on
DECLARE
  tst_outline clob;
BEGIN
  tst_outline := DBMS_SPM.MIGRATE_STORED_OUTLINE(attribute_name => 'OUTLINE_NAME',
attribute_value => 'KEV_OUTLINE');
END;
/
```

Here is the output:

```
PL/SQL procedure successfully completed.
```

To migrate all stored outlines:

```
DECLARE
uw_outlines CLOB;
BEGIN
  uw_outlines := dbms_spm.migrate_stored_outline('ALL');
END;
/
```

To retrieve the status of the stored outline and the plan outline after the migration:

```
select *
from   user_outlines;

NAME
--------------------
CATEGORY
--------------------------------------------------------------------------------
USED   TIMESTAMP
------ ---------
VERSION
----------------------------------------------------------------
SQL_TEXT
--------------------------------------------------------------------------------
SIGNATURE                        COMPATIBLE   ENABLED   FORMAT  MIGRATED
-------------------------------- ------------ --------- ------- ------------
```

```
KEV_OUTLINE
DEFAULT
USED   06-JUN-16
12.2.0.0.2
select * /* ebk2 */ from emp where job='PRESIDENT'
A4D01876FB+C06A2BCB8420DBA307B0C COMPATIBLE   ENABLED  NORMAL MIGRATED


select plan_name, sql_handle, enabled, accepted, fixed, module,
       origin, sql_text
from   dba_sql_plan_baselines;

PLAN NAME                      SQL HANDLE                     ENA ACC FIX MODULE
------------------------------ ------------------------------ --- --- --- ------------
ORIGIN
--------------
SQL TEXT
--------------------------------------------------------------------------------
KEV_OUTLINE                    SQL_a698a39a23157c6c           YES YES NO  DEFAULT
STORED-OUTLINE
select * /* ebk2 */ from emp where job='PRESIDENT'
```

Note that ACCEPTED is set to YES for the PLAN OUTLINE and MIGRATED is set to MIGRATED for STORED_OUTLINE. Because the status of the STORED OUTLINE is MIGRATED, the optimizer will not look at the STORED OUTLINE when determining which plan to use.

To drop the migrated stored outline:

```
DECLARE
  drp_outline PLS_INTEGER;
BEGIN
  drp_outline := DBMS_SPM.DROP_MIGRATED_STORED_OUTLINE();
END;
/
```

This drops all migrated stored outlines.

Adaptive Plans (12*c* New Feature) and SPM

The concept of an adaptive plan is that the execution of a statement can start with one execution plan (say, for instance, a join using nested loops) and switch to another (join using a Hash Join) *during* execution without rerunning based on what it's seeing (statistics-wise) while it's running. Statistic collectors are set at critical points during the plan execution to see if the *actual* execution is varying greatly from what was *expected* originally, based on the statistics. This allows Oracle to compare actual row counts (during the execution) with estimates (prior to execution that were used). If the difference in the comparison crosses certain thresholds, Oracle will switch to a better execution plan during execution. If automatic plan capture is enabled and the SQL statement is identified as an adaptive plan, only the plan that is executed will be captured in the baseline if a plan for the SQL statement does not already exist in the baseline. If a plan already exists in the baseline, then the new plan will be marked as ADAPTIVE and that plan will be checked during the evolve process (either the automatic or manual evolve process—see the next section for an example). Oracle also ensures the *next* execution of this statement will use the *new* execution plan.

Adaptive SQL Plan Management

There have been changes in 12*c* to the process of evolving SQL Plan Baselines. SYS_AUTO_SPM_EVOLVE_TASK is a new automatic evolve task that runs in the default maintenance window (normally starting at 22:00 M–F and 6:00 Sat–Sun). The task is used to rank all unaccepted plans and run the evolve process on those plans. Unaccepted plans whose performance is better than the existing accept plan(s) by a defined amount are "evolved" to an ACCEPTED status. In addition to this automatic evolve process, there is also a manual evolve process.

Settings for the task SYS_AUTO_SPM_EVOLVE_TASK are listed next. DBMS_SPM.set_evolve_task_parameter can be used to change parameters.

```
col parameter_name format a30
col parameter_value format a45

select parameter_name, parameter_value
from   dba_advisor_parameters
where  task_name = 'SYS_AUTO_SPM_EVOLVE_TASK'
and    parameter_value != 'UNUSED'
order BY parameter_name
/

PARAMETER_NAME                 PARAMETER_VALUE
------------------------------ ---------------------------------------------
ACCEPT_PLANS                   TRUE
ALTERNATE_PLAN_BASELINE        EXISTING
ALTERNATE_PLAN_LIMIT           0
ALTERNATE_PLAN_SOURCE        CURSOR_CACHE+AUTOMATIC_WORKLOAD_REPOSITORY
DAYS_TO_EXPIRE                 UNLIMITED
DEFAULT_EXECUTION_TYPE         SPM EVOLVE
EXECUTION_DAYS_TO_EXPIRE       30
JOURNALING                     INFORMATION
MODE                           COMPREHENSIVE
TARGET_OBJECTS                 1
TIME_LIMIT                     3600
 SPM_VERIFY                    TRUE
```

Evolving SQL Plan Baseline Manually Using an Example

Here is the initial setup: Table EBKM_TAB has 10,000 rows with no indexes. The OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES =TRUE and OPTIMIZER_USE_SQL_PLAN_BASELINES =TRUE. The following SQL statement will be executed several times in this test:

```
select *
from   ebkm_tab
where  emp_id = 500;
```

Following is the initial run of the SQL statement:

```
select *
from   ebkm_tab
where  emp_id = 500;

Execution Plan
----------------------------------------------------------
Plan hash value: 618087802

| Id  | Operation          | Name     | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |          |     1 |    25 |    14   (0)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| EBKM_TAB |     1 |    25 |    14   (0)| 00:00:01 |
```

Another execution is needed so that the SQL is added to the SQL Plan Baseline:

```
select *
from   ebkm_tab
where  emp_id = 500;

Execution Plan
----------------------------------------------------------
Plan hash value: 618087802

------------------------------------------------------------------------------
| Id  | Operation          | Name     | Rows  | Bytes | Cost (%CPU)| Time     |
------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |          |     1 |    25 |    14   (0)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| EBKM_TAB |     1 |    25 |    14   (0)| 00:00:01 |
------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   1 - filter("EMP_ID"=500)

Note
-----
   - SQL plan baseline "SQL_PLAN_1vgsrj4ry0aws4fe1fc32" used for this statement
```

Now an index is added to the EMP_ID column of the EBKM_TAB table and stats are computed:

```
create index ebkm_tab_idx on ebkm_tab(emp_id);
Index created.

EXECUTE DBMS_STATS.GATHER_SCHEMA_STATS(ownname => 'KEVIN');
PL/SQL procedure successfully completed.
```

Rerun the original SQL statement:

```
select *
from   ebkm_tab
where  emp_id = 500;

Execution Plan
----------------------------------------------------------
Plan hash value: 618087802
```

```
--------------------------------------------------------------------------------
| Id  | Operation         | Name     | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT  |          |     1 |    25 |    14   (0)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| EBKM_TAB |     1 |    25 |    14   (0)| 00:00:01 |
--------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
   1 - filter("EMP_ID"=500)

Note
-----
   - SQL plan baseline "SQL_PLAN_1vgsrj4ry0aws4fe1fc32" used for this statement
```

A second SQL_HANDLE has been added for the SQL statement but with ACCEPTED = NO:

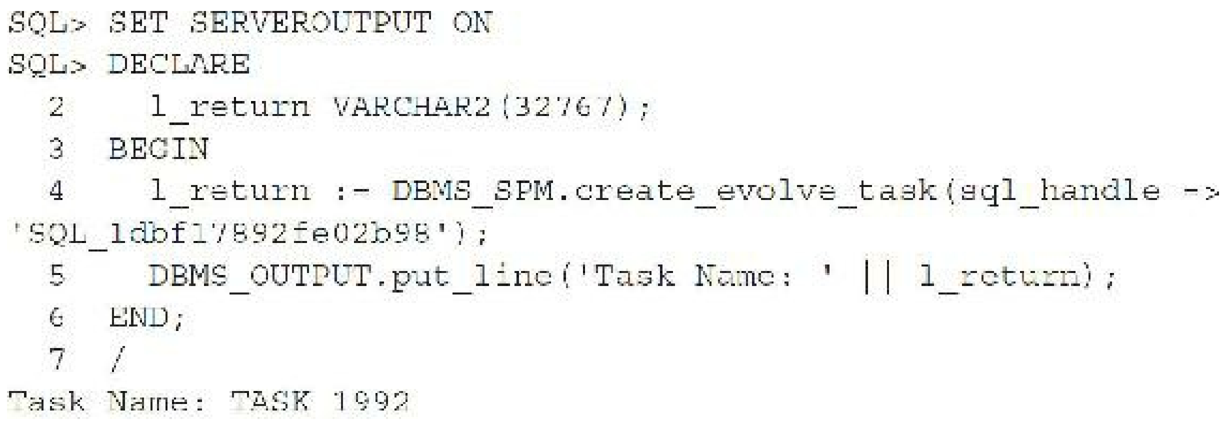
```
select plan_name,sql_handle,enabled,accepted,fixed,adaptive,sql_text
from   dba_sql_plan_baselines
where  creator='KEVIN'
and    sql_text like '%ebkm_t%';

PLAN_NAME
--------------------------------------------------------------------------------
SQL_HANDLE                     ENA ACC FIX ADA

------------------------------ --- --- --- ---
SQL_TEXT
--------------------------------------------------------------------------------
SQL_PLAN_1vgsrj4ry0aws4fe1fc32
SQL_1dbf17892fc02b98           YES YES NO  NO
select * from ebkm_tab where emp_id = 500

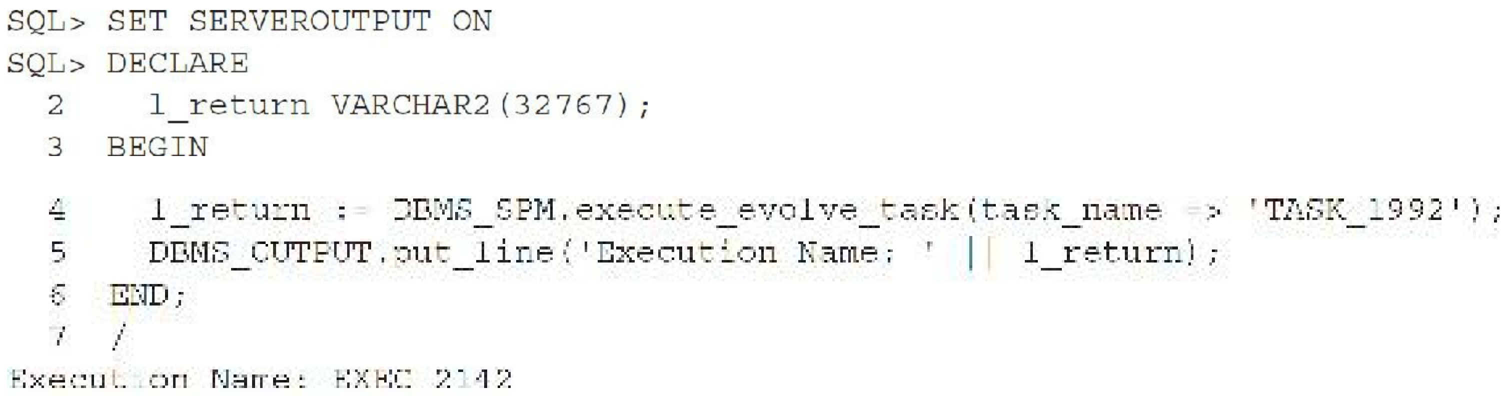
SQL_PLAN_1vgsrj4ry0awsd2487c70
SQL_1dbf17892fc02b98           YES NO  NO  NO
select * from ebkm_tab where emp_id = 500
```

The first step in manually evolving the statement is the CREATE_EVOLVE_TASK:



```
SQL> SET SERVEROUTPUT ON
SQL> DECLARE
  2     l_return VARCHAR2(32767);
  3   BEGIN
  4     l_return := DBMS_SPM.create_evolve_task(sql_handle =>
'SQL_1dbf17892fe02b98');
  5     DBMS_OUTPUT.put_line('Task Name: ' || l_return);
  6   END;
  7   /
Task Name: TASK 1992
```

Use the TASK_NAME in the following EXECUTE_EVOLVE_TASK:



```
SQL> SET SERVEROUTPUT ON
SQL> DECLARE
  2     l_return VARCHAR2(32767);
  3   BEGIN
  4     l_return := DBMS_SPM.execute_evolve_task(task_name => 'TASK_1992');
  5     DBMS_OUTPUT.put_line('Execution Name: ' || l_return);
  6   END;
  7   /
Execution Name: EXEC 2142
```

Use TASK_NAME and EXECUTION_NAME in the following REPORT_EVOLVE _TASK:

```
SQL> SET LONG 1000000 PAGESIZE 1000 LONGCHUNKSIZE 100 LINESIZE 100
SQL>
SQL> SELECT DBMS_SPM.report_evolve_task(task_name => 'TASK_1992', execution_name =>
'EXEC_2142') AS output
  2  FROM   dual;

OUTPUT
---------------------------------------------------------------------------------
GENERAL INFORMATION SECTION
---------------------------------------------------------------------------------

 Task Information:
 ---------------------------------------------
 Task Name               : TASK_1992
 Task Owner              : KEVIN
 Execution Name          : EXEC_2142
 Execution Type          : SPM EVOLVE
 Scope                   : COMPREHENSIVE
 Status                  : COMPLETED
 Started                 : 06/06/2016 07:12:56
 Finished                : 06/06/2016 07:12:59
 Last Updated            : 06/06/2016 07:12:59
 Global Time Limit       : 2147483646
 Per-Plan Time Limit     : UNUSED
 Number of Errors        : 0
---------------------------------------------------------------------------------

SUMMARY SECTION
---------------------------------------------------------------------------------
  Number of plans processed  : 1
  Number of findings         : 1
  Number of recommendations  : 1
  Number of errors           : 0
---------------------------------------------------------------------------------

DETAILS SECTION
---------------------------------------------------------------------------------
 Object ID          : 2
 Test Plan Name     : SQL_PLAN_1vgsrj4ry0awsd2487c70
 Base Plan Name     : SQL_PLAN_1vgsrj4ry0aws4fe1fc32
 SQL Handle         : SQL_1dbf17892fe02b98
 Parsing Schema     : KEVIN
 Test Plan Creator  : KEVIN
 SQL Text           : select * from cbkm_tab where emp_id = 500
```

```
Execution Statistics:
-----------------------------
                      Base Plan                     Test Plan
                      ----------------------------  ----------------------------
 Elapsed Time (s):    .000028                       .000003
 CPU Time (s):        .000033                       0
 Buffer Gets:         5                             0
 Optimizer Cost:      14                            2
 Disk Reads:          0                             0
 Direct Writes:       0                             0
 Rows Processed:      0                             0
 Executions:          10                            10


FINDINGS SECTION
---------------------------------------------------------------------------------

Findings (1):
-----------------------------
 1. The plan was verified in 0.09200 seconds. It passed the benefit criterion
    because its verified performance was 18.01110 times better than that of the
    baseline plan.

Recommendation:
-----------------------------
 Consider accepting the plan. Execute
 dbms_spm.accept_sql_plan_baseline(task_name => 'TASK_1992', object_id => 2,
 task_owner => 'KEVIN');


EXPLAIN PLANS SECTION
---------------------------------------------------------------------------------

Baseline Plan
-----------------------------
 Plan Id          : 203
 Plan Hash Value  : 1340210226

-------------------------------------------------------------------------
| Id  | Operation              | Name      | Rows | Bytes | Cost | Time     |
-------------------------------------------------------------------------
|   0 | SELECT STATEMENT       |           |    1 |    25 |   14 | 00:00:01 |
| * 1 |   TABLE ACCESS FULL    | EBKM_TAB  |    1 |    25 |   14 | 00:00:01 |
-------------------------------------------------------------------------

Predicate Information (identified by operation id):
------------------------------------------
* 1 - filter("EMP_ID"=500)
```

```
Test Plan
--------------------------------------------
 Plan Id          : 204
 Plan Hash Value  : 3527065808

---------------------------------------------------------------------------------------
| Id  | Operation                            | Name          | Rows | Bytes | Cost
| Time     |
---------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                     |               |    1 |    25 |    2
| 00:00:01 |
|   1 |   TABLE ACCESS BY INDEX ROWID BATCHED | EBKM_TAB      |    1 |    25 |    2
| 00:00:01 |
| * 2 |    INDEX RANGE SCAN                  | EBKM_TAB_IDX |    1 |       |    1
| 00:00:01 |
---------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
------------------------------------------
* 2 - access("EMP_ID"=500)
```

The unaccepted plan has met the performance improvement criteria and can be changed to an accepted plan:

```
SQL> SET SERVEROUTPUT ON
SQL> DECLARE
  2    l_return NUMBER;
  3  BEGIN
  4    l_return := DBMS_SPM.implement_evolve_task(task_name => 'TASK_1992');
  5    DBMS_OUTPUT.put_line('Plans Accepted: ' || l_return);
  6  END;
  7  /
Plans Accepted: 1


PLAN_NAME
--------------------------------------------------------------------------------
SQL_HANDLE                     ENA ACC FIX ADA
------------------------------ --- --- --- ---
SQL_TEXT
--------------------------------------------------------------------------------
SQL_PLAN_1vgsrj4ry0aws4fe1fc32
SQL_1dbf17892fe02b98           YES YES NO  NO
select * from ebkm_tab where emp_id = 500

SQL_PLAN_1vgsrj4ry0awsd2487c70
SQL_1dbf17892fe02b98           YES YES NO  NO
select * from ebkm_tab where emp_id = 500
```

The new accepted plan is now being used:

```
select *
from   ebkm_tab
where  emp_id = 500;

Execution Plan
----------------------------------------------------------
Plan hash value: 1322099859

--------------------------------------------------------------------------------
| Id  | Operation                            | Name          | Rows  | Bytes |
Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                     |               |     1 |    25 |
2   (0)| 00:00:01 |
|   1 |  TABLE ACCESS BY INDEX ROWID BATCHED| EBKM_TAB      |     1 |    25 |
2   (0)| 00:00:01 |
|*  2 |   INDEX RANGE SCAN                   | EBKM_TAB_IDX  |     1 |       |
1   (0)| 00:00:01 |
--------------------------------------------------------------------------------
```

Tips Review

- Setting TIMED_STATISTICS = TRUE in the `init.ora` will enable the collection of time statistics. The initialization parameter SQL_TRACE has been deprecated (may go away in the future).
- The TKPROF utility converts traced output into a readable format. Without running TKPROF, reading the output of a TRACE would be difficult. By specifying `explain = username/password`, you can get the EXPLAIN execution path, in addition to the execution statistics for the query. There is also an option for a PDB (pluggable database) in R12.
- Run TKPROF from the command line without any parameter for a list of all the parameters.
- A traced query with a large number of physical reads may indicate a missing index.
- The trace file is a point-in-time picture of what happened on the system at the time that the trace was run (includes the row source operation). In contrast, the EXPLAIN PLAN is generated when the TKPROF listing is created, which could be some time later. The row source operation listing is generated as part of the trace file and can be used to see if the database objects have changed since the TRACE was performed.
- Full table scans are one of the first things Oracle pushes out of memory (becoming least recently used as soon as you run them) because they are so inefficient, generally using a lot of memory.
- Using a value of ALL_EXECUTIONS for the PLAN_STAT ensures that information regarding the execution plan is always contained in the trace file.
- When using DBMS_MONITOR, disable tracing when you are done; otherwise, every session that meets the criteria specified will be traced.
- Use the SET STATEMENT_ID = *'your_identifier'* when the PLAN_TABLE will be populated by many different developers. I rarely use the SET STATEMENT_ID statement. Instead, I explain a query, look at the output, and then delete from the PLAN_TABLE table. I continue to do this (making changes to the query) until I see an execution plan that I think is favorable. I then run the query to see if performance has improved. If multiple developers/DBAs are using the same PLAN_TABLE, the SET STATEMENT_ID (case sensitive) is essential to identifying a statement.
- Use EXPLAIN instead of TRACE so you don't have to wait for the query to run. EXPLAIN shows the path of a query without actually running the query. Use TRACE only for multiquery batch jobs to find out which of the many queries in the batch job are slow.
- You can use the `utlxpls.sql` and `utlxplp.sql` queries provided by Oracle to query the PLAN_TABLE table without having to write your own query and format the output.
- Whether the EXPLAIN PLAN is read from top to bottom or from bottom to top depends entirely on the query used to select information from the PLAN_TABLE. Both methods of reading the query may be correct, given that the query selecting the information is correctly structured.

- If the error "Unable to verify plan table format or existence" occurs when enabling AUTOTRACE, you must create a PLAN_TABLE using `utlxplan.sql`.
- AUTOTRACE may fail when querying system views because the user may not have permission to view underlying objects.
- Partitions can also be viewed by the EXPLAIN PLAN by accessing the columns PARTITION_START and PARTITION_STOP in the PLAN_TABLE table.
- Accessing the V$SQLAREA table can give statistics that are often found when tracing a query.
- You can also use TRACE within the Fusion Middleware (Developer) products. You simply need to set `statistics = yes` on the command line for some products, or you may embed the tracing within an actual trigger to turn tracing on and off.
- The OPERATION and OPTIONS columns of the PLAN_TABLE are the most important columns for tuning a query. The OPERATION column shows the actual operation performed (including type of join), and the OPTIONS column tells you when a full table scan is being performed (that may need an index).
- The PARENT_ID column is very important because it shows the dependencies of two steps in an EXPLAIN PLAN. If a step in the EXPLAIN PLAN has a PARENT_ID, it implies that this statement must run prior to the PARENT_ID that is specified.
- The BYTES column is extremely important when evaluating how to tune a query. When an index is used and the number of bytes is great, it implies that doing a full table scan would perhaps be more efficient (i.e., reading the index and data is more costly than just reading the data in a full table scan). Also, the number of bytes helps you determine which table should be accessed first in the query (driving table) because one table may limit the number of bytes needed from another.
- Both the COST and BYTES values in a query are estimates; it is quite possible for a version of a query with a higher estimated cost or bytes to run faster than another with a lower value.
- The X$KSPPI table can be accessed only by the SYS user. See Chapter 13 for tips on accessing the X$ tables and using some of these parameters. Do not use *any* undocumented parameters without consulting My Oracle Support. Note that the layout and column names of these views have been known to change between Oracle releases.
- Tracing queries can help performance, but using the TRACE facility built into the undocumented TRACE `init.ora` parameters can give you great insight into solving errors within Oracle.
- STORED OUTLINES freeze an execution plan whereas SQL Plan Management allows a new execution plan as long as the plan improves the performance of the SQL statement. If both a stored outline and an SPM plan exist for a SQL statement, the stored outline takes precedence.
- A SQL Plan Baseline must be both ENABLED and ACCEPTED to be considered by the optimizer.
- An adaptive plan is one in which the execution of a statement can start with one execution plan (a join using nested loops) and switch to another (join using a Hash Join) *during* execution

without rerunning based on what it's seeing (statistics-wise) while it's running. Statistic collectors are set at critical points during the plan execution to see if the *actual* execution is varying greatly from what was expected originally, based on the statistics. If the difference in the comparison crosses certain thresholds, Oracle will switch to a better execution plan *during* execution. Comparing EXPLAIN PLAN (execution at start) to DBMS_XPLAN (final plan at completion), you can see the before/after plans.

References

My Oracle Support (Metalink) Notes: 293661.1, 13737.1, 726802.1.

*Oracle Database 12*c *SQL Tuning Guide* (Oracle Corporation).

Many thanks to Warren Bakker for upgrading this chapter to Oracle 12*c*, 11*g*, and 10*g*. Thanks to Mark Riedel for previously upgrading this chapter to Oracle9*i*, and to Dave Hathway, Greg Pucka, and Roger Behm for their original contributions to this chapter.

CHAPTER

7

Basic Hint Syntax (Developer and DBA)

Although the cost-based optimizer is incredibly accurate in choosing the correct optimization path and use of indexes for thousands of queries on your system, it is not perfect (even with 12*c* Adaptive Query Optimization). To this end, Oracle provides hints that you can specify for a given query to override the optimizer, hopefully achieving better performance for a given query. This chapter focuses on the basic syntax and use of hints. The chapters following this one (Chapters 8 and 9) have more complex examples, using various hints covered in this chapter.

Because every system is diverse, the most useful hints for your system may not be the same ones that I have found to be best. Common to most systems is the use of the FULL, INDEX, ORDERED, and LEADING hints. A system with the parallel option may use the PARALLEL hint most often. In 12*c*, some of the best hints are those related to the In-Memory (IM) column store (INMEMORY and NO_INMEMORY hints), those related to pluggable databases (CONTAINERS hint), and those related to Adaptive Query Optimization (ADAPTIVE_PLAN and AUTO_REOPTIMIZE hints). Lastly, I do cover the hint that's not an optimizer hint (WITH_PLSQL). Other hints that were introduced in 11*g* that you might not be using yet include RESULT_CACHE, MONITOR, and NO_MONITOR. Several formerly supported hints were removed from the *Oracle Database SQL Language Reference* (these were deprecated/discouraged/unsupported): RULE, the anti-join hints (HASH_AJ, NL_AJ, MERGE_AJ), the semi-join hints (HASH_SJ, NL_SJ, MERGE_SJ), ROWID, and AND_EQUAL.

Tips covered in this chapter include the following:

- The top hints used, the available hints and groupings, and specifying multiple hints
- When using an alias, the necessity to use the alias, *not* the table name, in the hint
- Using the FIRST_ROWS hint generally to force the use of indexes
- Using the ALL_ROWS hint generally to force a full table scan
- Using the FULL hint to perform a full table scan
- Using the INDEX hint to affect the use of an index
- Using the NO_INDEX hint to disallow a specified index from being used
- Using the INDEX_ASC hint to use an index ordered in ascending order
- Using the INDEX_DESC hint to use an index ordered in descending order

- Using the INDEX_JOIN hint to allow the merging of indexes on a single table
- Using the INDEX_COMBINE hint to access multiple bitmap indexes
- Performing fast full scans with the INDEX_FFS hint
- Using the ORDERED hint to specify the driving order of tables
- Using the LEADING hint to specify just the first driving table
- Using the NO_EXPAND hint to avoid OR expansion
- Using queries involving multiple locations and the DRIVING_SITE hint
- Using the USE_MERGE, USE_NL, and USE_HASH hints to change how tables are joined internally
- Processing subqueries earlier with PUSH_SUBQ
- Using the parallel query option and PARALLEL and NO_PARALLEL
- Using APPEND and NOAPPEND for faster data inserts
- Caching and pinning a table into memory with the CACHE hint in the buffer cache
- Using the NOCACHE hint
- Caching table data with the RESULT_CACHE in the shared pool
- Overriding the CURSOR_SHARING setting with the CURSOR_SHARING_EXACT hint
- Using the INMEMORY and NO_INMEMORY hints (only 12.1.0.2+)
- Using the USE_INVISIBLE_INDEXES hint (12*c*)
- Using the CONTAINERS hint (12*c*)
- Using the WITH_PLSQL hint (12*c*)
- Miscellaneous hints and notes from 12*c* and other versions

Top Hints Used

I did an informal survey at TUSC to see which hints both DBAs and developers use in their day-to-day tuning. I asked them to give me only the top three that they used. The results were not surprising to me, but if you've never used hints, this is quite helpful in determining where to start. Here is the list of TUSC's top hints, in the order in which they are used (I personally use INDEX, ORDERED, PARALLEL, LEADING, FULL, APPEND, and NO_INDEX the most):

1. INDEX
2. ORDERED
3. PARALLEL
4. FIRST_ROWS
5. FULL

6. LEADING
7. USE_NL
8. APPEND
9. USE_HASH
10. RESULT_CACHE

NOTE
The top three in this list are also the top three that I've used the most since hints were introduced. I've frequently used all of these in my tuning, so they are a great place to start.

The Top Hints list will probably be expanded to add these five new hints by 12*c*R2:

1. INMEMORY/NO_INMEMORY
2. USE_INVISIBLE_INDEXES
3. CONTAINERS
4. AUTO_REOPTIMIZE/ADAPTIVE_PLAN
5. WITH_PLSQL

Use Hints Sparingly

Hints fall into two primary categories: usage directives and compiler directives. *Usage directives* are those that can be set using initialization parameters in addition to the statement level (i.e., FIRST_ROWS, ALL_ROWS). If you have an OLTP database, setting the optimizer (at the instance level) from ALL_ROWS to FIRST_ROWS immediately focuses the optimizer on returning the first few rows faster (best response time for most OLTP applications). Setting the optimizer (at the instance level) to ALL_ROWS immediately focuses the optimizer on returning all rows faster (best throughput for all rows, which may be preferred for batch operations or data warehouses). The hints you give the optimizer influence its choices for join operations and the order of operations. In both database cases (OLTP and data warehouse), the goal is to solve performance issues system-wide instead of needing to tune individual queries.

When there are queries inside a data warehouse that behave more like OLTP queries or vice versa, you may need to use hints for those specific statements. As you begin to use hints, you may find yourself tuning the same type of problem over and over, an indication that you have improper instance-level settings or improper database structures (missing indexes or I/O contention, for example) that are impacting performance. Tuning the symptoms (using *compiler directives* in the short term) leads you to the pattern that can be fixed for the long term. Then you will hopefully be able to apply a usage directive to fix the problem system-wide. Try to use hints with this in mind and you'll use them only rarely.

Hints are best used sparingly. Hints are called “hints” and not “commands” for a reason: the cost-based optimizer may reject the instruction if it decides that the query will perform better without implementing the hint. Furthermore, hints can perform unpredictably when used with other hints, upgrading the database, applying patches, or changing database initialization/session parameters. Hints can provide valuable functionality, but you should only use them when other ways of achieving the same goals do not work.

Fix the Design First

In a three-table join, depending on the column order of the index on the intersection table, the query usually accesses the tables in a particular order. By correctly indexing the intersection table and the joined columns of the other tables, you will eliminate many of your performance problems before they happen. If you are using an ORDERED or LEADING hint over and over for joins, review the indexes on the joined tables to help you change how the optimizer is looking at the problem. Rewriting SQL statements so they correctly use indexes will also solve many of your problems, eliminating the need for a hint. Putting a function on an indexed column may suppress the index and cause the tables to drive differently (be read in a different order). Use hints when you have exhausted the other avenues for tuning a query. If you find that you are using the same hint for the same problem over and over, you almost certainly have a problem that can be fixed system-wide instead. Always try to unlock the system problem inside each query-level issue. This also helps you avoid the pain caused by hints working differently when you upgrade to a new version.

For example, consider a typical three-table join between STUDENT, CLASS, and STUDENT_CLASS tables. The STUDENT table contains one row for each student, the CLASS table contains one row for each CLASS, and the STUDENT_CLASS table is the intersection table, as multiple students attend multiple classes. The primary keys for the tables may look like this:

STUDENT primary key STUDENT_ID
CLASS primary key CLASS_ID
STUDENT_CLASS concatenated primary key of (CLASS_ID, STUDENT_ID)

When the primary keys are defined in this manner, Oracle automatically creates indexes to support them. The intersection table, STUDENT_CLASS, has a concatenated index on two columns, CLASS_ID and STUDENT_ID, with CLASS_ID as the leading column. Is this the best column order for all of the application’s queries? Unless you can forecast all of the queries that will join these tables, you should create a second index on the STUDENT_CLASS table’s primary key columns:

STUDENT_CLASS secondary index on (STUDENT_ID, CLASS_ID)

When processing a join of these three tables, the optimizer can now choose to begin at either the STUDENT or CLASS table and will have an available index on STUDENT_CLASS that will support its needs. You may find that the secondary index is rarely used—but it is there when it is needed to support application users and their related business processes. By designing the indexing structures to support multiple access paths, you give the optimizer the tools it needs to choose the best execution path without resorting to a hint.

Available Hints and Groupings

The available hints vary according to the version of the database installed. While this chapter focuses on frequently used hints, many hints that are not covered in detail may give great performance gains for someone with a particular system. Hint functionality and syntax is listed in the Oracle documentation in the *Oracle Database SQL Language Reference*.

Hints are separated into the different categories described in the following sections according to which type of operation is being modified by the hint. Each hint is discussed in detail, including syntax and examples, in the sections that follow. The view V$SQL_HINT lists the available hints, the version in which they became available, and the hint class (such as ACCESS, CACHE, etc.).

Execution Path

Hints modify the execution path when an optimizer processes a particular statement. The instance-level parameter OPTIMIZER_MODE can be used to modify all statements in the database to follow a specific execution path, but a hint to a different execution path overrides anything that is specified in the instance parameter file. If a SQL statement has a hint specifying an optimization approach and goal, then the optimizer should use the specified approach regardless of the presence or absence of statistics, the value of the OPTIMIZER_MODE initialization parameter, and the OPTIMIZER_MODE parameter of the ALTER SESSION statement. Oracle also notes this in its documentation: If these statistics have not been gathered, or if the statistics are no longer representative of the data stored within the database, then the cost-based optimizer does not have sufficient information to generate the best plan.

Hints that change the execution path include the following:

- ALL_ROWS
- FIRST_ROWS(*n*)

Access Methods

The hints that are grouped into access methods allow the coder to vary the way the data is accessed. This group of hints is most frequently used, especially the INDEX hint. The INDEX hint provides direction as to whether and how indexes are used, and how the corresponding indexes will be merged to get the final answer.

The access method hints are listed here and described later in this chapter:

- FULL
- INDEX, INDEX_ASC, INDEX_DESC
- NO_INDEX, NO_INDEX_FFS, NO_INDEX_SS
- INDEX_COMBINE

- INDEX_JOIN
- INDEX_FFS
- INDEX_SS, INDEX_SS_ASC, INDEX_SS_DESC

Query Transformation Hints

Query transformation hints are especially helpful in a data warehouse if you are familiar with using fact and dimension tables. The FACT hint can designate a given table to be the FACT or driving table for a query. The NO_FACT hint does the opposite. The STAR_TRANSFORMATION hint is used to access the fact table efficiently when joining multiple tables. The NO_STAR_TRANSFORMATION hint instructs the optimizer *not* to perform a star query transformation when you have a schema whose structure appears to be that of a data warehouse but isn't actually. Persuading the cost-based optimizer to use star plans is assisted by using bitmap indexes instead of b-tree indexes.

Some of the query transformations have nothing to do with star queries. Many transformations take place behind the scenes without using hints at all, but hints are available to help this process along. MERGE requests index values (not table values) as the primary data source; REWRITE rewrites a query to access a materialized view instead of source tables; and UNNEST works with subqueries to restructure the query to use a table join. Use NO_QUERY_TRANSFORMATION to avoid query transformations.

The query transformation hints are

- FACT, NO_FACT
- MERGE, NO_MERGE
- USE_CONCAT, NO_EXPAND
- NO_QUERY_TRANSFORMATION
- REWRITE, NO_REWRITE
- STAR_TRANSFORMATION, NO_STAR_TRANSFORMATION
- UNNEST, NO_UNNEST

Join Operations

The join operations group of hints controls how joined tables merge data together. A join operation may direct the optimizer to choose the best path for retrieving all rows for a query (*throughput*) or for retrieving the first row (*response time*).

Two hints are available to influence join order directly. LEADING specifies a table to start with for the join order to use, whereas ORDERED tells the optimizer to join the tables based on their order in the FROM clause, using the first table listed as the driving table (*accessed first*).

Hints available to direct the use of join operations include

- LEADING, ORDERED
- USE_HASH, NO_USE_HASH
- USE_MERGE, NO_USE_MERGE
- USE_NL, USE_NL_WITH_INDEX, NO_USE_NL

Parallel Execution

The parallel execution group of hints applies to databases using the parallel option (only available with Oracle Enterprise Edition). These hints override the table specification for the degree of parallelism.

The parallel execution hints are

- PARALLEL, NO_PARALLEL
- PARALLEL_INDEX, NO_PARALLEL_INDEX

Other Hints

Other hints are not easily grouped into categories. The APPEND and NOAPPEND hints can be used without the parallel option, but they are frequently used with it. The cache grouping pertains to the hints that will put items as most recently used (CACHE) or least recently used (NOCACHE).

Like APPEND and CACHE, the following hints are available to influence the ways in which the optimizer processes the table accesses:

- APPEND, NOAPPEND
- CACHE, NOCACHE
- CURSOR_SHARING_EXACT
- DRIVING_SITE
- DYNAMIC_SAMPLING
- MODEL_MIN_ANALYSIS
- PUSH_PRED, NO_PUSH_PRED
- PUSH_SUBQ, NO_PUSH_SUBQ
- QB_NAME
- OPT_PARAM
- RESULT_CACHE, NO_RESULT_CACHE

Specifying a Hint

If you incorrectly specify a hint in any way, it becomes a comment and is ignored. No error is issued because the botched hint becomes a comment (unless the comment structure itself is incorrect). Be very careful to get the hint syntax *exactly* correct. The best way to ensure that a hint has been correctly specified is to run an EXPLAIN PLAN (or DBMS_XPLAN), or set AUTOTRACE to ON in SQL*Plus to see if the hint was used; check to see if the execution plan is producing the expected results if the hint should affect the plan. Some hints are overridden by the optimizer despite the fact that a hint is primarily for influencing decisions made by the Oracle optimizer. The basic hint syntax (in this example, it is for a FULL hint) is shown here. Note that the difference in these two formats is that the first uses multiline comment delimiters and the second uses inline comment delimiters. If you use the inline comment delimiter, then anything that comes after it (like column names) is ignored. You must continue the query on the next line.

```
select     /*+ FULL(table) */ column1, ...
```

or

```
select     --+FULL(table)
           column1, ...
```

The (*TABLE*) in the preceding code snippet is the table name on which to perform a full table scan, or the alias for the table if you specified an alias in the FROM clause, as shown here:

```
select     /*+ FULL(employees) */ employee_id, last_name, department_id
from       employees
where      department id = 1;
```

In this example, even if you have an index on the DEPARTMENT_ID column, a full table scan should be performed. The hint is not required to be uppercase. If using block comments with hints, be careful not to try to comment out the hinted text later with an enclosing block comment. The database ignores the second start block comment marker (it will be commented), uses the first closing block comment marker (from the hint) to close the initial block comments, and raises a *syntax error* when the second, unmatched block comment terminator is found.

```
select     /* FULL(employees) */ employee id, last name, department id
from       employees
where      department id = 1;
```

In this query, if there were an index on the DEPARTMENT_ID column, the index would be used because the hint is missing the plus sign (+) and becomes a comment.

When a hint accepts multiple arguments, spaces *or* commas may separate arguments:

```
select      /*+ index(employees emp emp id pk emp job ix) */ ...
```

or

```
select      /*+ index(employees,emp emp id pk,emp job ix) */ ...
```

TIP
Incorrect hint syntax leads to the hint being interpreted as a comment. If an additional hint is specified correctly, it will be used.

By default, hints only affect the code block in which they appear. If you hint the access of the EMPLOYEES table in a query that is part of a UNION operation, the other queries within the UNION are not affected by your hint. If you want all of the unioned queries to use the same hint, you need to specify the hint in each of the queries. This also applies to views, subqueries, and subquery factoring (the WITH clause).

You can specify the query block name in hints to specify the query block to which the hint applies. Thus, in an outer query, you can specify a hint that applies to a subquery. The hint syntax for the *QUERY_BLOCK* argument is in the form

```
@query_block
```

where *QUERY_BLOCK* is a user-specified or system-generated identifier. Use the QB_NAME hint to specify the name for the query block. If you are using system-generated hints, you can view the query block names via the EXPLAIN PLAN for the query (an example is given later in this chapter).

Specifying Multiple Hints

You can use more than one hint at a time, although this may cause some or all of the hints to be ignored. Separate hints with spaces, as shown here:

```
select     /*+ FULL(table) CACHE(table)*/ column1,…
```

The (*TABLE*) in this code snippet is the table name to perform the full scan and cache on:

```
select      /*+ FULL(employees) CACHE(employees)*/
            employee_id, last_name, department_ID
from        employees
where       department id = 1;
```

TIP
Multiple hints are separated with a space. Specifying multiple hints that conflict with each other causes the query to use none of the conflicting hints.

When Using an Alias, Hint the Alias, Not the Table

When you use aliases on a given table that you want to use in a hint, you must specify the alias and *not* the table name in the hint. If you specify the table name in the hint when an alias is used, the hint is *not* used.

```
select      /*+ FULL(table) */ column1,...
```

The (*TABLE*) in this code snippet has to be replaced with the alias that follows since the query uses an alias. If an alias is used, the alias *must* be used in the hint or the hint will *not* work:

```
select      /*+ FULL(A) */ employee id, last name, department id
from        employees A
where       department id = 1;
```

TIP
If an alias is used, the alias must be used in the hint or the hint will not work.

The Hints

The hints discussed here are available as of Oracle Database 12*c* Release 1 as well as being available in Oracle Database 12*c* Release 2. Consult the Oracle documentation for more information on these or other hints.

As of 11*g* and continuing into 12*c*, Oracle Database automatically maintains optimizer statistics if it is enabled. The database automatically collects optimizer statistics for tables with absent or stale statistics. If fresh statistics are required for a table, then the database collects them both for the table and associated indexes. The automatic optimizer statistics collection runs as part of AutoTask and is enabled by default to run in all predefined maintenance windows (which means, once daily). Automatic optimizer statistics collection relies on the modification monitoring feature. This monitoring is enabled by default when STATISTICS_LEVEL is set to TYPICAL or ALL. Monitoring tracks the approximate number of INSERTs, UPDATEs, and DELETEs for that table and whether the table has been truncated since the last time statistics were gathered. If a monitored table has been modified more than 10 percent, then these statistics are considered stale and gathered again. You use the DBMS_STATS package to manage the statistics manually. Adaptive Query Optimization (discussed in Chapter 8 in detail) improves the Oracle optimizer.

The Oracle Demo Sample HR Schema

I used the sample Oracle demo HR schema to produce the examples that follow. In some cases, I created additional objects to facilitate working with some of the hints where they were not created with the sample schema.

```
create bitmap index employees_first_name_bmp on employees(first_name);
create bitmap index employees_commision_bmp on employees(commission_pct);
```

The FIRST_ROWS Hint

The FIRST_ROWS hint directs the optimizer to optimize a query on the basis of retrieving the first rows the fastest. This approach is especially helpful when users of the system are using online transaction processing (OLTP) systems to retrieve a single record on their screen. This approach would be a poor choice for a batch-intensive environment where a lot of rows are generally retrieved by a query. The FIRST_ROWS hint generally forces the use of indexes, which, under normal circumstances, may not have been used. The FIRST_ROWS or ALL_ROWS hint (the optimizer makes a best-guess effort to choose the better of the two) is used, even when statistics are not gathered for the optimizer (ALL_ROWS is the default).

The FIRST_ROWS hint is ignored in UPDATE and DELETE statements since all rows of the query must be updated or deleted. It is also ignored when any grouping statement is used (GROUP BY, DISTINCT, INTERSECT, MINUS, UNION) because all of the rows for the grouping have to be retrieved for the grouping to occur. The optimizer may also choose to avoid a sort when there is an ORDER BY in the statement if an index scan can do the actual sort. The optimizer may also choose NESTED LOOPS over a SORT MERGE when an index scan is available and the index is on the inner table. The inner table shortens the result set that is joined back to the outside table in the query, and specifying access paths overrides this hint.

You may also specify the number of rows (as in the second example that follows) that you want FIRST_ROWS to optimize getting (the default is one). Note that this is specified in powers of 10 up to 1000. Using FIRST_ROWS (*n*) is totally based on costs and is sensitive to the value of *n*. With small values of *n*, the optimizer tends to generate plans that consist of nested loops joins with index lookups. With large values of *n*, the optimizer tends to generate plans that consist of hash joins and full table scans (behaving more like ALL_ROWS).

Syntax

```
select      /*+ FIRST_ROWS(n) */ column1, …
```

Example

```
select      /*+ FIRST_ROWS */ employee_id, last_name, department_id
from        employees
where       department_id = 1;
```

Example

```
select      /*+ FIRST_ROWS(10) */ employee_id, last_name, department_id
from        employees
where       department_id = 1;
```

TIP

The FIRST_ROWS hint causes the optimizer to choose a path that retrieves the first row (or a specified number of rows) of a query fastest, at the cost of retrieving multiple rows slower. The FIRST_ROWS hint may be set as the default for the entire database by setting OPTIMIZER_MODE = FIRST_ROWS in the system parameter file; query-level hints will override the default setting for a given query. You can also set the optimizer to FIRST_ROWS_n (see Chapter 4 for additional information).

The ALL_ROWS Hint

The ALL_ROWS (*best throughput*) hint directs a query to optimize a query on the basis of retrieving all of the rows the fastest. This approach is especially helpful when users of the system are in a heavy batch report environment and running reports that retrieve a lot of rows. This would be a poor choice for a heavy transaction processing environment where users are trying to view a single record on a screen. The ALL_ROWS hint may suppress the use of indexes that under normal circumstances would have been used. Specifying access path hints overrides the use of this hint.

Syntax

```
select      /*+ ALL_ROWS */ column1, …
```

Example

```
select      /*+ ALL ROWS */ employee id, last name, department id
from        employees
where       department id = 1;
```

TIP
The ALL_ROWS hint causes the optimizer to choose a path that retrieves all the rows of a query fastest, at the cost of retrieving one single row slower. The ALL_ROWS hint may be set as the default for the entire database by setting OPTIMIZER_MODE = ALL_ROWS (the default) in the system parameter file; query-level hints will override the default setting for a given query.

The FULL Hint

The FULL hint directs a query to override the optimizer and perform a full table scan on the specified table in the hint. The FULL hint has different functionality based on the query that you are tuning. You can use it to force a full table scan when a large portion of the table is being queried. The cost of retrieving the index *and* the rows may be greater than just retrieving the entire table. The FULL hint may also cause an unexpected result. Causing a full table scan may cause tables to be accessed in a different order, because a different driving table is used. This may lead to better performance, leading one to believe that the full table scan was the key benefit, when changing the order of the driving table was the real cause of the improved performance.

Syntax

```
select      /*+ FULL([query block] table) */ column1,…
```

Here, (*TABLE*) is the table name to perform the full scan on. If an alias is used, the alias *must* be used in the hint or it will *not* work.

Note that you should only specify the table name in the hint, not the schema name.

Example

```
select      /*+ FULL(employees) */ employee_id, last_name, department_id
from        employees
where       department_id = 1;
```

The FULL hint in this example would be particularly helpful if the only department in the company was one (1). Going to an index on DEPARTMENT_ID and the EMPLOYEES table would be slower than simply performing a full table scan on the EMPLOYEES table.

The FULL hint is also a necessary part of using some of the other hints. The CACHE hint can cache a table in memory only when the full table is accessed. Some of the hints in the parallel grouping also necessitate the use of a full table scan. I cover each of these hints later in this chapter.

TIP
The FULL hint performs a full table scan on the table that is specified, not all tables in the query. The FULL hint may also lead to better performance, which is attributable to causing a change in the driving table of the query and not to the actual full table scan.

If multiple tables have the same name in the same query, assign aliases to them in the FROM clause and then reference the aliases in the hints.

The INDEX Hint

The INDEX hint is frequently used to request one or more indexes to be used for a given query. Oracle generally chooses the correct index or indexes with the optimizer, but when the optimizer chooses the wrong index or no index at all, this hint is excellent. You may also use multiple indexes with this hint, and Oracle will choose one or more of the indexes specified based on the best plan. If you only specify one index, the optimizer considers only the specified index.

Syntax

```
select     /*+ INDEX([query block] table index1 [, index2...]) */ column1, ...
```

Example

```
select     /*+ INDEX (employees emp_emp_id_pk) */ employee_id, last_name
from       employees
where      employee_id = 7750;
```

In the preceding example, the EMP_EMP_ID_PK index on the EMPLOYEES table is used.

Example

```
select     /*+ INDEX (employees emp_department_ix emp_emp_id_pk) */
           employee_id, last_name
from       employees
where      employee_id = 7750
and        department_id = 1;
```

In the second example, Oracle may use the EMP_DEPARTMENT_IX index or the EMP_EMP_ID_PK index or a merge of both of them. I've given these choices to the optimizer to decipher the best choice. It would have been best, however, to only specify the index on the EMPLOYEE_ID column (EMP_EMP_ID_PK) if this were the most restrictive statement (usually much more restrictive than the department).

TIP
The INDEX hint causes the optimizer to choose the index specified in the hint. Multiple indexes for a single table can be specified, but it is usually better to specify only the most restrictive index on a given query (and, that way, avoid the merging of each index's result). If multiple indexes are specified, Oracle chooses which (one or more) to use, so be careful or your hint could potentially be overridden.

Example

```
select      /*+ INDEX */ employee_id, last_name
from        employees
where       employee_id = 7750
and         department_id = 1;
```

In this example, no index is specified. Oracle now weighs all of the possible indexes that are available and chooses one or more to be used. Since I have not specified a particular index, but I have specified the INDEX hint, the optimizer should *not* do a full table scan.

TIP
The INDEX hint, without a specified index, should not consider a full table scan, even though no indexes have been specified. The optimizer will choose the best index or indexes for the query.

As of Oracle Database 10*g*, you can specify column names as part of the INDEX hint. The columns can be prefixed with the table names (not table aliases). Each column listed in the hint must be a physical column in the table, not an expression or calculated column.

Syntax

```
select      /*+ INDEX ([@query_block][table.]column1 [[table2.]column2...]) */
           column1, ...
```

Example

```
select      /*+ INDEX (employees.department_id) */ employee_id, last_name
from        employees
where       department_id = 1;
```

The NO_INDEX Hint

The NO_INDEX hint disallows the optimizer from using a specified index. This is a great hint for tuning queries with multiple indexes. Although you may not know which of multiple indexes to drive the query with, you might know which ones that you *don't* want the optimizer to use (NO_INDEX). You may also want to disallow an index for many queries prior to dropping an index or, as of Oracle

11*g*, make invisible an index that you don’t think is necessary.

Syntax

```
select     /*+ NO_INDEX([@query_block] table index1 [,index2...]) */ column1, ...
```

Example

```
select     /*+ NO_INDEX (employees emp_department_ix) */ employee_id, last_name
from       employees
where      employee_id = 7750
  and      department_id = 1;
```

In this example, the specified index on the EMPLOYEES table should *not* be used. If the NO_INDEX hint is used and no index is specified, a full table scan is performed. If the NO_INDEX and a conflicting hint (such as INDEX) are specified for the same index, then both hints are ignored (as in the example that follows).

Example

```
select       /*+ NO_INDEX(employees emp_department_ix)
                INDEX(employees emp_department_ix) */
             last_name, department_id
 from        employees
 where       department_id = 1
and          last_name = 'SMITH';
```

TIP
The NO_INDEX hint must be in the tuning expert’s toolkit. It is used to remove an index from consideration by the optimizer, so you may evaluate the need for the index prior to dropping it or so you can evaluate other indexes. Be careful not to conflict with other index hints. The NO_INDEX hint is one of my personal favorites when I want to drop an index and check which index (if any) will be used instead of the one that I plan to drop.

The INDEX_JOIN Hint

The INDEX_JOIN hint merges separate indexes from a single table together so *only* the indexes need to be accessed. This approach saves a trip back to the table.

Syntax

```
select     /*+ INDEX_JOIN([@query_block] table index1 [,index2...]) */ column1, …
```

Example

```
select      /*+ INDEX_JOIN(employees emp_emp_id_pk emp_department_ix) */
            employee_id, last_name
from        employees
where       employee_id = 7750
and         department_id = 1;
```

In this query, the optimizer should merge both specified indexes and *not* need to access the table. All information needed is contained in these two indexes when they are merged. For a more detailed example, see Chapter 8.

TIP
Not only does the INDEX_JOIN hint allow you to access only indexes on a table, which is a scan of fewer total blocks, but also it can be five times faster (in some of my tests) than using an index and scanning the table by ROWID.

The INDEX_COMBINE Hint

The INDEX_COMBINE hint is used to specify multiple bitmap indexes when you want the optimizer to use *all* indexes that you specify. You can also use the INDEX_COMBINE hint to specify single indexes (this is preferred over using the INDEX hint for bitmaps). For b-tree indexes, use the INDEX hint instead of this one. The INDEX_COMBINE hint is similar to the INDEX_JOIN hint but is used for bitmap indexes.

Syntax

```
select /*+ INDEX_COMBINE([@query_block] table index1 [,index2...]) */ column1, ...
```

Example

```
select     /*+ INDEX_COMBINE (employees employees_first_name_bmp,
           employees_commission_bmp) */
           employee_id, last_name
from       employees
where      first_name = 'MATT'
and        commission_pct = 5;
```

TIP
The INDEX_COMBINE hint causes the optimizer to merge multiple bitmap indexes for a single table instead of choosing which one is better (as with the INDEX hint).

The INDEX_ASC Hint

The INDEX_ASC hint currently does *exactly* the same thing as the INDEX hint. Since indexes are already scanned in ascending order, this does nothing more than the current INDEX hint. So what is it good for? Oracle does not guarantee that indexes will be scanned in ascending order in the future, but this hint does guarantee that an index will be scanned in ascending order.

Syntax

```
select  /*+ INDEX_ASC ([@query_block] table index1 [, index2...]) */ column1, ...
```

Example

```
select      /*+ INDEX_ASC(employees emp_department_ix) */
            department_id, employee_id, last_name
from        employees
where       department_id <= 30;
```

In this example, the specified index should be used.

TIP
The INDEX_ASC hint does exactly what the INDEX hint does because indexes are already scanned in ascending order. INDEX_ASC guarantees this to be true, however, as Oracle may change this default in the future. Descending indexes are actually sorted in descending order. Oracle treats descending indexes as function-based indexes. The columns marked DESC are sorted in descending order.

The INDEX_DESC Hint

The INDEX_DESC hint causes indexes to be scanned in descending order (of their indexed value or order), which is the opposite of the INDEX and INDEX_ASC hints. This hint is overridden when the query has multiple tables because the index needs to be used in the normal ascending order to be joined to the other table in the query. Some restrictions for this include that it does not work for bitmap indexes or for descending indexes (because it causes the index to be scanned in ascending order), and it does not work across partitioned index boundaries but performs a descending index scan of each partition. The execution plan should list "INDEX RANGE SCAN DESCENDING" for an operation when this hint is adopted, and the data *might* come back in reverse order (though the *only* way to be certain of sorting is to use an ORDER BY clause).

Syntax

```
select   /*+ INDEX_DESC ([@query_block] table index1 [,index2...]) */ column1, ...
```

Example

```
select      /*+ INDEX_DESC(employees emp_department_ix) */
            department_id, employee_id, last_name
from        employees
where       department_id <= 30;
```

TIP
The INDEX_DESC hint processes an index in descending order of how it was built. This hint should not be used if more than one table exists in the query.

The INDEX_FFS Hint

The INDEX_FFS hint indicates a fast full scan of the index should be performed. That is, all values in the index will be read without sorting. INDEX_FFS accesses only the index and *not* the corresponding table. The fast full scan of the index is used only if all of the information that the query needs to retrieve is in the index. This hint can give great performance gains, especially when the table has a large number of columns. Beware, at times a fast full scan of an index is the wrong path for the optimizer to take (look for it in the EXPLAIN PLAN as a potential issue).

Syntax

```
select     /*+ [%query block] INDEX FFS(table index) */ column1, ...
```

Example

```
select     /*+ INDEX_FFS (employees emp_name_ix) */ first_name, last_name
from       employees
where      last_name = 'SMITH';
```

The INDEX_FFS hint is used only if the index contains all the columns in the SELECT list. The NO_INDEX_FFS hint has the same syntax, but this hint tells the optimizer *not* to perform fast full index scans of the specified indexes. You must specify both the table and index in both of these hints.

TIP
The INDEX_FFS hint processes only the index and does not take the result and access the table. All columns that are used and retrieved by the query must be contained in the index.

The ORDERED Hint

The ORDERED hint directs tables to be accessed in a particular order, based on the order of the tables in the FROM clause of the query, which is often referred to as the *driving order* for a query. Generally, the last table in the FROM clause is the driving table in queries (this is version dependent); however, using the ORDERED hint causes the first table in the FROM clause to be the driver (and each table in order). The ORDERED hint also guarantees the driving order. When the ORDERED hint is not used, Oracle may internally switch the driving table, when you compare how tables are listed in the FROM clause (EXPLAIN PLAN can show how tables are accessed). The complexity of possibilities when this hint is used is so great that much of the next chapter is focused on this subject (please see Chapter 8 for more information regarding tuning joins). This chapter briefly covers this hint, mainly for syntactical purposes.

Syntax

```
select      /*+ ORDERED */ column1, ...
```

Example

```
select      /*+ ORDERED */ employee_id, last_name,
            d.department_id
from        employees e, departments d
where       e.department_id = d.department_id
and         d.department_id = 10
and         e.employee id = 7747;
```

If both tables (EMPLOYEES and DEPARTMENTS) have been analyzed *and* there are *no* indexes on either table, the EMPLOYEES table should be accessed first and the DEPARTMENTS table is accessed second. There are many possible variations (covered in the next two chapters) that cause this to work differently (especially based on the join).

Example

```
select     /*+ ORDERED */ employee_id, last_name,
           d.department_id, j.job_title
from       employees e, departments d, jobs j
where      e.department_id = d.department_id
and        d.department_id = 10
and        e.employee_id = 7747
and        e.job_id = j.job_id
/
```

In this example for a three-table join, EMPLOYEES should be joined first to DEPARTMENTS (second as listed in the FROM clause), and then the result set joined to JOBS. There are many possible join-order variations (covered in the next chapter) that could cause this to work differently, but generally, when the ORDERED hint is used, if accepted, the join order should be as specified.

TIP

The ORDERED hint is one of the most powerful hints available. It processes the tables of the query in the sequential order in which they are listed in the FROM clause. There are many variations that cause this to work differently. The version of Oracle, the existence of indexes on the tables, and which tables have been analyzed can all cause this to work differently. However, when a multiple join is slow and you don't know what to do, this is one of the first hints you should try!

The LEADING Hint

As the complexity of queries becomes greater, figuring out the order of *all* of the tables using the ORDERED hint becomes more difficult. You can often figure out which table should be accessed *first* (driving table), but you may not know which table to access after that one. The LEADING hint allows you to specify *one* table to drive the query; the optimizer figures out which table to use after that. If you specify more than one table with this hint, it is ignored. The ORDERED hint overrides the LEADING hint.

Syntax

```
select     /*+ LEADING([@query block] table [table]...) */ column1, ...
```

Example

```
select      /*+ LEADING(d) */ employee_id, last_name,
            d.department_id, j.job_title
from        departments d, employees e, jobs j
where       e.department_id = d.department_id
and         d.department_id = 10
and         e.employee_id = 7747
and         e.job id - j.job id;
```

As stated in the discussion of the ORDERED hint, the process by which a leading table is selected is complex. In this example, the EMPLOYEES table would probably be chosen as the driving table as it is the intersection table. The LEADING hint allows you to specify another table (I chose DEPARTMENTS as the driving table) to be the first table accessed in the query. Be sure you have properly configured the indexes to support the join order you specify.

TIP
The LEADING hint works similarly to the ORDERED hint. The LEADING hint is used to specify a single table to drive a query while allowing the optimizer to figure out the rest.

The NO_EXPAND Hint

The NO_EXPAND hint is used to keep the optimizer from “going off the deep end” when evaluating IN lists that are combined with an OR. It disallows the optimizer from using *OR expansion*, which refers to converting a query to apply OR conditions to execute as separate subqueries whose results are merged with UNION ALL instead of applying OR conditions as a filter. Without the NO_EXPAND hint, the optimizer may create a very long execution plan or use an INLIST ITERATOR access method. To use OR expansion, use the USE_CONCAT hint.

Syntax

```
select      /*+ NO EXPAND [@query block] */ column1, …
```

Example

```
select      /*+ NO_EXPAND */ department_id, employee_id, last_name
from        employees
where       manager_id = 200
or          manager_id = 210;
```

I have used the NO_EXPAND hint and was able to increase performance to almost 50 times faster than without the hint. For simple queries, there may not be much difference in the EXPLAIN PLAN with or without the hint. However, when using a query that joins the EMPLOYEES and DEPARTMENTS tables and selects at least one column from each table, you can see a *big* difference in the EXPLAIN PLAN. In 12*c*R2, the optimizer uses the UNION ALL operator to perform OR expansion, where previously the optimizer used the CONCATENATION operator. It's yet to be seen if this will correct some of the issues.

TIP
The NO_EXPAND hint prevents the optimizer from using OR expansion and is used when the query becomes substantially more complex as a result of the expansion.

The DRIVING_SITE Hint

The DRIVING_SITE hint is for processing distributed queries in the designated database. The table specified in the hint should determine the driving site that will be used to process the actual join.

Syntax

```
select      /*+ DRIVING_SITE ([@query_block] table) */ column1, ...
```

Example

```
select      /*+ DRIVING_SITE (deptremote) */ employee_id, last_name
from        employees, departmentoratusc deptremote
where       employees.department_id = deptremote.deptno
and         deptremote.department_id = 10
and         employee_id = 7747;
```

Oracle normally retrieves the rows from the remote site and joins them at the local site if this hint is not specified. Because the EMPLOYEE_ID = 7747 limits the result set, I would rather pass the small number of rows from the EMPLOYEES table to the remote site instead of pulling an entire DEPARTMENTS table department back to my local site to process to minimize the overhead of data transfer.

A similar benefit may be achieved by limiting the rows that are retrieved from a remote site by creating a view locally for the remote table (if you can have a limiting WHERE clause in the view that still retrieves the desired data). The local view should include the WHERE clause that will be used, so the view will limit the rows returned from the remote database before they are sent back to the local database. I have personally tuned queries from hours to seconds using this method of creating a remote view versus using the DRIVING_SITE hint.

When using the DRIVING_SITE hint, the location is not specified in the hint (just the table name). However, if an alias is used, the alias has to be used instead of the table name in the hint.

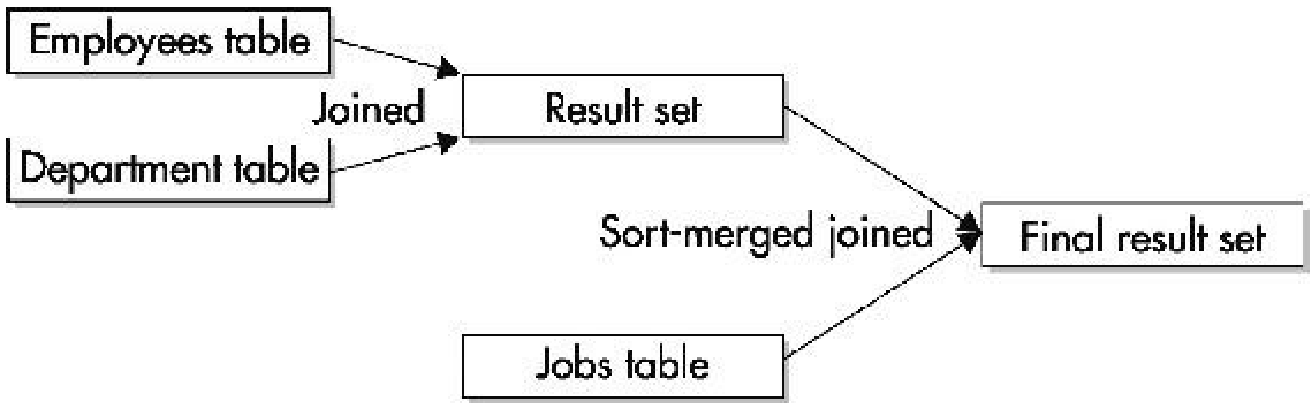
TIP
The DRIVING_SITE hint is extremely powerful, as it will potentially limit the amount of information that will be processed over your network. The table specified with the DRIVING_SITE hint is the location where the join will be processed. Using views for remote tables can also lead to better performance by limiting the number of rows passed from the remote site before the records are sent to the local site.

The USE_MERGE Hint

The USE_MERGE hint is a hint that tells the optimizer to use a MERGE JOIN operation when performing a join. A MERGE JOIN operation may be useful when queries perform set operations on large numbers of rows, perhaps on non-equijoin conditions.

Assume you are joining two tables together. In a MERGE JOIN, the row set returned from each table is sorted and then merged to form the final result set. Because each result is sorted and then merged together, this action is most effective when retrieving all rows from a given query. If you want the first row faster instead, then USE_NL might be a better hint (to force a nested loops join).

In the following illustration, the EMPLOYEES and DEPARTMENTS tables are joined, and that result set is then joined to the JOBS table via a MERGE JOIN operation.



Syntax

```
select      /*+ USE_MERGE([@query_block] table [table]) */ column1, ...
```

where the first table should be accessed by a merge join. The second table specification is optional, and, if unspecified, the optimizer decides what to join the first table to.

Example

```
select      /*+ use_merge(j) */ employee_id, last_name,
            d.department_id, j.job_title
from        departments d, employees e, jobs j
where       e.department_id = d.department_id
and         d.department_id = 10
and         e.employee_id = 7747
and         e.job_id = j.job_id;
```

The USE_MERGE hint in this query causes the JOBS table to be joined in a *sort-merge join* to the returned row source resulting from the join of the EMPLOYEES and DEPARTMENTS tables. The rows are sorted and then merged together to find the final result. The NO_USE_MERGE hint uses the same syntax but instructs the optimizer to not use merge joins when selecting execution paths for a query. The optimizer will instead favor other join methods such as hash joins and nested loops joins. See Chapter 9 for a more detailed discussion of joins.

TIP
In a join of three or more tables, the USE_MERGE hint causes the table(s) specified in the hint to be sort-merge joined with the resulting row set from a join of the other tables in the join.

The USE_NL Hint

The USE_NL (*use nested loops*) hint is usually the fastest way to return a single row (in terms of response time); it may be slower at returning all the rows. This hint causes a statement to be processed using nested loops, which takes the first matching row from one table based on the result from another table. This is the opposite of a merge join, which retrieves rows that match the conditions from each table and then merges them together.

Syntax

```
select     /*+ USE_NL([@query_block] table1[,  table2]) ... */ column1, ...
```

where `table1` should be the first table read (usually the smaller of the two tables by blocks) and `table2` the inner or lookup table. Reversing the order of the tables *might* persuade the cost-based optimizer to read the tables in the suggested order; if not, try the LEADING or ORDERED hints to specify the order of the tables, which can affect performance. If only one table is specified in the hint, use a nested loops access method with the optimizer, choosing the table listed in the hint to be the inner or lookup table.

Example

```
select     /*+ ORDERED USE_NL(d e) */ e.employee_id, e.last_name,
           d.department_id, d.department_name
from       employees e, departments d
where      e.department_id = d.department_id
and        d.department_id = 110
and        e.employee_id = 206;
```

The USE_NL hint directs the optimizer to take the resulting rows returned from the EMPLOYEES table and process them with the matching rows from the DEPARTMENTS table (the specified nested loop table). The first row that matches from the DEPARTMENTS table can be returned to the user immediately (as in a web-based application), as opposed to waiting until all matching rows are found. The ORDERED hint specifies that the EMPLOYEES table should be processed first. Note that there is a difference between using this query with or without the ORDERED hint as well.

TIP
The USE_NL hint usually provides the best response time (first row comes back faster) for smaller result sets, whereas the USE_MERGE hint usually provides the best throughput when the USE_HASH hint can't be used.

The NO_USE_NL hint uses the same syntax but instructs the optimizer not to use nested loops joins. A related hint, USE_NL_WITH_INDEX, takes two parameters—the name of the inner or lookup table for the join along with the name of the index to use when performing the join.

The USE_HASH Hint

The USE_HASH (*use hash join*) hint is usually the fastest way to join many rows together from multiple tables *if you have adequate memory for this operation*. The USE_HASH <hint or method> is similar to the nested loops where one result of one table is looped through the result from the joined table. The difference is that the second table (the lookup table) is put into memory and should usually be the smaller table. You must have a large enough HASH_AREA_SIZE or PGA_AGGREGATE_LIMIT (see Chapter 4) for this to work properly; otherwise, the operation will occur on disk (which slows things down).

NOTE
Don't confuse USE_HASH with HASH, which is used with hash clusters—physical data structures that store master and detail rows together in the same databases as already joined.

Syntax

```
select      /*+ USE_HASH ([@query_block]table1 [, table2,...]) */ ...
```

Example

```
select      /*+ use_hash(d) */ employee_id, last_name,
            d.department_id
from        employees e, departments d
where       e.department_id = d.department_id;
```

The USE_HASH hint directs the optimizer to take the rows returned from the EMPLOYEES table and process them with the matching rows from the DEPARTMENTS table (the specified hash table), which are hashed into memory. The first row that matches from the DEPARTMENTS table can be returned to the user immediately, as opposed to waiting until all matching rows are found. There are cases in which the optimizer overrides this hint, and environmental settings greatly affect the optimizer's decision to use hash joins. In the preceding query, if you added the condition "AND D.DEPARTMENT_ID=1", the optimizer would override the USE_HASH hint and do the more efficient nested loops join (since the DEPARTMENTS table has been narrowed down by this condition) or use a merge join.

The NO_USE_HASH hint has a similar syntax but instructs the optimizer to not use hash joins when selecting execution paths for a query. The optimizer should instead use other join methods such as nested loops or merge joins. You often need to add the ORDERED hint in addition to table join hints to drive things the way you want them.

TIP
The USE_HASH hint usually provides the best response time for larger result sets.

SWAP_JOIN_INPUTS is an undocumented hint (there are My Oracle Support articles about it) used to persuade the cost-based optimizer to use the specified table as the lookup hash table. Even though it is undocumented, it is listed in the V$SQL_HINT view.

Syntax

```
Select       /*+ SWAP_JOIN_INPUTS(table1) */ ...
```

The QB_NAME Hint

The QB_NAME hint is used to assign a name to a query block within a statement. You can then assign a hint elsewhere in the statement that references the query block. For example, if you have a query that contains a subquery, you can assign a query block name to the subquery and then provide the hint at the outermost query level. If two or more query blocks are given the same QB_NAME value, the optimizer ignores the hints. You can also use the query block names when looking at execution plans to decide to which part of the query a particular operation belongs. This hint in 12*c*R2 is used in the CONTAINERS hint (described later in the chapter) to push hints to pluggable databases (PDBs).

If you have a complex query, with subqueries in the EXPLAIN PLAN, it appears that the optimizer generates a default name for these query blocks, such as emp@sel$4. By using the QB_NAME hint, you can specify the name instead (use a name that means something to you). This option is very helpful when trying to tune extremely complex queries that contain more than one subquery.

Syntax

```
Select      /*+ QB NAME(query block) */ column1...
```

Example

```
select      /*+ FULL(@deptblock departments) */ employee_id
from        employees
where       employees.department_id IN
               (select /*+ QB_NAME(deptblock) */ department_id
                from  departments
                where location_id = 10);
```

Even though the FULL hint is specified in the outer query (main query), it should affect the subquery because you used the query block specified in the inner query (subquery).

The PUSH_SUBQ Hint

The PUSH_SUBQ hint can lead to dramatic performance gains (an increase of more than 100 times in terms of performance) when used in the appropriate situation. The best situation in which to use this hint is when the subquery returns a relatively small number of rows (quickly); those rows can then be used to substantially limit the rows in the outer query. PUSH_SUBQ causes the subquery to be evaluated at the earliest possible time. This hint cannot be used when the query uses a merge join and cannot be used with remote tables. Moving the subquery to be part of the main query (when possible) can lead to the same gains when the tables are driven in the correct order (accessing the former subquery table first).

Syntax

```
select      /*+ PUSH_SUBQ [(@query_block)] */ column1, ...
```

Example

```
select      /*+ cardinality(e,1000000) push_subq  */
            e.department_id,
            e.employee_id,
            m.last_name   as manager_last_name,
            max(e.salary) as max_salary
```

```
from        employees e,
            employees m,
            departments d
where       e.employee_id in (
              select employee_id
              from   job_history jh)
and         to_char(e.hire_date,'Month') = 'June'
and         e.manager_id = m.employee_id (+)
and         e.department_id = d.department_id
group by    e.department_id, e.employee_id, m.last_name, e.salary;
```

This query processes the subquery to be used by the outer query at its earliest possible time. I used the undocumented CARDINALITY hint to simulate a large dataset because it was impossible to get PUSH_SUBQ to do anything with the small amount of rows I had. CARDINALITY tells the optimizer to use the indicated number as the expected number of rows in a data source instead of data dictionary statistics or defaults.

TIP
The PUSH_SUBQ hint can improve performance greatly when the subquery returns only a few rows very fast, and those rows can be used to limit the rows returned in the outer query.

The PARALLEL Hint

The PARALLEL hint tells the optimizer to break a query into pieces (the *degree of parallelism*) and process each piece with a different process simultaneously. The degree of parallelism is applied to each parallelizable operation of a SQL statement. A query that requires a sort operation causes the number of processes used to be double the degree specified, as both the table accesses and the sorts are parallelized. A query coordinator process is also invoked to split and put the results together, so if you set the degree of parallelism for a query to four, it may use four processes for the query plus four *more* processes for the sorting, plus one *more* process for the breaking up and putting together of the four pieces, or nine (9) total processes.

PARALLEL can be applied to the INSERT, UPDATE, and DELETE portions of a statement (you have to commit immediately after if you use this) as well as to SELECT commands. You should create tables with the PARALLEL clause when you plan to use this option (which should make using the hint unnecessary, although the degree of parallelism can be changed with the hint). See Chapter 11 for a detailed look at all of the requirements and rules associated with this powerful option.

Syntax

```
/*+ PARALLEL ([@query_block]table, degree) */
```

The `degree` is the number of pieces (processes) into which the query is broken.

Example

```
select      /*+ PARALLEL (employees) */ employee_id, hire_date
from        employees
order by    hire date;
```

This statement does not specify a degree of parallelism. The default degree of parallelism is dictated by the table definition when the table was created or the system default is used.

Example

```
select      /*+ PARALLEL (employees,4) */ employee_id, hire_date
from        employees
order by    hire date;
```

This statement specifies a degree of parallelism of 4. Per previous discussion, as many as nine query servers may be allocated or created to satisfy this query. If you have multiple tables and you specify the PARALLEL hint with a numeric value, that is the degree of parallelism used for *all* the tables in the query, overriding the parallel setting at the table level. If you specify a table name (as in the previous example), then the PARALLEL hint applies to only that table; any other tables accessed by the query use the table's parallelism setting.

TIP
Using the PARALLEL hint enables the use of parallel operations. If the degree is not specified with the hint, the default degree specified during table creation is used.

The NO_PARALLEL Hint

If a table is created with a parallel degree set, the table should automatically be queried in parallel and should use that degree for all full table scan queries. You may, however, also "turn off" the use of parallel operations in any one given query on a table that has been specified to use parallel operations by using the NO_PARALLEL hint. The NO_PARALLEL hint results in a query with a degree of one (1).

NOTE
The NO_PARALLEL hint used to be NOPARALLEL before Oracle standardized the naming.

Syntax

```
select      /*+ NO PARALLEL ([@query block]table) */ ...
```

Example

```
select      /*+ NO_PARALLEL(employees) */ employee_id, hire_date
from        employees
order by    hire date;
```

TIP
Using the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.

The PARALLEL_INDEX Hint

The PARALLEL_INDEX hint asks the optimizer to parallelize index scans (full, range, or fast full) for b-tree indexes. Oracle documentation suggests that PARALLEL_INDEX works with partitioned indexes, but I found that it worked with nonpartitioned indexes too. Essentially PARALLEL_INDEX is a PARALLEL hint for index reads and, like the PARALLEL hint, specifying the degree of parallelism is optional.

Syntax

```
/*+ PARALLEL INDEX([@query block] table index [degree]) */
```

Example

```
select       /*+ PARALLEL_INDEX(employees emp_emp_id_pk) */ count(*)
from         employees;
```

NO_PARALLEL_INDEX (formerly NOPARALLEL_INDEX) is used to avoid parallel index reads.

Syntax

```
/*+ NO PARALLEL INDEX([@query block] table index) */
```

The APPEND Hint

The APPEND hint can improve the performance of INSERTs (at times dramatically), but with a potential cost in terms of physical database space. The APPEND hint does not check to see if there is space within currently used blocks for INSERTs but instead appends the data into new blocks. You might potentially waste space, but you will gain speed. If you never delete rows from a table, you should definitely consider the APPEND hint.

If an INSERT is parallelized using the PARALLEL hint, then APPEND is used by default. You can use the NOAPPEND hint (next section) to override this behavior. Also note that before you can use this example, you must first enable parallel DML.

Syntax

```
insert /*+ APPEND */ ...
```

Example

```
insert /*+ APPEND */  into sales_hist
  select *
  from   sales
  where  cust_id = 8890;
```

There are a couple of things to consider when using the APPEND hint. First, remember that APPEND ignores existing free space, so you can waste a lot of disk space when using this option.

Second, APPEND does not work with single-row inserts using a VALUES clause; it only works with INSERTS whose data comes from subqueries. Finally, a COMMIT should follow an INSERT using APPEND to avoid an error when querying back newly inserted data.

TIP
The APPEND hint inserts values into a table without checking the free space in the currently used blocks, instead appending the data into new blocks. Great performance is often the end result at the cost of physical disk space (and well worth it).

The NOAPPEND Hint

The NOAPPEND hint overrides the default for the PARALLEL inserts (the default, of course, is APPEND). The NOAPPEND hint turns off the direct-path INSERT option.

Syntax

```
insert      /*+ NOAPPEND */ ...
```

Example

```
insert /*+ NOAPPEND */
into job_history (employee_id, start_date, end_date, job_id,department_id)
  select employee_id, hire_date, to_date('12/31/2099','mm/dd/yyyy'),
         job_id, department_id
  from   employees e
  where  not exists(
             select 0
             from   job_history jh
             where  jh.employee_id = e.employee_id);
```

TIP
The NOAPPEND hint overrides a PARALLEL hint, which normally uses the APPEND hint by default.

The CACHE Hint

The CACHE hint causes a full table scan to be cached (pinned) into memory (into the buffer cache), so future queries accessing the same table find it in memory instead of going to disk. This creates one potentially huge problem. If the table is very large, then it takes up an enormous amount of memory (data block buffer cache space in particular). For small lookup tables, however, this is an excellent option. Tables can be created with the CACHE option to be cached the first time they are accessed.

Syntax

```
select     /*+ CACHE([@query_block] table) */ column1, ...
```

Example

```
select     /*+ FULL(departments) CACHE(departments) */ department_id, location_id
from       departments;
```

The entire DEPARTMENTS table is now cached in memory and is marked as a most recently used (MRU) object.

TIP
The CACHE hint should be used with small lookup tables that are often accessed by users. This ensures the table remains in memory.

The NOCACHE Hint

The NOCACHE hint causes a table that is specified to be CACHED at the database level to *not* get cached when you access it and is usually used to override an existing table specification.

Syntax

```
select     /*+ NOCACHE(table) */ column1, ...
```

Example

```
alter      table departments cache;

select     /*+ NOCACHE(departments) */ department_id, location_id
from       departments;
```

In this example, the table should not be cached despite the ALTER statement and is put on the least recently used (LRU) list.

TIP
The NOCACHE hint should be used to prevent caching a table specified with the CACHE option—basically, when you want to access the table but you don't want to cache it.

The RESULT_CACHE Hint

As of 11*g* (and now in 12*c*), Oracle provides a new, separate shared memory pool to store query results. This Result Cache is allocated directly from the shared pool but is maintained separately. Queries executed often may experience better performance when using the new pool through the RESULT_CACHE hint. Setting the RESULT_CACHE_MODE initialization parameter to FORCE stores all results in the new cache for every query executed (this may not be desirable), but the NO_RESULT_CACHE hint can be used to override this behavior. The difference between RESULT_CACHE and CACHE is *where* the data is stored. NO_RESULT_CACHE requests that data not be cached in the shared pool (it still can be cached in the buffer cache).

The RESULT_CACHE hint should work with individual parts of a query (query blocks) as well as entire result sets. The RESULT_CACHE operation appears in an execution plan as RESULT_CACHE with a system-generated temporary table name when the hint is used or when the query results are retrieved from the Result Cache (best used with SUM, MAX, MIN, etc.).

Syntax

```
select       /*+ RESULT_CACHE */ column1 ...
```

Example

```
select       /*+ RESULT_CACHE */ employee_id, last_name
from         employees
where        department_id = 10;
```

TIP
The RESULT_CACHE hint caches query results in the shared pool; the NO_RESULT_CACHE hint is used when you don't want to cache data in the shared pool (it still can be cached in the buffer cache).

The CURSOR_SHARING_EXACT Hint

The CURSOR_SHARING_EXACT hint is used to ensure that literals in SQL statements are not replaced with bind variables. This hint can be used to correct any minor issues when you *don't* want to use cursor sharing even though the instance-level CURSOR_SHARING parameter is set to either FORCE or SIMILAR (but note that SIMILAR is deprecated and its use should be avoided).

Syntax

```
select      /*+ CURSOR_SHARING_EXACT */ column1, ...
```

Example

```
select      /*+ CURSOR_SHARING_EXACT */ employee_id, last_name
from        employees
where       employee_id = 123;
```

In this example, Oracle will not be able to reuse a current statement in the shared pool unless it is *exactly* like this one (including white space and the 123 literal). It should not create a bind variable. Additional examples related to cursor sharing are in Chapter 4.

TIP

The CURSOR_SHARING_EXACT hint overrides the system parameter file setting of CURSOR_SHARING to either FORCE or SIMILAR.

The INMEMORY and NO_INMEMORY and Other IM Hints

One of the biggest changes in 12*c* (12.1.0.2+) is the addition of the In-Memory (IM) column store (covered in detail in Chapter 4). Included in this release are several hints to help drive a query. The main ones are the INMEMORY and NO_INMEMORY hints.

INMEMORY (*table_name*) and NO_INMEMORY(*table_name*)

A quick example (drives the query to use INMEMORY):

```
select /*+ INMEMORY(emp) */ ename, deptno
from   emp;
```

The INMEMORY_PRUNING hint (and NO_INMEMORY_PRUNING) controls the use of the IM storage index (which scans the CUs, or *compression units*). You can use it and then also check if a storage index (automatically built by Oracle in the IM) was used to further prune the result. Note the following example first selects values from the EMP table, and then runs the query used to check for storage index pruning in the V$STATNAME and V$MYSTAT views.

```
select /*+ (INMEMORY_PRUNING(emp) */ ename, deptno
from   emp
WHERE  empid = 7777;

select name, value, sysdate
from   v$statname a, v$mystat b
where  name = 'IM scan CUs pruned'
and    a.statistic#=b.statistic#;
(If "no rows selected" then storage indexes are not being leveraged)
```

The IM option has several hints that you can use in your SQL as well to force the optimizer to utilize the In-Memory column store. The following are used most often:

- /*+ **INMEMORY(***table***)** */ (place a table into the In-Memory column store)
- /*+ **NO_INMEMORY(***table***)** */ (remove a table from the In-Memory column store)
- /*+ **INMEMORY_PRUNING(***table***)** */ (control the use of the IM storage index)
- /*+ **NO_INMEMORY_PRUNING(***table***)** */ (control the use of the IM storage index)

- /*+ **PX_JOIN_FILTER(***table***)** */ (force Bloom filter for a join if optimizer doesn't)
- /*+ **NO_PX_JOIN_FILTER(***table***)** */ (force *non*-use of Bloom filter for a join if optimizer doesn't)
- /*+ **VECTOR_TRANSFORM** */ (force use of VECTOR GROUP BY—not in docs!)

TIP
In 12c (12.1.0.2+) the addition of the In-Memory (IM) column store brought us several hints. The INMEMORY hint (also, NO_INMEMORY) can be used to help drive a query to use (or not use) the In-Memory column store.

The USE_INVISIBLE_INDEXES Hint

You can create or alter an index to be invisible. In 11*g*, when you set an index to invisible, it required an exclusive lock that *not* many people noticed (since it was always fast if you weren't doing a lot of DML). In 12*c*, the lock is not needed anymore (truly performed *online*). The following query shows the creation of a new invisible index on the DEPTNO column of the EMP table and subsequent query where the index is not seen/used, and finally using the hint to force it:

```
create index dept_inv_idx on dept_rich(deptno) invisible;
Index created.

select count(*)
from   dept_rich
where  deptno = 30; (doesn't see the index)

COUNT(*)
--------------
           512

Execution Plan
----------------------------------------------------------
Plan hash value: 3024595593
--------------------------------------------------------------------------------
| Id  | Operation           | Name      | Rows  | Bytes | Cost  (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT    |           |     1 |     2 |      4   (0)| 00:00:01 |
|   1 |  SORT AGGREGATE     |           |     1 |     2 |             |          |
|*  2 |   TABLE ACCESS FULL| DEPT_RICH |   512 |  1024 |      4   (0)| 0:00:01  |
--------------------------------------------------------------------------------
```

You can still force the use of the index if you use a hint, in 12*c*R2, with a

USE_INVISIBLE_INDEXES hint—or by setting the initialization parameter (see Chapter 4) OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE:

```
select /*+ USE_INVISIBLE_INDEXES */ count(*)
from   dept_rich
where  deptno = 30;   (forces the index with hint)

COUNT(*)
--------
     512

Execution Plan
----------------------------------------------------------
Plan hash value: 3699452051
-------------------------------------------------------------------------------
| Id |  Operation          | Name         | Rows  | Bytes | Cost  (%CPU)| Time     |
-------------------------------------------------------------------------------
|  0 | SELECT STATEMENT    |              |     1 |     2 |    1     (0)| 00:00:01 |
|  1 |  SORT AGGREGATE     |              |     1 |     2 |             |          |
|* 2 |   INDEX RANGE SCAN|DEPT_INV_IDX   |   512 |  1024 |    1     (0)| 00:00:01 |
```

TIP
You can still force the use of an invisible index in 12cR2 with the USE_INVISIBLE_INDEXES hint.

The CONTAINERS Hint

With the advent of pluggable databases (PDBs) in 12*c* (see Chapter 3), there are hints that help you do more, even across PDBs. The ability to aggregate data across multiple PDBs using the CONTAINERS hint, as a common user (like SYSTEM) in the CDB, is helpful. The CONTAINERS hint causes the SQL to be recursively executed in each PDB. You can even pass hints to those PDBs as well with the *hint_string*. Basic syntax example:

```
select /*+ CONTAINERS(DEFAULT_PDB_HINT=hint_string */...from
CONTAINERS(object)...
```

TIP
With pluggable databases (PDBs) in 12c, you can aggregate data across multiple PDBs, while in the CDB, using the CONTAINERS hint. The CONTAINERS hint causes the SQL to be recursively executed in each PDB.

The WITH_PLSQL Hint

Lastly, the hint that's not an optimizer hint: WITH_PLSQL. If a query containing the PL/SQL declaration section *is not* the top-level query, the top-level query must include the WITH_PLSQL hint (if not included, you will receive an ORA-32034 error). It can be a SELECT or DML (both will fail under these conditions). The WITH_PLSQL hint allows the statement to compile and run as expected, but it is not an *optimizer* hint, just a hint. Basic syntax example:

```
UPDATE /*+ WITH_PLSQL */ ...
SELECT /*+ WITH PLSQL */ * from (WITH FUNCTION...
```

TIP
In 12c, if a query containing the PL/SQL declaration section is not the top-level query, the top-level query must include the WITH_PLSQL hint, but it is not an optimizer hint.

Some Miscellaneous Hints and Notes

This section lists "the best of the rest" of the hints that are available. Each hint is listed with a brief explanation. Please see the Oracle documentation if you want to use one of them.

- **DYNAMIC_SAMPLING** The DYNAMIC_SAMPLING hint is set from 0 to 10. The higher the number is set, the more effort the compiler puts into dynamic sampling. It generates statistics at run time for use in a query.
- **INDEX_SS** The INDEX_SS hint instructs the optimizer to use the skip-scan option for an index on the specified table. A skip-scan is when Oracle skips the first column of a concatenated index and uses the rest of the index. This hint works well with a two-part concatenated index, where you often use both parts but infrequently need only the second part (at times you don't have any condition for the first part). You need to specify both the table and the index.
- **INDEX_SS_ASC** The INDEX_SS_ASC hint is the same as the INDEX_SS hint, but this could change in a future version of Oracle.

- **INDEX_SS_DESC** The INDEX_SS_DESC hint uses the same syntax as the INDEX_SS hint but instructs the optimizer to scan the index skip-scan in descending order.
- **MODEL_MIN_ANALYSIS** The MODEL_MIN_ANALYSIS hint instructs the optimizer to omit some compile-time optimizations of spreadsheet rules. This hint can reduce the compilation time required during spreadsheet analysis and is used with SQL modeling queries (queries using the MODEL clause).
- **MONITOR** The MONITOR hint turns index monitoring on for short queries. For MONITOR to work, the initialization/session parameter CONTROL_MANAGEMENT_PACK_ACCESS must be set to "DIAGNOSTIC+TUNING". NO_MONITOR turns off index monitoring, even for long-running queries. *Monitoring* refers to entries logged in the V$SQL_MONITOR and V$SQL_PLAN_MONITOR tables during query execution.
- **NATIVE_FULL_OUTER_JOIN** When the full outer join condition between two tables is an equijoin, Oracle Database automatically uses a native execution method based on a hash join. This hint instructs the optimizer to consider using the hash full–outer join execution method, when it might not normally do so. If you specify NO_NATIVE_FULL_OUTER_JOIN, then the full outer join is executed as a union of the left outer join and an antijoin.
- **NOLOGGING** There is *no* "NOLOGGING" *hint* to turn off archive logging for a DML statement although developers sometimes think there is. You can, however, ALTER TABLE EMP NOLOGGING and then do an INSERT /*+ APPEND */ into the EMP table to bypass the redo if the database is in ARCHIVELOG mode (careful, as this has major recovery implications—back up after this). If the database is in NOARCHIVELOG mode (not recommended), any direct load operations, such as the INSERT /*+ APPEND */, are not recoverable. NOLOGGING works with many DDL commands, such as for creating tables, creating indexes, and rebuilding indexes (careful, as this also has major recovery implications; back up after and don't leave tables and indexes in NOLOGGING mode).
- **OPT_PARAM** This hint allows you to modify the parameter setting in effect for the duration of the query. This only works with session parameters that can be changed! Remember to put parameter names in single quotes.
- **PUSH_PRED** This hint causes WHERE clause conditions to be pushed into a query view to exclude rows as soon as possible in the select process. NO_PUSH_PRED reverses this activity.
- **REWRITE_OR_ERROR** The REWRITE_OR_ERROR hint in a query produces the following error if the query did not rewrite for queries against materialized views (this happens when there are no suitable materialized views for query rewrite to use):
- *ORA-30393: a query block in the statement did not rewrite*
- Support My Oracle Support Note 1215173.1 discusses this hint.
- **USE_NL_WITH_INDEX** The USE_NL hint instructs the optimizer to use a nested loops join with the specified table as the nondriving table (or as the inner table that is *looped* through with the result of the driving table). The USE_NL_WITH_INDEX hint allows you to also specify the index that is used during access. However, the optimizer must be able to use that

index with at least one join.

- **GATHER_OPTIMIZER_STATISTICS** The use of GATHER_OPTIMIZER_STATISTICS (and NO_GATHER_OPTIMIZER_STATISTICS) is now allowed in 12*c* during bulk loads CREATE TABLE should be ... AS SELECT and INSERT INTO... SELECT. There is also an undocumented parameter that can force things as well (_OPTIMIZER_GATHER_STATS_ON_LOAD)
- **USE_CUBE** Use a cube join for the query in 12*c* (also, NO_USE_CUBE). You need to ensure the initialization parameter _OPTIMIZER_CUBE_JOIN_ENABLED=true (for the system or session). Also, CUBE_AJ and CUBE_SJ are available.
- **AUTO_REOPTIMIZE** The optimizer changes execution plan on future executions of the query (also, NO_AUTO_REOPTIMIZE) starting in 12*c*.
- **ADAPTIVE_PLAN** Use an adaptive plan (also, NO_ADAPTIVE_PLAN hints) starting in 12*c* when _OPTIMIZER_ADAPTIVE_PLANS=false.

Undocumented Hints

The *Oracle Database SQL Language Reference* contains seldom-used hints that I have not mentioned. Other hints are mentioned in the Oracle documentation but not the SQL guide. These hints are generally found in sources such as the *Oracle Database Data Warehousing Guide* or performance tuning manuals but without a formal write-up of their syntax and functionality. Some hints exist but are not mentioned anywhere in the documentation (as mentioned previously, V$SQL_HINT gives you a complete list of all hints). A few undocumented hints like SWAP_JOIN_INPUTS are included in My Oracle Support articles describing their syntax and functionality, but most are a complete mystery. Distinguishing between undocumented hints and mere comments included in the hint comment structure can be difficult. What might appear to be an undocumented hint may actually be nothing more than a comment that uses the same comment delimiters (/* */) as hints, but without the "+" sign.

You should not use undocumented hints unless directed to by Oracle Support. Undocumented features tend to be unsupported.

The RULE hint is deprecated, undocumented, and is unsupported in 12*c* (and 11*g*R2), even though it was supported in previous versions of the database. The RULE optimizer mode was officially desupported in Oracle 10.1. My Oracle Support (Doc ID 189702.1) has a good write-up on this change, and also contains links and tips for migrating to the cost-based optimizer. Even the *Performance Tuning Guide* for Oracle 10.1 release says, "The CHOOSE and RULE optimizer hints are no longer supported. The functionalities of those hints still exist but will be removed in a future release." I believe these hints are currently only retained to support upgrades from older systems (such as 9*i*). However, as Oracle9*i* moves into complete obsolescence, the RULE-related parameter settings and hints will most likely be removed from the software. Prepare now!

RULE invokes the *rule-based optimizer*, an older way of determining an execution path for a query based on a set of rules. The rule-based optimizer is generally less efficient than the cost-based optimizer but can be useful under some rare conditions, generally where no valid statistics for query objects exist:

- CAST conversions of collections to temporary tables
- TABLE function temporary table conversions (pipelined functions)
- When joining views (including views of views and inline views)
- When joining many tables together (more than three, *very* rarely) and the cost-based optimizer becomes overwhelmed and chooses a suboptimal path (and takes a while to do it)
- Queries against system tables where the cost-based optimizer is not making optimal choices

It has been suggested that the undocumented CARDINALITY hint (which allows override of the cardinality statistic) can overcome some of these limitations, but CARDINALITY requires an estimate of the number of rows beforehand and table cardinality is only a part of what the cost-based optimizer uses to determine an execution path.

Because the RULE hint is unsupported (according to the 12*c*, 11*g*, and 10*g* documentation), only use it with extreme caution, if at all. The RULE hint should probably only be used when migrating queries written for the rule-based optimizer to the cost-based optimizer.

Using Hints with Views

Although hints can be hard-coded into views, doing so is generally a bad idea because it is impossible to know how a view will be used (selected standalone, joined to other tables or views, or even used by other views). It is better to push a hint into a view when needed in a query rather than permanently embed a hint in a view through a *global hint*.

To use a global hint, use the view name followed by a period followed by the name of the affected table designation, as used inside the view (table name or alias).

Example

```
select /*+ USE_HASH(v.emp) */ count(*)
from   emp_details_view v
where  employee_id = 100;
```

When using global hints, you need to know the usage of tables and aliases in the target view. In this example, the EMP_DETAILS_VIEW uses the alias d for DEPARTMENTS, so that designator must be used in the global hint. The underlying table name is EMP.

Notes on Hints and Stored Outlines (or SQL Plan

Baselines)

SQL Plan Baselines or stored outlines, which still work, but are deprecated/discouraged in 11*g*, are covered in Chapter 6, but a note here is relevant for the discussion on hints. Migrating from stored outlines to SQL Plan Baselines is also covered in Chapter 6. STORED OUTLINES or baselines allow a query to use a predetermined execution plan every time that query is run, no matter where the query is run from. People sometimes speak of the STORED OUTLINES as storing an execution plan, but this is not really what happens. Instead, Oracle stores a series of hints to duplicate the execution plan as saved during a recording session. If you want to query the hints for a STORED OUTLINE, you can use the following query to USER_OUTLINE_HINTS:

Example

```
select        hint
from          user_outline_hints
where         name = 'your_outline_name';
```

The very same considerations regarding using hints apply to stored outlines: unpredictable behavior when upgrading, applying patches, or changing initialization/session parameters. Also, if the query structure changes in any way, the stored outline may stop working.

Why Isn't My Hint Working?

Often a hint won't behave like you want it to. Sometimes the optimizer overrides the hint, but usually people have a problem related to one of the following:

- The hint syntax is incorrect.
- The table(s) is not analyzed or the statistics are not current.
- There is a conflict with another hint.
- The hint requires a system parameter to be set for it to work.
- The table name was aliased in the query, but you used the table name, not the alias, in the hint.
- The hint requires a different version of Oracle than you have.
- You don't understand the correct application for the hint.
- You haven't slept lately—for many of the reasons cited here.
- There is a software bug.

Hints at a Glance

The following table lists many hints discussed in this chapter (and a couple of others) and how the hint is used.

Hint	Use
FIRST_ROWS	Generally force the use of indexes
ALL_ROWS	Generally force a full table scan
FULL	Force a full table scan
INDEX	Force the use of an index
NO_INDEX	Disallow a specified index from being used
INDEX_JOIN	Allow the merging of indexes on a single table
INDEX_ASC	Use an index ordered in ascending order
INDEX_DESC	Use an index ordered in descending order
INDEX_COMBINE	Access multiple bitmap indexes
INDEX_FFS	Perform a fast full index scan
ORDERED	Specify the driving order of tables
LEADING	Specify just the first driving table
INMEMORY	Allow the query to use the In-Memory column store
NO_INMEMORY	Disallow the query to use the In-Memory column store
CONTAINERS	Aggregate data from PDBs while in the main CDB
NO_EXPAND	Help eliminate OR expansion
STAR_TRANSFORMATION	Force a star query transform
DRIVING_SITE	Process data by driving it from a particular database
USE_MERGE	Change how tables are joined internally to merge joining
USE_HASH	Change how tables are joined internally to hash joining
USE_NL	Change how tables are joined internally to nested loops
PUSH_SUBQ	Force the subquery to process earlier
PARALLEL	Cause full table scan queries to break a query into pieces and process each piece with a different process
NO_PARALLEL	Turn off use of parallel operations for one given query
PARALLEL_INDEX	Perform index scan in parallel
NO_PARALLEL_INDEX	Does not perform index scan in parallel
APPEND	Append data into new blocks
NOAPPEND	Check for free space within current blocks before using new ones
CACHE	Cause a full table scan to be pinned into memory
NOCACHE	Cause a table that is specified to be cached at database level to not get cached when you access it
RESULT_CACHE	Cache data in the shared memory pool
NO_RESULT_CACHE	Cause data not to be cached in the shared memory pool
CURSOR_SHARING_EXACT	Override the CURSOR_SHARING setting
QB_NAME	Assign a name to a query block

Tips Review

- Incorrect hint syntax leads to the hint being interpreted as a comment. If an additional hint is specified correctly, it will be used.
- Multiple hints are separated with a space. Specifying multiple hints that conflict with each other causes the query to use *none* of the conflicting hints.
- If an alias is used, the alias *must* be used in the hint or it will *not* work.
- The FIRST_ROWS hint causes the optimizer to choose a path that retrieves the first row (or a specified number of rows) of a query the fastest, at the cost of retrieving multiple rows more slowly. The FIRST_ROWS hint may be set as the default for the entire database by setting OPTIMIZER_MODE = FIRST_ROWS in the system parameter file; query-level hints will override the default setting for a given query. You can also set the optimizer to FIRST_ROWS_*n*.
- The ALL_ROWS hint causes the optimizer to choose a path that retrieves all the rows of a query the fastest, at the cost of retrieving one single row more slowly. The ALL_ROWS hint may be set as the default for the entire database by setting OPTIMIZER_MODE = ALL_ROWS (the default) in the system parameter file; query-level hints will override the default setting for a given query.
- The FULL hint performs a full table scan on the table that is specified, not all tables in the query. The FULL hint may also lead to better performance, which is attributable to causing a change in the driving table of the query and *not* to the actual full table scan.
- The INDEX hint causes the optimizer to choose the index specified in the hint. Multiple indexes for a single table can be specified, but it is usually better to specify only the most restrictive index on a given query (and, that way, avoid the merging of each index's result). If multiple indexes are specified, Oracle chooses which (one or more) to use, so *be careful* or your hint could potentially be overridden.
- The INDEX hint, without a specified index, should not consider a full table scan, even though no indexes have been specified. The optimizer will choose the best index or indexes for the query.
- The NO_INDEX hint must be in the tuning expert's toolkit. It is used to remove an index from consideration by the optimizer, so you may evaluate the need for the index prior to dropping it or so you can evaluate other indexes. Be careful not to conflict with other index hints. The NO_INDEX is one of my personal favorites when I want to drop an index and check which index (if any) will be used instead of the one that I plan to drop.
- Not only does the INDEX_JOIN hint allow you to access only indexes on a table, which is a scan of fewer total blocks, but also it can be five times faster (in some of my tests) than using an index and scanning the table by ROWID.
- The INDEX_COMBINE hint causes the optimizer to merge multiple bitmap indexes for a single table instead of choosing which one is better (as with the INDEX hint).

- The INDEX_ASC hint does exactly what the INDEX hint does because indexes are already scanned in ascending order. INDEX_ASC guarantees this to be true, however, as Oracle may change this default in the future. Descending indexes are actually sorted in descending order. Oracle treats descending indexes as function-based indexes. The columns marked DESC are sorted in descending order.
- The INDEX_DESC hint processes an index in descending order of how it was built. This hint should not be used if more than one table exists in the query.
- The INDEX_FFS hint processes *only* the index and does not take the result and access the table. All columns that are used and retrieved by the query *must* be contained in the index.
- The ORDERED hint is one of the most powerful hints available. It processes the tables of the query in the sequential order in which they are listed in the FROM clause. There are many variations that cause this hint to work differently. The version of Oracle, the existence of indexes on the tables, and which tables have been analyzed can all cause this to work differently. However, when a multiple join is slow and you don't know what to do, this is one of the first hints you should try!
- The LEADING hint works similarly to the ORDERED hint. The LEADING hint is used to specify a single table to drive a query while allowing the optimizer to figure out the rest.
- The NO_EXPAND hint prevents the optimizer from using OR expansion and is used when the query becomes substantially more complex as a result of the expansion.
- The DRIVING_SITE hint is extremely powerful, as it will potentially limit the amount of information that will be processed over your network. The table specified with the DRIVING_SITE hint is the location where the join will be processed. Using views for remote tables can also lead to better performance by limiting the number of rows passed from the remote site *before* the records are sent to the local site.
- In a join of three or more tables, the USE_MERGE hint causes the table(s) specified in the hint to be *sort-merge joined* with the resulting row set from a join of the other tables in the join.
- The USE_NL hint *usually* provides the best response time (first row comes back faster) for smaller result sets, whereas the USE_MERGE hint *usually* provides the best throughput when the USE_HASH hint can't be used.
- The USE_HASH hint usually provides the best response time for larger result sets.
- The PUSH_SUBQ hint can improve performance greatly when the subquery returns only a few rows very fast, and those rows can be used to limit the rows returned in the outer query.
- Using the PARALLEL hint enables the use of parallel operations. If the degree is not specified with the hint, the default degree specified during table creation is used.
- Using the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.
- The APPEND hint inserts values into a table without checking the free space in the currently used blocks, instead appending the data into new blocks. Great performance is often the end result at the cost of physical disk space (and well worth it).

- The NOAPPEND hint overrides a PARALLEL hint, which normally uses the APPEND hint by default.
- The CACHE hint should be used with small lookup tables that are often accessed by users. This ensures that the table remains in memory.
- The NOCACHE hint should be used to prevent caching a table specified with the CACHE option—basically, when you want to access the table but you *don't* want to cache it.
- The RESULT_CACHE hint caches query results in the shared pool; the NO_RESULT_CACHE hint is used when you don't want to cache data in the shared pool (it still can be cached in the buffer cache).
- The CURSOR_SHARING_EXACT hint overrides the system parameter file setting of CURSOR_SHARING to either FORCE or SIMILAR.
- In 12*c* (12.1.0.2+) the addition of the In-Memory (IM) column store brought us several hints. The INMEMORY hint (also, NO_INMEMORY) can be used to help drive a query to use (or not use) the In-Memory column store.
- In 12*c* (12.1.0.2+) the INMEMORY_PRUNING hint controls the use of the IM storage index. You can check to see if a storage index was used to further prune the result by checking V$STATNAME and V$MYSTAT views.
- You can still force the use of an invisible index in 12*c*R2 with the USE_INVISIBLE_INDEXES hint.
- With pluggable databases (PDBs) in 12*c*, you can aggregate data across multiple PDBs, while in the CDB, using the CONTAINERS hint. The CONTAINERS hint causes the SQL to be recursively executed in each PDB.
- In 12*c*, if a query containing the PL/SQL declaration section *is not* the top-level query, the top-level query must include the WITH_PLSQL hint, but it is not an optimizer hint.

References

My Oracle Support Document 453567.1: SQL Query Result Cache.

Rich Niemiec*, Expert Tuning Tips: Beginners Will Be Toast!*, TUSC, IOUG Conference Paper, 2005.

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Oracle Database SQL Language Reference (Oracle Corporation).

Many thanks to Mark Riedel for upgrading this chapter to Oracle 11*g*! Lucas Niemiec also did some research on a few of the hints and My Oracle Support notes listed.

CHAPTER
8

Query Tuning (Developer and Beginner DBA)

This chapter focuses on specific queries that you may encounter and some general information for tuning those specific queries, but it has also been updated to include some great information on Oracle 12*c* Adaptive Query Optimization, on Oracle's Automatic SQL Tuning, and some queries to access Oracle's Automatic Workload Repository (AWR). Examples of query tuning are spread throughout this book as well as instructions on making them more effective in terms of your system's architecture. This chapter centers on some of the most common queries that can be tuned on *most* systems. A query can display several variations in behavior, depending on system architecture, the data distribution in the tables, what tool or application is accessing the database, the specific version of Oracle Database, and a variety of other exceptions to the rules. Your results will vary; use your own testing to come up with the most favorable performance. The goal in this chapter is to show you many of the issues to watch for and how to fix them.

This chapter uses strictly cost-based examples for timings (except where noted). No other queries were performed at the time of the tests performed for this chapter. I also flush the buffer cache and shared pool to retest things. Many hints are also used throughout this chapter. For a detailed look at hints and the syntax and structure of hints, please refer to Chapter 7. Multiple table and complex queries are the focus of the next chapter and are not covered here.

Please note that this is not an all-inclusive chapter. Many other queries are covered throughout the book, which need to be investigated when trying to increase performance for a given query. Some of the most dramatic include using the parallel features of Oracle Database (Chapter 11), using partitioned tables and indexes (Chapter 2), and using PL/SQL to improve performance (Chapter 10). Note the benefits of using EXPLAIN and TRACE for queries (Chapter 6). Oracle Database 12*c* provide the AWR and Automatic Database Diagnostic Monitor (ADDM). The Oracle Enterprise Manager Cloud Control views of these new features are shown in Chapter 5. Tips covered in this chapter include the following:

- Which queries do I tune? Querying the V$SQLAREA and V$SQL views
- Some useful 12*c* views for locating resource-intensive sessions and queries
- When should I use an index?
- What if I forget the index?
- Creating and checking an index

- What if I create a bad index?
- Exercising caution when dropping an index
- Using invisible indexes
- Function-based indexes and virtual columns
- Increasing performance by indexing the SELECT and WHERE columns
- Using the Fast Full Scan feature to guarantee success
- Making queries "magically" faster
- Caching a table into memory
- Using the Result Cache
- Choosing between multiple indexes on a table (use the most selective)
- Indexes that can get suppressed
- Tuning OR clauses
- Using the EXISTS clause and the nested subquery
- That table is a view!
- SQL and the Grand Unified Theory
- Tuning changes in Oracle Database 12*c*
- 12*c* Adaptive Query Optimization
- Automatic SQL Tuning and the SQL Tuning Advisor
- Using the SQL Performance Analyzer (SPA)

Which Queries Do I Tune? Querying V$SQLAREA and V$SQL Views

V$SQLAREA and V$SQL are great views that you can query to find the worst-performing SQL statements that need to be optimized. The value in the DISK_READS column signifies the volume of disk reads that are being performed on the system. This, combined with the executions (DISK_READS/EXECUTIONS), returns the SQL statements that have the most disk hits per statement execution. Any statement that makes the top of this list is most likely a problem query that needs to be tuned. The AWR Report or Statspack Report also lists the resource-intensive queries; see Chapter 14 for detailed information.

Selecting from the V$SQLAREA View to Find the Worst Queries

The following query can be used to find the worst queries in your database. This query alone is worth the price of this book if you've not heard of V$SQLAREA yet.

```
select      b.username username, a.disk_reads reads,
             a.executions exec, a.disk_reads /decode
            (a.executions, 0, 1,a.executions) rds_exec_ratio,
             a.sql_text Statement
from        v$sqlarea a, dba_users b
where       a.parsing user id – b.user id
and         a.disk reads> 100000
order       by a.disk_readsdesc;

USERNAME     READS  EXEC  RDS_EXEC_RATIO STATEMENT
--------  ------- ----- -------------- --------------------
--------------------------------------------------
ADHOC1    7281934     1        7281934  select custno, ordno
from cust, orders

ADHOC5    4230044     4        1057511  select ordno
from orders where trunc(ordno) = 721305

ADHOC1     801716     2         400858  select custno,
ordno from cust where substr(custno,1,6) = '314159'
```

The DISK_READS column in the preceding statement can be replaced with the BUFFER_GETS column to provide information on SQL statements requiring the largest amount of memory.

Now consider the output in a second example where there is a count of a billion-row table (EMP3) and a count of what was originally a 130M-row table (EMP2), where all of the rows in EMP2, except the first 15 rows inserted, were deleted. Note that Oracle counts all the way up to the high water mark (HWM) of EMP2 (it read over 800,000, 8K blocks even though *all* of the data was only in 1 block). This listing would have told you something is wrong with the query on EMP2 that needs to be addressed, given that it only has 15 rows in it (analyzing the table will not improve this).

```
USERNAME     READS  EXEC RDS_EXEC_RATIO STATEMENT
--------  ------- ----- -------------- ------------------------
SCOTT     5875532     1        5875532 select count(*) from emp3
SCOTT      800065     1         800065 select count(*) from emp2
```

For this issue, if the EMP2 table was *completely* empty, you could simply truncate the table to fix it. Since the table still has 15 rows, you have a few options; *which* option you choose depends on your unique situation. I can

- EXPORT/TRUNCATE/IMPORT; CREATE TABLEemp2b AS SELECT * FROM emp2 (CTAS) and then DROP and RENAME (I have to worry about indexes/related objects, etc.)

- Do an “ALTER TABLE *emp2* MOVE TABLESPACE *new1*” and rebuild the indexes.
- If it has a primary key, use DBMS_REDEFINITION.CAN_REDEF_TABLE to verify that the table can be redefined online.

Please check the Oracle documentation for syntax/advantages/disadvantages and stipulations (not all are listed here) for each of these options, so you can apply the best option to your situation (each of these options has major downsides, including users not being able to access the table and related objects getting dropped depending on which you use, so be *careful*). Once I reorganize the table, the next `count(*)` only reads 1 block instead of 800,065 blocks (it was well worth fixing the problem). Note in the query, I change “emp2” to “emP2” so I can find that cursor in the cache.

```
alter table emp2 move;    -- You can specify a tablespace

select count(*)
from   emP2;

select      b.username username, a.disk_reads reads,
            a.executions exec, a.disk_reads /decode
           (a.executions, 0, 1,a.executions) rds_exec_ratio,
            a.sql_text Statement
from        v$sqlarea a, dba_users b

where       a.parsing_user_id = b.user_id
and         a.sql_text like '%emP2%'
order by    a.disk_readsdesc;

USERNAME    READS  EXEC  RDS_EXEC_RATIO  STATEMENT
--------  ------- ----- --------------- --------------------
SCOTT           1     1               1 select count(*) from emP2
```

You can also shrink space in a table, index-organized table, index, partition, subpartition, materialized view, or materialized view log. You do this using the ALTER TABLE, ALTER INDEX, ALTER MATERIALIZED VIEW, or ALTER MATERIALIZED VIEW LOG statement with the SHRINK SPACE clause. See the *Oracle Administrators Guide* for additional information. Lastly, if you want to use the “ALTER TABLE *table* MOVE TABLESPACE *tablespace_name*” command, consider using the same size tablespace (or smaller if appropriate) to move things “back and forth” so as not to waste space.

TIP
Query V$SQLAREA to find your problem queries that need to be tuned.

Selecting from the V$SQL View to Find the Worst Queries

Querying V$SQL allows you to see the shared SQL area statements individually versus grouped together (as V$SQLAREA does). Here is a faster query to get the top statements from V$SQL (this query can also access V$SQLAREA by only changing the view name):

```
select *
from   (select address,
        rank() over ( order by buffer_getsdesc ) as rank_bufgets,
        to_char(100 * ratio_to_report(buffer_gets) over (), '999.99') pct_bufgets
from    v$sql )
where   rank bufgets< 11;

ADDRESS  RANK_BUFGETS PCT_BUF
-------- ------------ -------
131B7914            1   66.36
131ADA6C            2   24.57
131BC16C            3    1.97
13359B54            4     .98
1329ED20            5     .71
132C7374            5     .71
12E966B4            7     .52
131A3CDC            8     .48
131947C4            9     .48
1335BE14           10     .48
1335CE44           10     .48
```

You can alternatively select SQL_TEXT instead of ADDRESS if you want to see the SQL:

```
COL SQL_TEXT FOR A50
select *
from  (select sql_text,
       rank() over ( order by buffer getsdesc ) as rank bufgets,
       to char(100 * ratio to report(buffer gets) over (), '999.99') pct bufgets
from   v$sql )
where  rank bufgets< 11;
```

TIP
You can also query V$SQL to find your problem queries that need to be tuned.

Oracle 12*c* Views for Locating Resource-Intensive Sessions and Queries

Oracle 12*c* provides many views, giving you access to a wealth of information from the OS (operating system) and the Automatic Workload Repository (AWR). The AWR provides metric-based information, which is useful for monitoring and diagnosing performance issues. Metrics are a set of statistics for certain system attributes as defined by Oracle. Essentially, they are context-defined statistics that are collated into historical information within the AWR.

Accessing the AWR and ADDM information via Enterprise Manager is covered in Chapter 5 as well as in the Oracle documentation. In this section, I am only looking at pulling some specific information out of these views using SQL to locate queries that may need tuning. Please check your licensing to ensure which products are an added cost (this can vary by version!). You must have the Oracle Diagnostics Pack license to use AWR and ADDM (including accessing their underlying tables, such as the DBA_HIST tables). Statspack was still free the last time I checked, but check Oracle licensing on any product you use to be sure. You can also check the DBA_FEATURE_USAGE_STATISTICS table.

Selecting from V$SESSMETRIC to Find Current Resource-Intensive Sessions

The following query shows the sessions that are heaviest in physical reads, CPU usage, or logical reads over a defined interval (15 seconds, by default). You may want to adjust the thresholds as appropriate for your environment.

```
select TO_CHAR(m.end_time,'DD MON YYYY HH24:MI:SS') e_dttm,       Interval End Time
       m.intsize_csec/100 ints,     -- Interval size in sec
       s.usernameusr,
       m.session_idsid,
       m.session_serial_numssn,
       ROUND(m.cpu) cpu100,         -- CPU usage 100th sec
       m.physical_readsprds,       -- Number of physical reads
       m.logical_readslrds,        -- Number of logical reads
       m.pga_memorypga,            -- PGA size at end of interval
       m.hard_parseshp,
       m.soft_parsessp,
       m.physical_read_pctprp,
       m.logical_read_pctlrp,
       s.sql_id
from   v$sessmetric m, v$session s
where  (m.physical_reads> 100
or     m.cpu> 100
or     m.logical_reads> 100)
and    m.session_id = s.sid
and    m.session_serial_num = s.serial#
order by m.physical_reads DESC, m.cpu DESC, m.logical_reads DESC;

E_DTTM               INTS USR SID SSN  CPU100  PRDS LRDS    PGA HP SP PRP
LRP        SQL_ID
-------------------- ---- --- --- ---- ------ ----- ---- ------ -- -- ---
---------- -------------
20-NOV-2010 00:11:07   15 RIC 146 1501   1758 41348    1 781908  0  0 100
.512820513 03ay719wdnqz1
```

Viewing Available AWR Snapshots

The next few queries access AWR snapshot information (including the next section).

Query the DBA_HIST_SNAPSHOT view to find more information about specific AWR snapshots:

```
select snap_id,
       TO_CHAR(begin_interval_time,'DD-MON-YYYY HH24:MI:SS') b_dttm,
       TO_CHAR(end_interval_time,'DD-MON-YYYY HH24:MI:SS') e_dttm
from   dba_hist_snapshot
where  begin_interval_time> TRUNC(SYSDATE);


SNAP_ID  B_DTTM               E_DTTM
-------- -------------------- --------------------
     503 25-MAY-2011 00:00:35 25-MAY-2011 01:00:48
     504 25-MAY-2011 01:00:48 25-MAY-2011 02:00:00
     505 25-MAY-2011 02:00:00 25-MAY-2011 03:00:13
     506 25-MAY-2011 03:18:38 25-MAY-2011 04:00:54
     507 25-MAY-2011 04:00:54 25-MAY-2011 05:00:07
```

Selecting from the DBA_HIST_SQLSTAT View to Find the Worst Queries

SQL statements that have exceeded predefined thresholds are kept in the AWR for a predefined time (seven days, by default). You can query the DBA_HIST_SQLSTAT view to find the worst queries. The following is the equivalent statement to the V$SQLAREA query earlier in this chapter.

```
select snap_id, disk_reads_delta reads_delta,
       executions_delta exec_delta, disk_reads_delta /decode
      (executions_delta, 0, 1, executions_delta) rds_exec_ratio,
       sql_id
from   dba_hist_sqlstat
where  disk_reads_delta> 100000
order  by disk_reads_delta desc;

SNAP_ID   READS_DELTA   EXEC_DELTA  RDS_EXEC_RATIO      SQL_ID
------- ------------- ------------ ---------------  -------------
38            9743276            0         9743276  03ay719wdnqz1
39            9566692            0         9566692  03ay719wdnqz1
37            7725091            1         7725091  03ay719wdnqz1
```

Note that in the output, the same SQL_ID appears in three different AWR snapshots. (In this case, it was executed during the first one and is still running.) You could also choose to filter on other criteria, including cumulative or delta values for DISK_READS, BUFFER_GETS, ROWS_PROCESSED, CPU_TIME, ELAPSED_TIME, IOWAIT, CLWAIT (cluster wait), and so on. Run a DESC command of the view DBA_HIST_SQLSTAT to get a full list of its columns. This listing shows different SQL_IDs at the top of the list.

```
  SNAP_ID READS_DELTA EXEC_DELTA RDS_EXEC_RATIO SQL_ID
---------- ----------- ---------- -------------- -------------
       513     5875532          1        5875532 f6c6qfq28rtkv
       513      800065          1         800065 df28xa1n6rcur
```

When Should I Use an Index?

In Oracle version 5, many DBAs called the indexing rule the 80/20 Rule; you needed to use an index if less than 20 percent of the rows were being returned by a query. In version 7, this number was reduced to about 7 percent on average, and in versions 8*i* and 9*i*, the number was closer to 4 percent. In versions 10*g* and 11*g*, Oracle is better at retrieving the entire table, so the value continues to be in the 5 percent or less range, although it depends not only on the number of rows but also on how the blocks are distributed (see Chapter 2 for additional information).

Figure 8-1 shows when an index should generally be used (in V5 and V6 for rule-based optimization and in V7, V8*i*, V9*i*, V10*g*, V11*g*, or V12*c* for cost-based optimization). However, based on the distribution of data, parallel queries or partitioning can be used and other factors need to be considered. In Chapter 9, you will see how to make this graph for your own queries using mathematical models. If the table has fewer than 1000 records (small tables), then the graph is also different. For small tables, Oracle's cost-based optimizer generally uses the index when only less than 1 percent of the table is queried. This graph shows you the progress in versions of Oracle (these are hardware dependent). The lower the percentage of rows returned, the more likely you would use an index. This graph shows the speed of a full table scan becoming faster. Because of the many variables starting with Oracle9*i*, the percentage could continue to decrease as the trend shows happening from V5 to V8*i*, or it could increase slightly, depending on how you architect the database. In Oracle9*i*, Oracle 10*g*, Oracle 11*g*, or 12*c*, you create where the graph goes. Hardware like Exadata and Exalogic enhancements can further alter this graph (where percentage could decrease to less than 1 percent); your choice may depend on how the data and indexes are architected, how the data is distributed within the blocks, and how it is accessed.

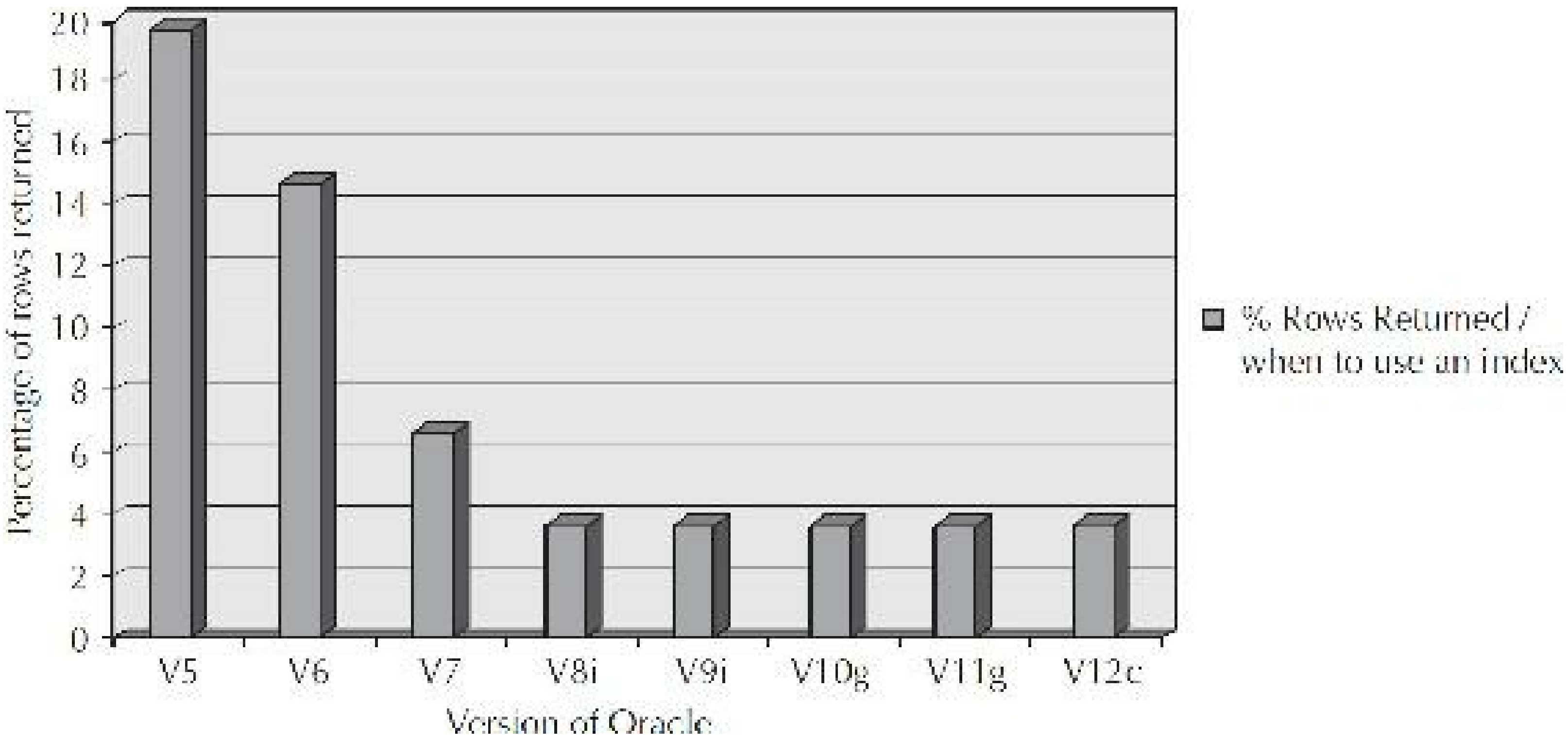


FIGURE 8-1. *When to generally use an index based on the percentage of rows returned by a query*

TIP

When a small number of rows ("small" is version and hardware dependent, but almost always less than 5 percent, and even less than 1 percent at times) are returned to meet a condition in a query, you generally want to use an index on that condition (column), given that the small number of rows also returns a small number of individual blocks (usually the case).

Selecting Query Text from the DBA_HIST_SQLTEXT View

The query text for the offending queries shown in the previous two examples can be obtained from the DBA_HIST_SQLTEXT view with the following query:

```
select  command_type, sql_text
from    dba_hist_sqltext
where   sql_id='03ay719wdnqz1';

COMMAND_TYPE  SQL_TEXT
------------  ----------------------------
           3  select count(1) from t2, t2

select  command_type, sql_text
from    dba_hist_sqltext
where   sql_id='f6c6qfq28rtkv';

COMMAND_TYPE  SQL_TEXT
------------  ---------------------------
           3  select count(*) from emp3
```

Selecting Query EXPLAIN PLAN from the DBA_HIST_SQL_PLAN View

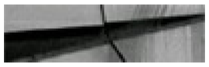
The EXPLAIN PLAN for the offending SQL is also captured. You may view information about the execution plan through the DBA_HIST_SQL_PLAN view. If you want to display the EXPLAIN PLAN, the simplest way is to use the DBMS_XPLAN package with a statement such as this one:

```
select *
from   table(DBMS_XPLAN.DISPLAY_AWR('03ay719wdnqz1'));

PLAN_TABLE_OUTPUT
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
SQL_ID 03ay719wdnqz1
--------------------
select count(1) from t2, t2

Plan hash value: 1163428054
--------------------------------------------------------------------------------
| Id | Operation             | Name  | Rows  | Cost  (%CPU)| Time      |
--------------------------------------------------------------------------------
| 0  | SELECT STATEMENT      |       |       | 10G(100)    |           |
| 1  | SORT AGGREGATE        |       |     1 |             |           |
| 2  | MERGE JOIN CARTESIAN  |       | 6810G| 10G  (2)     |999:59:59  |
| 3  | INDEX FAST FULL SCAN  | T2_I1 | 2609K| 3996  (2)    | 00:00:48  |
| 4  | BUFFER SORT           |       | 2609K| 10G  (2)     |999:59:59  |
| 5  | INDEX FAST FULL SCAN  | T2_I1 | 2609K| 3994  (2)    | 00:00:48  |
--------------------------------------------------------------------------------
```

As you can see, this particular query is a Cartesian join, which is normally not a valid table join (certainly not a good idea as it joins *every* row of one table with *every* row of another table) and can lead to the massive resource consumption. This query was used to show how to take advantage of some of the new functionality for identifying and collecting information about poorly performing SQL. Here is the output for the query that was used earlier that queries the EMP3 table, which is over 1 billion rows (still fast at 5 minutes, even though it's 1B rows):



```
select *
from   table(DBMS_XPLAN.DISPLAY_AWR('f6c6qfq28rtkv'));

PLAN_TABLE_OUTPUT
-------------------------------------------------------------------
SQL_ID f6c6qfq28rtkv
--------------------
select count(*) from emp3

Plan hash value: 1396384608
----------------------------------------------------------------------
| Id  | Operation          | Name | Rows   | Cost  (%CPU)| Time      |
----------------------------------------------------------------------
|   0 | SELECT STATEMENT   |      |        |  1605K(100)|           |
|   1 |  SORT AGGREGATE    |      |      1 |            |           |
|   2 | TABLE ACCESS FULL| EMP3 |  1006M|  1605K   (1)| 05:21:10  |
----------------------------------------------------------------------
```

What If I Forget the Index?

Although it seems obvious that columns, which are generally restrictive, require indexes, this requirement is not always such common knowledge among users or managers. I once went to a consulting job where their database was suffering from incredibly poor performance. When I asked for a list of tables and indexes, they replied, “We have a list of tables, but we haven’t figured out what indexes are yet and if we should use them or not—do you think you can help our performance?” My first thought was, “Wow, can I ever—my dream tuning job.” My second thought was that I had been training experts too long and had forgotten that not everyone is as far along in their performance education. While basic index principles and structure are covered in Chapter 2, this section will focus on query-related issues surrounding indexes.

Even if you have built indexes correctly for most columns needing them, you may miss a crucial column here and there. If you forget to put an index on a restrictive column, then the speed of those queries will not be optimized. Consider the following example where the percent of rows returned by any given CUST_ID is less than 1 percent (there are about 25M rows on the SALES2 table and about 25K of them are CUST_ID=22340). Under these circumstances, an index on the CUST_ID column should normally be implemented. The next query does *not* have an index on CUST_ID:

```
select  count(*)
from    sales2
where   cust_id = 22340;

 COUNT(*)
----------
   25750

Elapsed: 00:00:08.47 (8.47 seconds)

Execution Plan
------------------------------------------------------------
Plan hash value: 2862189843

-----------------------------------------------------------------------
| Id  | Operation            | Name    | Rows   | Cost  (%CPU)| Time     |
-----------------------------------------------------------------------
|   0 | SELECT STATEMENT     |         |      1 | 32639    (1)| 00:06:32 |
|   1 |  SORT AGGREGATE      |         |      1 |             |          |
|   2 |   TABLE ACCESS FULL  | SALES2  |    24M| 32639    (1)| 00:06:32 |
-----------------------------------------------------------------------
119260 consistent gets (memory reads)
119258 physical reads (disk reads)
1,000 times more blocks read than using an index (we'll see this in a moment)
```

Not only is the query extremely slow, but it also uses a tremendous amount of memory and CPU to perform the query. This results in an impatient user and a frustrating wait for other users due to the lack of system resources. (Sound familiar?)

Creating an Index

To accelerate the query in the last example, I build an index on the CUST_ID column. The storage clause must be based on the size of the table and the column. The table is over 25 million rows (the space for the index is about 461M). Specifying Automatic Segment Space Management for the underlying tablespace allows Oracle to manage segment space automatically for best performance. I could also perform an ALTER SESSION SET SORT_AREA_SIZE = 500000000 (if I had the necessary OS memory) and the index creation would be much faster.

```
create index sales2_idx1 on sales2(cust_id)
tablespace rich;

Index Created.
```

Invisible Index

Oracle has a feature called invisible indexes. An invisible index is invisible to the optimizer by default. Using this feature, you can test a new index without affecting the execution plans of the existing SQL statements or you can test the effect of dropping an index without actually dropping it (the index continues to be maintained even though it is not seen by the optimizer; this ensures if you make it visible again, it's up to date). Note that Chapter 2 has additional information and queries related to invisible indexes.

You can create an invisible index or you can alter an existing index to make it invisible. To enable the optimizer to use *all* invisible indexes (not a good idea usually), set the new initialization parameter called OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE. This parameter is set to FALSE by default. You can run this CREATE instead of the one in the previous section:

```
create index sales2_idx1 on sales2(cust_id)
tablespace rich
storage (initial 400M next 10M pctincrease 0) invisible;

Index Created
```

Checking the Index on a Table

Before creating indexes, check for current indexes that exist on that table to ensure there are no conflicts.

Once you have created the index, verify that it exists by querying the DBA_IND_COLUMNS view:

```
select  table_name, index_name, column_name, column_position
from    dba_ind_columns
where   table_name = 'SALES2'
and     table_owner = 'SH'
order   by index_name, column_position;

TABLE_NAME INDEX_NAME_ COLUMN_NAME COLUMN_POSITION
---------- ----------- ----------- ---------------
SALES2     SALES2_IDX1 CUST_ID                   1
```

The TABLE_NAME is the table that is being indexed; the INDEX_NAME is the name of the index; the COLUMN_NAME is the column being indexed; and the COLUMN_POSITION is the order of the columns in a multipart index. Because our index involves only one column, the COLUMN_POSITION is 1 (CUST_ID is the first and only column in the index).

Query USER_INDEXES to verify the visibility of the index:

```
select index_name, visibility
from   user_indexes
where  index_name = 'SALES2_IDX1';

INDEX_NAME             VISIBILITY
---------------------- ----------
SALES2_IDX1            VISIBLE
```

Is the Column Properly Indexed?

Rerun the same query now that the CUST_ID column is properly indexed. The query is dramatically faster, and more important, it no longer “floods” the system with a tremendous amount of data to the SGA (it has a much lower number of block reads) and subsequently reduces the physical I/O as well. Originally, this query took around 120,000 physical reads. Now it only takes about 60 physical reads (1000× less) and over 800× faster. Even though the query itself runs in seconds, this time difference can be a big deal if the query runs many times.

```
select count(*)
from   sales2
where  cust_id = 22340;

 COUNT(*)
----------
   25750

Elapsed: 00:00:00.01 (0.01 seconds - )

Execution Plan
----------------------------------------------------------
Plan hash value: 3721387097
--------------------------------------------------------------------------------
| Id  | Operation          | Name       | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |            |     1 |     4 |    10   (0)| 00:00:01 |
|   1 |  SORT AGGREGATE    |            |     1 |     4 |            |          |
|*  2 |   INDEX RANGE SCAN| SALES2_IDX |  3514 | 14056 |    10   (0)| 00:00:01 |
--------------------------------------------------------------------------------

127 consistent gets (memory reads)
60 physical  reads (disk reads)
```

TIP

The first tip concerning slow queries is that you'll have a lot of them if you don't index restrictive columns (return a small percentage of the table). Building indexes on restrictive columns is the first step toward better system performance.

What If I Create a Bad Index?

In the query to the PRODUCT table, I have a COMPANY_NO column. Since this company's expansion has not occurred, all rows in the table have a COMPANY_NO = 1. What if I am a beginner and I have heard that indexes are good and have decided to index the COMPANY_NO column? Consider the following example which selects only certain columns from the PLAN_TABLE after executing the query.

The cost-based optimizer will analyze the index as bad and suppress it. The table *must* be reanalyzed after the index (depending on the statistics level) is created for the cost-based optimizer to make an informed choice. The index created on COMPANY_NO is correctly suppressed by Oracle internally (since it would access the entire table and index).

```
select  product_id, qty
from    product
where   company_no = 1;

Elapsed time: 405 seconds (all records are retrieved via a full table scan)

OPERATION           OPTIONS         OBJECT NAME
------------------  --------------  -----------
SELECT STATEMENT
TABLE ACCESS        FULL            PRODUCT

49,825 consistent gets (memory reads)
41,562 physical reads (disk reads)
```

You can force an originally suppressed index to be used (bad choice), as follows:

```
select  /*+ index(product company_idx1) */ product_id, qty
from    product
where   company_no = 1;

Elapsed time: 725 seconds  (all records retrieved using the index on company_no)

OPERATION           OPTIONS         OBJECT NAME
------------------  --------------  -----------
SELECT STATEMENT
TABLE ACCESS        BY ROWID        PRODUCT
INDEX               RANGE SCAN      COMPANY_IDX1

4,626,725 consistent gets (memory reads)
80,513 physical reads (disk reads)
```

Indexes can also be suppressed when they cause poorer performance by using the FULL hint:

```
select  /*+ FULL(PRODUCT) */ product_id, qty
from    product
where   company_no = 1;

Elapsed time: 405 seconds (all records are retrieved via a full table scan)

OPERATION           OPTIONS         OBJECT NAME
------------------  --------------  -----------
SELECT STATEMENT
TABLE ACCESS            FULL        PRODUCT

49,825 consistent gets (memory reads)
41,562 physical reads (disk reads)
```

Next, consider a similar example on a faster server with a 25M-row table where I am summing *all* rows together. Oracle *is* once again smart enough to do a full table scan since I am summing the *entire* table. A full table scan only scans the table, but if I force an index (as in the second example), it has to read many more blocks (almost 50 percent more), scanning both the table and the index (resulting in a query that is almost four times slower).

```
select sum(prod_id)
from   sales
where  cust_id=1;

SUM(PROD_ID)

------------
 1939646817

Elapsed: 00:00:08.58

Execution Plan
-------------------------------------------------------------------------------
| Id  | Operation            | Name   | Rows   | Bytes  | Cost  (%CPU)| Time     |
|   0 | SELECT STATEMENT     |        |      1 |      7 | 33009    (2)| 00:06:37 |
|   1 |  SORT AGGREGATE      |        |      1 |      7 |             |          |
|*  2 |   TABLE ACCESS FULL| SALES3 |    24M|   165M| 33009    (2)| 00:06:37 |
-------------------------------------------------------------------------------

"Statistics"
------------------------------------------------------------
    119665  consistent gets
    119660  physical reads
```

Now let’s try scanning the index and then go to the table (bad idea):

```
select /*+ index (sales3 sales3_idx) */ sum(prod_id)
from   sales

where  cust_id=1


SUM(PROD_ID)
------------
 1939646817

Elapsed: 00:00:33.9

Execution Plan
------------------------------------------------------------------------------------
| Id  | Operation                    | Name       | Rows  |Bytes| Cost  (%CPU)|Time     |
|   0 | SELECT STATEMENT             |            |     1 |  7  | 213K  (1)   |00:42:37 |
|   1 |  SORT AGGREGATE              |            |     1 |  7  |             |         |
|   2 |  TABLE ACCESS BY INDEX ROWID | SALES3     |   24M|165M | 213K  (1)   |00:42:37 |
|*  3 |   INDEX RANGE SCAN           | SALES3_IDX|   24M|     |47976  (1)   |00:09:36 |
------------------------------------------------------------------------------------

Statistic
----------------------------------------------------------
    168022  consistent gets
    168022  physical reads
```

TIP

Bad indexes (indexing the wrong columns) can cause as much trouble as forgetting to use indexes on the correct columns. While Oracle's cost-based optimizer generally suppresses poor indexes, problems can still develop when a bad index is used at the same time as a good index. The cost of each index for INSERTs and DELETEs must also be considered when adding many indexes.

Exercising Caution When Dropping an Index

Some people's first reaction when they find a query that is using a poor index is to drop the index. Suppressing the index should be your first reaction, however, and investigating the impact of the index on other queries should be the next action. Unless your query was the only one being performed against the given table, changing/dropping an index might be a detrimental solution (perhaps it's only used during month-end or year-end reporting). The invisible index feature can be used to determine the effect of dropping an index without actually dropping it (Chapter 2 covers the indexes in detail as well using the invisible index to create multiple types of indexes on the same column at the same time in 12*c*). Issue the following command against the index that needs to be dropped:

```
alter index sales2_idx1 invisible;
```

An invisible index is an index that continues to be maintained, but is ignored by the optimizer unless you explicitly set it back to being visible or turn *all* invisible indexes on by setting the OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE (careful). This way you can test the effect of dropping a particular index. If you want to reverse it, all you need to do is

```
alter index sales2 idx visible;
```

The next section investigates indexing columns that are both in the SELECT and WHERE clauses of the query.

Indexing the Columns Used in the SELECT and WHERE

The preceding section described how dropping an index can hurt performance for a query. Consider the following query where the index was created to help. I built a million-row EMPLOYEES table from the famous SCOTT.EMP table. This query does not have indexed columns:

```
select ename
from   employees
where  deptno = 10;

Elapsed time: 55 seconds (a full table scan is performed)

OPERATION            OPTIONS          OBJECT NAME
-------------------  ---------------  -----------
SELECT STATEMENT
TABLE ACCESS         FULL             EMPLOYEES
```

First, I place an index on the DEPTNO column to try to improve performance:

```
Create index dept_idx1 on employees (deptno)
Tablespace test1
Storage (initial 20M next 5M pctincrease 0);

select  ename
from    employees
where   deptno = 10;

Elapsed time: 70 seconds (the index on deptno is used but made things worse)

OPERATION           OPTIONS          OBJECT NAME
------------------  -------------    -----------
SELECT STATEMENT
TABLE ACCESS        BY INDEX ROWID    EMPLOYEES
INDEX               RANGE SCAN        DEPT_IDX1
```

This situation is now worse since almost all values for DEPTNO were equal to 10 (we read the entire index and almost the entire table, which takes longer than just reading the entire table). In this query, only the ENAME is selected. If this is a crucial query on the system, choose to index both the SELECT and the WHERE columns. By doing this, you create a concatenated index:

```
Drop index dept_idx1;

Create index emp_idx1 on employees (deptno, ename)
Tablespace test1
Storage (initial 20M next 5M pctincrease 0);
```

The query is now tremendously faster:

```
select  ename
from    employees
where   deptno = 10;

Elapsed time: Less than 1 second (the index on deptno AND ename is used)

OPERATION           OPTIONS     OBJECT NAME
------------------  ----------  -----------
SELECT STATEMENT
INDEX               RANGE SCAN  EMP_IDX1
```

The table itself did not have to be accessed (only read the entire index), which increases the speed of the query. Indexing both the column in the SELECT clause and the column in the WHERE clause allows the query to only access the index.

Consider the following 25M-row SALES3 table (created from SALES2). I have a two-part single index on the CUST_ID and PROD_ID columns. Oracle only needs to access the index (no table access), since all needed information is contained in the index (60K reads instead of the 160K you saw earlier).

```
select sum(prod_id)
from   sales3
where  cust_id=1;

SUM(PROD_ID)
------------
 1939646817

Elapsed: 00:00:05.4

Execution Plan
| Id  | Operation             | Name           | Rows  | Bytes |Cost (%CPU|  Time    |
--------------------------------------------------------------------------------------
|   0 |SELECT STATEMENT       |                |     1 |     7 |16690   (2)|00:03:21 |
|   1 |SORT AGGREGATE         |                |     1 |     7 |           |         |
| * 2 |INDEX FAST FULL SCAN SALES_IDX_MULTI|  24M|  165M|16690   (2)|00:03:21 |

Statistics:
-----------------------------------
60574  consistent gets
60556  physical reads
```

TIP
For crucial queries on your system, consider concatenated indexes on the columns contained in both the SELECT and the WHERE clauses so only the index is accessed.

Using the Fast Full Scan

The preceding section demonstrated that if I index both the SELECT and the WHERE columns, the query is much faster. Oracle does not guarantee that only the index will be used under these circumstances. However, there is a hint that guarantees (under most circumstances) that only the index will be used. The INDEX_FFS hint is a fast full scan of the index. This hint accesses only the index and not the corresponding table. Consider a query from a table with 100M rows with the index on CUST_ID called SALES2_IDX.

First, you check the number of blocks read for a full table scan and then a fast full index scan:

```
select /*+ full(sales2) */ count(*)
from   sales2;

 COUNT(*)
----------
 100153887

Elapsed: 00:01:42.63

Execution Plan
----------------------------------------------------------
Plan hash value: 2862189843
---------------------------------------------------------------------
| Id  | Operation           | Name    | Rows  | Cost (%CPU)| Time     |
---------------------------------------------------------------------
|   0 | SELECT STATEMENT    |         |     1 | 32761   (1)| 01:06:32 |
|   1 |  SORT AGGREGATE     |         |     1 |            |          |
|   2 |   TABLE ACCESS FULL| SALES2  |   24M| 32761   (1)| 01:06:32 |
---------------------------------------------------------------------

Statistics
----------------------------------------------------------
    820038  consistent gets
    481141  physical reads
```

Now let’s try to select using a full index scan instead:

```
select /*+ index_ffs (sales2 sales2_idx) */ count(*)
from sales2;

 COUNT(*)
----------
 100153887

Elapsed: 00:24:06.07
```

```
Execution Plan
----------------------------------------------------------
Plan hash value: 3956822556

--------------------------------------------------------------------------
| Id  | Operation              | Name        | Rows  | Cost (%CPU)| Time     |
--------------------------------------------------------------------------
|   0 | SELECT STATEMENT       |             |     1 | 81419   (2)| 00:16:18 |
|   1 |  SORT AGGREGATE        |             |     1 |            |          |
|   2 |   INDEX FAST FULL SCAN | SALES2_IDX  |   24M | 81419   (2)| 00:16:18 |
--------------------------------------------------------------------------

Statistics
----------------------------------------------------------
    298091  consistent gets
    210835  physical reads
```

The query with the INDEX_FFS hint now only accesses the index. Instead of scanning over 800K blocks (of which 400K were physical reads), you only scan around 300K blocks (of which 210K are physical reads). Also note, sometimes your queries scan the *entire* index (as this one did), which is often not as good as if you have a limiting condition, so be careful; using an index search is much better than a full index scan when possible. Oracle often scans the index versus scanning the table for a `count(*)`, by default, in 12*c*. Running either of these queries a second time (see next section) does not get rid of the physical scans since the query retrieves enough data to fill half of the number of blocks as in the total buffer cache (it is pushed out of the cache quickly since it is not a short table; see Chapter 14 for additional details).

TIP

The INDEX_FFS hint processes only the index and does not access the table. All columns that are used and retrieved by the query must be contained in the index.

Making the Query “Magically” Faster

Consider the following query from the last example in which the user adds a hint called “RICHS_SECRET_HINT.” The user overheard a conversation about this hint at a recent user group and believes this hint (buried deep in the X$ tables) is the hidden secret to tuning. First, the query is run and no index can be used (a large EMPLOYEES table with over 14M rows):

```
select  ename, job
from    employees
where   deptno = 10
and     ename = 'ADAMS';

Elapsed time: 45.8 seconds (one record is retrieved in this query)

OPERATION             OPTIONS     OBJECT NAME
------------------    ---------   ----------
SELECT STATEMENT
TABLE ACCESS          FULL        EMPLOYEES
```

There is *no* index that can be used on this query. A full table scan is performed. The user now adds Rich's secret hint to the query:

```
select  /*+ richs_secret_hint */ ename, job
from    employees
where   deptno = 10
and     ename = 'ADAMS';

Elapsed time: under 1 second (one record is retrieved in this query)

OPERATION             OPTIONS     OBJECT NAME
------------------    ---------   ----------
SELECT STATEMENT
TABLE ACCESS          FULL        EMPLOYEES
```

The hint worked and the query is "magically" faster, although a full table scan was still performed in the second query. Actually, the data is now stored in memory and querying the data from memory is now much faster than going to disk for the data—so much for the magic! By effectively using the 12*c* Result Cache, you can *magically* make things faster as well. See the "Using the Result Cache" section later in this chapter.

TIP
When running a query multiple times in succession, it becomes faster because you have now cached the data in memory (although full table scans are aged out of memory quicker than indexed scans). At times, people are tricked into believing that they have made a query faster, when in actuality they are accessing data stored in memory. Flushing the buffer cache or restarting the test system can help you get accurate tuning results for comparisons. The next time a user calls and says a query was too slow, just say: Really? Try running it again.

Caching a Table in Memory

While it is disappointing that there is no “secret hint” for tuning (ORDERED and LEADING are the hints closest to magic), you can use the previous section to learn from, and then you can use this knowledge to your advantage. In the previous section, the query ran faster the second time because it was cached in memory. What if the tables used most often were cached in memory all the time? Well, the first problem is that if you cannot cache every table in memory, you must focus on the smaller and more often used tables to be cached. You can also use multiple buffer pools as discussed in Chapter 4. The following query is run against an unindexed CUSTOMER table to return one of the rows:

```
select prod_id, cust_id
from   sales
where  cust_id=999999999
and    prod_id is not null;

  PROD_ID    CUST_ID
---------- ----------
        13  999999999

Elapsed: 00:00:00.84

Execution Plan
-------------------------------------------------------------
Plan hash value: 781590677

---------------------------------------------------------------------------
| Id  | Operation          | Name  | Rows  | Bytes | Cost (%CPU)| Time     |
---------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |       |    50 |  1300 |  1241   (2)| 00:00:15 |
|*  1 |  TABLE ACCESS FULL| SALES |    50 |  1300 |  1241   (2)| 00:00:15 |
---------------------------------------------------------------------------
```

The database is then stopped and restarted so as to not influence the timing statistics (you can also perform an ALTER SYSTEM FLUSH BUFFER_CACHE, but only do this on a test system). The table is altered to cache the records:

```
alter table sales cache;

Table altered.
```

Query the unindexed, but now cached, SALES table and it still takes 0.84 seconds. The table has been altered to be cached, but the data is not in memory yet. Every subsequent query will now be faster (after the first one). I query the unindexed (but now cached) SALES table to return one of the rows in 0.04 seconds, or 21 times faster (this increase in speed could add up fast if this query is run thousands of times):

```
select prod_id, cust_id
from   sales
where  cust_id=999999999
and    prod_id is not null;

  PROD_ID    CUST_ID
---------- ----------
        13  999999999

Elapsed: 00:00:00.04

Execution Plan
----------------------------------------------------------
Plan hash value: 781590677
---------------------------------------------------------------------------------
| Id  | Operation           | Name  | Rows  | Bytes | Cost (%CPU)| Time     |
---------------------------------------------------------------------------------
|   0 | SELECT STATEMENT    |       |    50 |  1300 |  1241   (2)| 00:00:15 |
|*  1 |  TABLE ACCESS FULL| SALES |    50 |  1300 |  1241   (2)| 00:00:15 |
---------------------------------------------------------------------------------
```

The query is faster because the table is now cached in memory; in fact, all queries to this table are now fast regardless of the condition used. A cached table is “pinned” into memory and placed at the “most recently used” end of the cache; it is pushed out of memory only after other full table scans to tables that are not cached are pushed out. Running a query multiple times places the data in memory so subsequent queries are faster—only caching a table ensures that the data is not later pushed out of memory. Oracle caches frequently used data, by default, as you access things over and over.

TIP
Caching an often-used but relatively small table into memory ensures that the data is not pushed out of memory by other data. Be careful, however—cached tables can alter the execution path normally chosen by the optimizer, leading to an unexpected execution order for the query (for instance, affecting the driving table in nested loop joins).

Using the Result Cache

The Result Cache lets you cache SQL results in an area of the SGA to improve performance.

The following RESULT_CACHE hint caches the results on execution:

```
select /*+ result_cache */ SUM(sal)
from   scott.emp
where  deptno=20;
```

When a query with RESULT_CACHE hint is run, Oracle will see if the results of the query have already been executed, computed, and cached, and, if so, retrieve the data from the cache instead of querying the data blocks and computing the results again. Take the following important points into consideration before using this feature:

- The Result Cache feature is useful only for SQL queries that are executed frequently.
- The underlying data doesn't change very often. When the data changes, the result set is removed from the cache.

If you are executing the same queries over and over, using the RESULT_CACHE hint often makes subsequent queries run faster. Chapters 1 and 4 contain additional information on this.

TIP
If you are executing the same queries over and over (especially grouping or calculation functions), using the RESULT_CACHE hint often makes subsequent queries run faster (at times very much faster).

Choosing Among Multiple Indexes (Use the Most Selective)

Having multiple indexes on a table can cause problems when you execute a query where the choices include using more than one of the indexes. The optimizer almost always chooses correctly. Consider the following example where the percent of rows returned by any given PRODUCT_ID is less than 1 percent where the data is equally distributed between the blocks. Under these circumstances, place an index on the PRODUCT_ID column. The following query has a single index on PRODUCT_ID:

```
selectproduct_id, qty
from   product
where  company_no = 1
and    product_id = 167;

Elapsed time: 1 second (one record is retrieved; the index on product_id is used)

OPERATION            OPTIONS      OBJECT NAME
-------------------- -----------  -----------
SELECT STATEMENT
TABLE ACCESS         BY ROWID     PRODUCT
INDEX                RANGE SCAN   PROD_IDX1

107 consistent gets (memory reads)
1 physical reads (disk reads)
```

Now create an additional index on the COMPANY_NO column. In this example, all of the records have a COMPANY_NO = 1, an extremely poor index. Rerun the query with both indexes (one on PRODUCT_ID and one on COMPANY_NO) existing on the table:

```
select product_id, qty
from   product
where  company_no = 1
and    product_id = 167;

Elapsed time: 725 seconds (one record is returned; a full table scan is performed)

OPERATION            OPTIONS     OBJECT NAME
------------------   ----------  -----------
SELECT STATEMENT
TABLE ACCESS         FULL        PRODUCT

4,626,725 consistent gets (memory reads)
80,513 physical reads (disk reads)
```

Oracle has chosen not to use either of the two indexes (perhaps because of a multiblock initialization parameter or some other "exception to the rule"), and the query performed a full table scan. Depending on the statistical data stored and version of Oracle used, I have seen this same query use the right index, the wrong index, no index at all, or a merge of both indexes. The correct choice is to force the use of the correct index. The correct index is the most restrictive. Rewrite the query to force the use of the most restrictive index, as follows, or better yet, fix the real initialization parameter issue (the less hints that you use, the better—especially when you upgrade to the next version of Oracle).

To rewrite the query to force the use of the most restrictive index:

```
select /*+ index(product prod_idx1) */ product_id, qty
from   product
where  company_no = 1
and    product_id = 167;

Elapsed time: 1 second (one record is retrieved)

OPERATION            OPTIONS     OBJECT NAME
------------------   ----------  -----------
SELECT STATEMENT
TABLE ACCESS         BY ROWID    PRODUCT
INDEX                RANGE SCAN  PROD_IDX1

107 consistent gets (memory reads)
1 physical reads (disk reads)
```

TIP

When multiple indexes on a single table can be used for a query, use the most restrictive index when you need to override an optimizer choice. While Oracle's cost-based optimizer generally forces the use of the most restrictive index, variations will occur, depending on the version of Oracle used, the structure of the query, and the initialization parameters that you may use. Fix the larger issue (get rid of bad indexes) if you see this as a trend.

TIP

Bitmap indexes usually behave differently because they are usually much smaller. See Chapter 2 for more information on the differences between bitmap indexes and other indexes.

The Index Merge

Oracle's index merge feature allows you to merge two separate indexes and use the result of the indexes instead of going to the table from one of the indexes. Consider, for instructional purposes only, the following example (if you use a rule-based hint, which Oracle does not support, but uses internally at times, Oracle includes a note *in the EXPLAIN PLAN* that specifically suggests you use the cost-based optimizer). Also note that OPTIMIZER_MODE set to CHOOSE is not supported either, so use either ALL_ROWS or FIRST_ROWS instead.

The following statistics are based on 1,000,000 records. The table is 210M.

```
create  index year_idx on test2 (year);
create  index state_idx on test2 (state);

select  /*+ rule index(test2) */ state, year
from    test2
where   year = '1972'
and     state = 'MA';

SELECT STATEMENT Optimizer=HINT: RULE
  TABLE ACCESS (BY INDEX ROWID) OF 'TEST2'
    INDEX (RANGE SCAN) OF 'STATE_IDX' (NON-UNIQUE)

Note
---------------------------------------------------
  - rule based optimizer used (consider using cboose)

Elapsed time: 23.50 seconds

select  /*+ index_join(test2 year_idxstate_idx) */
state,  year
from    test2
where   year = '1972'
and     state = 'MA';

SELECT STATEMENT
  VIEW OF 'index$_join$_001'
     HASH JOIN
        INDEX (RANGE SCAN) OF 'YEAR_IDX' (NON-UNIQUE)
        INDEX (RANGE SCAN) OF 'STATE_IDX' (NON-UNIQUE)

Elapsed time: 4.76 seconds
```

In the first query, I test the speed of using just one of the indexes and then going back to the table (under certain scenarios, Oracle tunes this with an AND-EQUAL operation to access data from the indexes). I then use the INDEX_JOIN hint to force the merge of two separate indexes and use the result of the indexes instead of going back to the table. When the indexes are both small compared to the size of the table, this can lead to better performance. On a faster system, the second query takes only 0.06 seconds, so your mileage will vary.

Now, let's consider a query to the 25M-row SALES3 table on a faster server with separate indexes on the CUST_ID and PROD_ID columns. Using an index merge of the two indexes yields a *very* slow response time and many blocks read (over 200K physical reads):

```
select /*+ index_join (sales3 sales3_idx sales3_idx2) */ sum(prod_id)
from   sales3
where  cust_id=1;

SUM(PROD_ID)
------------
 1939646817

Elapsed: 00:01:57.5

Execution Plan
--------------------------------------------------------------------------------------------
| Id  | Operation              | Name             |Rows| Bytes |Cost(%CPU)|Time      |
--------------------------------------------------------------------------------------------
|   0 |SELECT STATEMENT        |                  |  1 |     7  158K  (1) |00:31:47|
|   1 | SORT AGGREGATE         |                  |  1 |     7           |        |
|*  2 |   VIEW                 | index$_join$_001 |24M| 165M   158K  (1) |00:31:47|
|*  3 |   HASH JOIN            |                  |    |                |        |
|*  4 |    INDEX RANGE SCAN    | SALES3_IDX       |24M| 165M  48211  (2) |00:09:39|
|   5 |    INDEX FAST FULL SCAN | SALES3_IDX2     |24M| 165M  63038  (1) |00:12:37|
--------------------------------------------------------------------------------------------

Statistic
------------------------
8535  consistent gets
217514  physical reads
```

If I drop the two indexes on SALES3 and replace them with a two-part single index on the CUST_ID and PROD_ID columns, performance improves greatly—over ten times faster. Another benefit is the reduction of physical block reads from over 200K to only 60K.

```
select sum(prod_id)
from   sales3
where  cust_id=1;SUM(PROD_ID)
------------
 1939646817

Execution Plan
------------------------------------------
| Id  | Operation            | Name            |Rows  | Bytes|Cost(%CPU)|Time     |
--------------------------------------------------------------------------------------
|   0 |SELECT STATEMENT      |                 |  1   |    7 |16690  (2) |00:03:21 |
|   1 |SORT AGGREGATE        |                 |  1   |    7 |           |         |
|*  2 |INDEX FAST FULL SCAN  |SALES_IDX_MULTI  | 24M  | 165M|16690(2)    |00:03:21 |
--------------------------------------------------------------------------------------

Statistic
------------------------
60574  consistent gets
60556  physical reads
```

Indexes That *Can* Get Suppressed

Building the perfect system with all of the correctly indexed columns does not guarantee successful system performance. With the prevalence in business of bright-eyed ad hoc query users comes a variety of tuning challenges. One of the most common is the suppression of perfectly good indexes. A modification of the column side of a WHERE clause often results in that index being suppressed (unless function-based indexes are utilized or the super-smart optimizer figures out a better path). Alternative methods for writing the same query do exist that do not modify the indexed column. A couple of those examples are listed next. Oracle *does* use the indexes in many cases, internally fixing the suppression (they continue to get better at this from version to version), especially when an index search or a full index scan can be run instead of a full table scan. If you use 3GL code or code within applications, the results vary, so I continue to show these areas that are a problem with certain tools or applications for you to consider when you run into that full table scan that you didn't expect.

A math function is performed on the column:

```
select   product_id, qty
from     product
where    product_id+12 = 166;

Elapsed time: 405 second

OPERATION                OPTIONS      OBJECT NAME
-----------------        -------      -----------
SELECT STATEMENT
TABLE ACCESS              FULL         PRODUCT
```

The math function is performed on the other side of the clause (Oracle often fixes this internally):

```
select   product_id, qty
from     product
where    product_id = 154;

Elapsed time: 1 second

OPERATION           OPTIONS     OBJECT NAME
----------------   -------    --------------
SELECT STATEMENT
TABLE ACCESS        BY ROWID    PRODUCT
    INDEX      RANGE SCAN   PROD_IDX1
```

A function is performed on the column:

```
select product_id, qty
from   product
where  substr(product_id,1,1) = 1;

Elapsed time: 405 second

OPERATION         OPTIONS  OBJECT NAME
----------------  -------  -----------
SELECT STATEMENT
TABLE ACCESS       FULL    PRODUCT
```

The function is rewritten so the column is not altered (a LIKE or function-based index would fix this):

```
select  product_id, qty
from    product
where   product_id like '1%';

Elapsed time: 1 second

OPERATION         OPTIONS     OBJECT NAME
----------------  ----------  -----------
SELECT STATEMENT
TABLE ACCESS       BY ROWID    PRODUCT
INDEX             RANGE SCAN  PROD_IDX1
```

As I stated previously, Oracle is often smart enough to figure out the issue and still use the index. The following query shows that the index is scanned with no table access despite the attempt to suppress the index (adding zero (0) or using an NULL Value (NVL) gave the same result). In the following case, everything needed is in the index. Oracle figures out the substring function on the leading edge of the index but is still able to use *only* the index despite needing both columns from the index (versus using the index to access back to the table).

```
select  sum(prod_id)
from    sales3
where   substr(cust_id,1)=1;

SUM(PROD_ID)
------------
 1939646817

Elapsed: 00:00:12.49

Execution Plan
----------------------------------------------------------------------------------------
| Id  | Operation              | Name            |Rows   Bytes|Cost(%CPU|  Time    |
|   0 |SELECT STATEMENT        |                 |   1       7|17651(8)  |00:03:32|
|   1 | SORT AGGREGATE         |                 |   1       7|          |        |
|*  2 |  INDEX FAST FULL SCAN|SALES_IDX_MULTI| 248K 1695K|17651 (8)|00:03:32|
----------------------------------------------------------------------------------------
```

TIP

At times, modifying the column side of the query can result in the index being suppressed unless a function-based index is used. Oracle may also fix this issue during parsing. The more complex the query, the less likely Oracle will fix it.

Function-Based Indexes

One of the largest problems with indexes, as seen in the previous section, is that indexes are often suppressed by developers and ad hoc users. Developers using functions often suppress indexes. There is a way to combat this problem. Function-based indexes allow you to create an index based on a function or expression. The value of the function or expression is specified by the person creating the index and is stored in the index. Function-based indexes can involve multiple columns, arithmetic expressions, or maybe a PL/SQL function or C callout.

The following example shows how to create a function-based index:

```
CREATE INDEX emp_idx ON emp (UPPER(ename));
```

An index that uses the UPPER function has been created on the ENAME column. The following example queries the EMP table using the function-based index:

```
select   ename, job, deptno
from     emp
where    upper(ename) = 'ELLISON';
```

The function-based index (EMP_IDX) can be used for this query. For large tables where the condition retrieves a small amount of records, the query yields substantial performance gains over a full table scan. See Chapter 2 for additional details and examples.

The following initialization parameters must be set (subject to change with each version) to use function-based indexes (the optimization mode must be cost-based as well). When a function-based index is not working, this is often the problem.

```
query_rewrite_enabled = true
query_rewrite_integrity = trusted (or enforced)
```

TIP
Function-based indexes can lead to dramatic performance gains when used to create indexes on functions often used on selective columns in the WHERE clause.

To check the details for function-based indexes on a table, you may use a query similar to this:

```
selecttable_name, index_name, column_expression
from   dba_ind_expressions
where  table_name = 'SALES2'
and   table_owner = 'SH'
order  by index_name, column_position;
```

Virtual Columns

A helpful feature introduced in Oracle 11*g* is the *virtual column*, a column that allows you to define a function on other column(s) in the same table. Here is an example of creating a table with a virtual column:

```
CREATE TABLE my_employees (
   empId      NUMBER,
   firstName  VARCHAR2(30),
   lastName   VARCHAR2(30),
   salary     NUMBER(9,2),
   bonus      NUMBER GENERATED ALWAYS AS (ROUND(salary*(5/100)/1
              VIRTUAL,
  CONSTRAINT myemp pk PRIMARY KEY (empId));
```

An important point to remember is that indexes defined against virtual columns are equivalent to function-based indexes.

The “Curious” OR

The optimizer often has problems when the OR clause is used. The best way to think of the OR clause is as multiple queries that are then merged. Consider the following example where there is a single primary key on PK_COL1, PK_COL2, and PK_COL3. Prior to Oracle 9*i*, Oracle Database performed this query in the following way:

```
select *
from   table_test
where  pk_col1 = 'A'
and    pk_col2 in ('B', 'C')
and   pk_col3 = 'D';

2      Table Access By Rowid TABLE_TEST
1       Index Range Scan TAB_PK
```

NOTE
PK_COL2 and PK_COL3 were not used for index access.

Since Oracle9*i*, Oracle has improved how the optimizer handles this query (internally performing an OR expansion). In 12*c*, the optimizer uses the full primary key and concatenates the results (as shown next), which is much faster than using only part of the primary key (as in the preceding access path). Even though the access path for the preceding query looks better because there are fewer lines, don’t be tricked; fewer lines in the EXPLAIN PLAN doesn’t mean a more efficient query.

```
5 Concatenation
2  Table Access By Rowid TAB
1  Index Unique Scan TAB_PK
4  Table Access By Rowid TAB
3  Index Unique Scan TAB_PK
```

To get this desired result prior to 9*i*, you would have needed to break up the query as shown here (I show this since often making a query longer can make it faster, as it's processed differently):

```
select *
from   table_test
where (pk_col1 = 'A'
and    pk_col2 = 'B'
and    pk_col3 = 'D')
or    (pk_col1 = 'A'
and    pk_col2 = 'C'
and    pk_col3 = 'D');
```

```
5 Concatenation
2  Table Access By Rowid TAB
1  Index Unique Scan TAB_PK
4  Table Access By Rowid TAB
3  Index Unique Scan TAB_PK
```

TIP
Oracle has improved the way that it performs the OR clause. The NO_EXPAND hint can still be helpful, as it prevents the optimizer from using OR expansion, as described in Chapter 7.

Using the EXISTS Function and the Nested Subquery

Another helpful tip to remember is to use the EXISTS function instead of the IN function in most circumstances. The EXISTS function checks to find a single matching row to return the result in a subquery. Because the IN function retrieves and checks all rows, it is slower. Oracle has also improved the optimizer so it often performs this optimization for you as well. Consider the following example, where the IN function leads to very poor performance. This query is faster only if the ITEMS table is extremely small.

```
select    product_id, qty
from      product
where     product_id = 167
and       item_no in
          (select  item_no
           from     items);

Elapsed time: 25 minutes (The items table is 10 million rows)


OPERATION        OPTIONS     OBJECT NAME
------------------  ----------  -----------
SELECT STATEMENT
NESTED LOOPS SEMI
 TABLE ACCESS      BY ROWID    PRODUCT
  INDEX          RANGE SCAN   PROD_IDX1
   SORT
    TABLE ACCESS   FULL       ITEMS
```

In this query, the entire ITEMS table is retrieved.

This query is faster when the condition PRODUCT_ID = 167 substantially limits the outside query:

```
select    product_id, qty
from       product a
where     product_id = 167
and       exists

         (select  'x'
          from     items b
          where    b.item_no = a.item_no);

Elapsed time: 2 seconds (The items table query search is limited to 3 rows)

OPERATION         OPTIONS    OBJECT NAME
------------------  ----------  -----------
SELECT STATEMENT
NESTED LOOPS SEMI
 TABLE ACCESS      BY ROWID    PRODUCT
  INDEX          RANGE SCAN   PROD_IDX1
   INDEX           RANGE SCAN   ITEM_IDX1
```

In this query, only the records retrieved in the outer query (from the PRODUCT table) are checked against the ITEMS table. This query can be substantially faster than the first query if the ITEM_NO in the ITEMS table is indexed or if the ITEMS table is very large, yet the items are limited by the condition PRODUCT_ID = 167 in the outer query.

TIP
Using the nested subquery with an EXISTS clause may make queries dramatically faster, depending on the data being retrieved from each part of the query. Oracle 12c often makes this translation internally, saving you time and giving you performance gains!

That Table Is Actually a View!

Views can hide the complexity of SQL but they can also add to the complexity of optimization. When looking at a SELECT statement, unless you have instituted some kind of naming convention for views, you cannot tell if an object is a table or a view from the SELECT statement alone. You must examine the object in the database to tell the difference. Views can join multiple tables. Be careful about joining views or using a view designed for one purpose for a different purpose, or you may pay a heavy performance price. Ensure that all tables involved in the view are actually required by your query. Also keep in mind that different types of triggers can also hide performance issues behind a simple query. Good developer documentation can save a lot of time in finding performance issues in complex code.

SQL and Grand Unified Theory

Many physicists have searched for a single theory that explains all aspects of how the universe works. Many theories postulated have worked well in certain circumstances and break down in others. This is fine for theoretical physics, but it can spell disaster in a database. When writing SQL, one should not attempt to write the "Grand Unified SQL" statement that will do all tasks, depending on the arguments passed to it. This typically results in suboptimal performance for most tasks performed by the statement (or you feel the effect during the next upgrade). It is better to write separate, highly efficient statements for each task that needs to be performed.

Tuning Changes in Oracle Database 12*c*

The general SQL tuning principles remain the same in 11*g* and 12*c*, but some significant cost-based optimizer changes should be noted:

- The RULE (and CHOOSE) OPTIMIZER_MODE has been deprecated and desupported in both 11*g* and 12*c*. (The only way to get rule-based behavior is by using the RULE hint in a query, which is *not* supported either.) In general, using the RULE hint is not recommended, but for individual queries that need it, it is there. Consult with My Oracle Support before using the RULE hint. See Chapter 4 for more information on initialization parameters. OPTIMIZER_MODE values include ALL_ROWS, FIRST_ROWS, and FIRST_ROWS_*n*.
- In 12*c*, the cost-based optimizer has two modes:
  - In NORMAL mode, the cost-based optimizer considers a very small subset of possible

execution plans to determine which one to choose. The number of plans considered is far smaller than in past versions of the database in order to keep the time to generate the execution plan within strict limits. SQL profiles (statistical information) can be used to influence which plans are considered.

  - The TUNING mode of the cost-based optimizer can be used to perform more detailed analysis of SQL statements and make recommendations for actions to be taken and for auxiliary statistics to be accepted into a SQL profile for later use when running under NORMAL mode. TUNING mode is also known as the *Automatic Tuning Optimizer mode*, and the optimizer can take several minutes for a single statement (good for testing). See the *Oracle Database Performance Tuning Guide Automatic SQL Tuning* (Chapter 17 in the 11.2 docs). Oracle states that the NORMAL mode should provide an acceptable execution path for most SQL statements. SQL statements that do not perform well in NORMAL mode may be tuned in TUNING mode for later use in NORMAL mode. This should provide a better performance balance for queries that have defined SQL profiles, with the majority of the optimizer work for complex queries being performed in TUNING mode once, rather than repeatedly, each time the SQL statement is parsed.

- In Oracle 12*c*, the optimizer has been greatly improved by introducing the Adaptive Query Optimization feature. This new feature allows the optimizer to "change its mind" during the first run of an execution plan, and then discover additional information to further fine-tune the plan going forward. In other words, the optimizer can now make runtime adjustments during the execution of the plan. Figure 8-2 shows all the components that make up Adaptive Query Optimization. Adaptive plans can change the join method or the parallel distribution method at execution time. Adaptive statistics can be gathered at execution time and then stored for future use. I'll go over each one of these components in detail in the next two subsections.

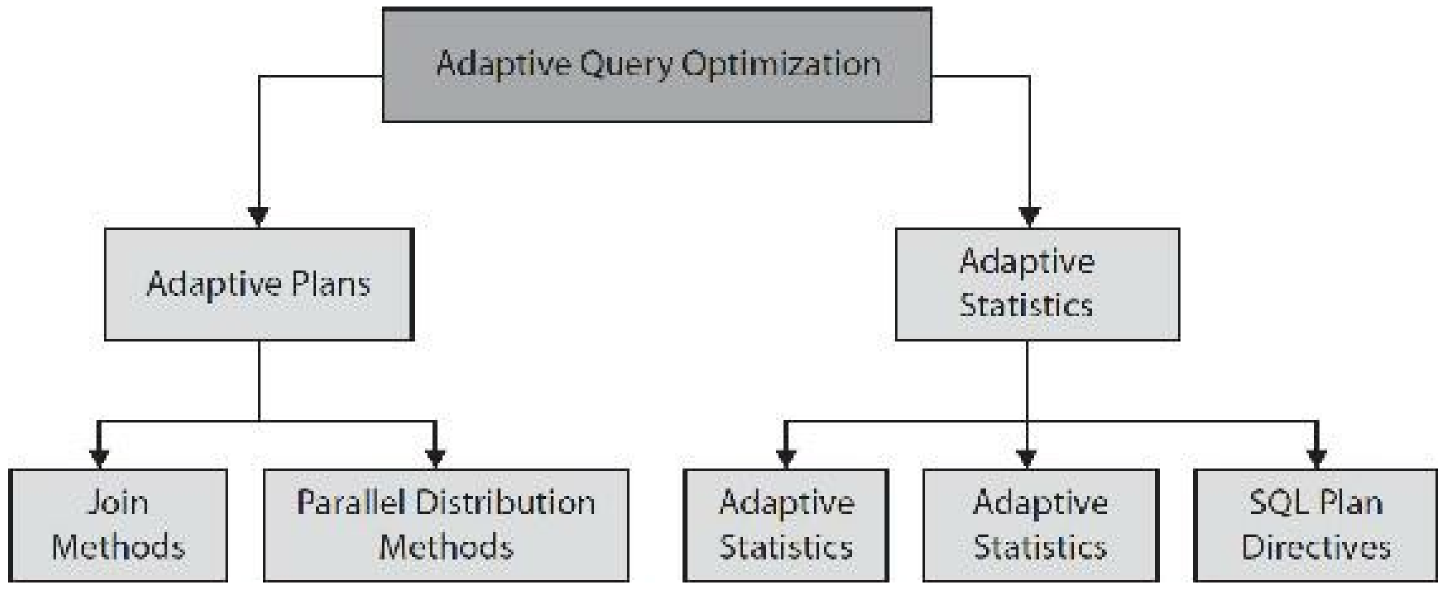
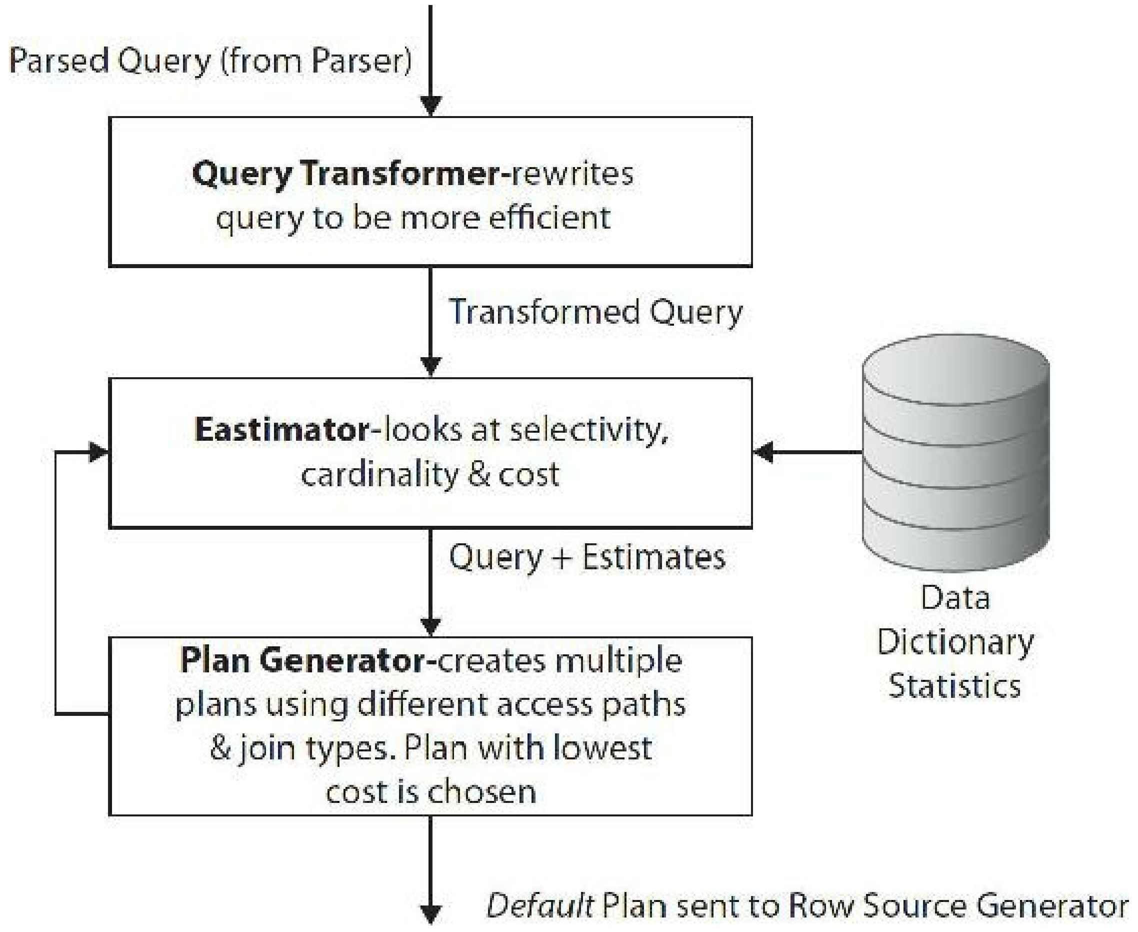


FIGURE 8-2. *Adaptive Query Optimization*

Oracle 12c Adaptive Query Optimization

Adaptive plans help the optimizer make the final plan choice on the first execution of a SQL statement. Let's review how the optimizer creates the default execution plan, as shown in Figure 8-3.



Parsed Query (from Parser)
Query Transformer-rewrites query to be more efficient
Transformed Query
Eastimator-looks at selectivity, cardinality & cost
Data Dictionary Statistics
Query + Estimates
Plan Generator-creates multiple plans using different access paths & join types. Plan with lowest cost is chosen
Default Plan sent to Row Source Generator

FIGURE 8-3. *Creation of a default execution plan*

After a SQL statement is parsed, the query is first sent to a query transformer, which tries to rewrite the SQL to be more efficient. After the query is transformed, it is sent to an estimator, which computes estimated costs of CPU and I/O by using default statistics. All of that information is then sent to the plan generator, which creates multiple plans using different data access paths and join methods. Only the plan with the lowest cost is chosen. After that, the default plan is sent to a row source generator, which creates all the steps and their associated default costs for actual execution.

In Oracle 12*c*, the optimizer now instruments the default plan with statistics collector. So at runtime, the optimizer reads and buffers a small number of rows in each step, and compares the actual statistics with the default plan estimates. If they are significantly different, the step is adapted to use the better plan to avoid poor performance. Currently the only steps that can change in a default plan are join method operations and parallel query distribution.

There are two new initialization parameters that control the adaptive features, OPTIMIZER_ADAPTIVE_FEATURES and OPTIMIZER_ADAPTIVE_REPORTING_ONLY. All of the parameters that can change the behavior of adaptive optimization are listed here:

```
NAME                                         TYPE         VALUE
-------------------------------------------- ------------ -----------
optimizer_adaptive_featuresboolean                        TRUE
optimizer adaptive reporting onlyboolean                  FALSE
optimizer_dynamic_sampling  integer                       2
optimizer features enablestring                           12.1.0.2
```

By default, the OPTIMIZER_ADAPTIVE_FEATURES parameter is set to TRUE so execution plans can automatically change the join method operations (I've seen this work well) or the parallel query distribution on the first run. The OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter can be set to TRUE to first test which queries are going to adapt before the optimizer actually uses the adapted plan. This might be helpful when first upgrading from an earlier version of Oracle to avoid any unexpected behavior. By default, the REPORTING_ONLY option is set to FALSE. Both parameters can be set at system or session levels. You can also set the OPTIMIZER_FEATURES_ENABLE parameter to something less than 12.1.0.1 in order to turn this feature off. However, I recommend using the REPORTING_ONLY parameter to control this feature as it's less intrusive. Finally, the OPTIMIZER_DYNAMIC_SAMPLING parameter has a new level that helps control dynamic statistics, which I'll talk about later in this section.

To identify whether a SQL statement is using an adaptive plan, we need to look at a new column in the V$SQL table called IS_RESOLVED_ADAPTIVE_PLAN. If the value of this column is Y, then the plan has been adapted and is the final plan. If the column value is N, then the plan is adaptable but the final plan has not yet been chosen. The N value is rarely seen, as the final plan is chosen on the first run. If the column is null, then the plan is not adaptable. Another new column in V$SQL is called IS_REOPTIMIZABLE. This column is used to tell the optimizer to look for a better plan on the next execution. We will discuss this column in more detail when looking at adaptive statistics.

The following query can be used to quickly identify which SQL statements are using adaptive plans:

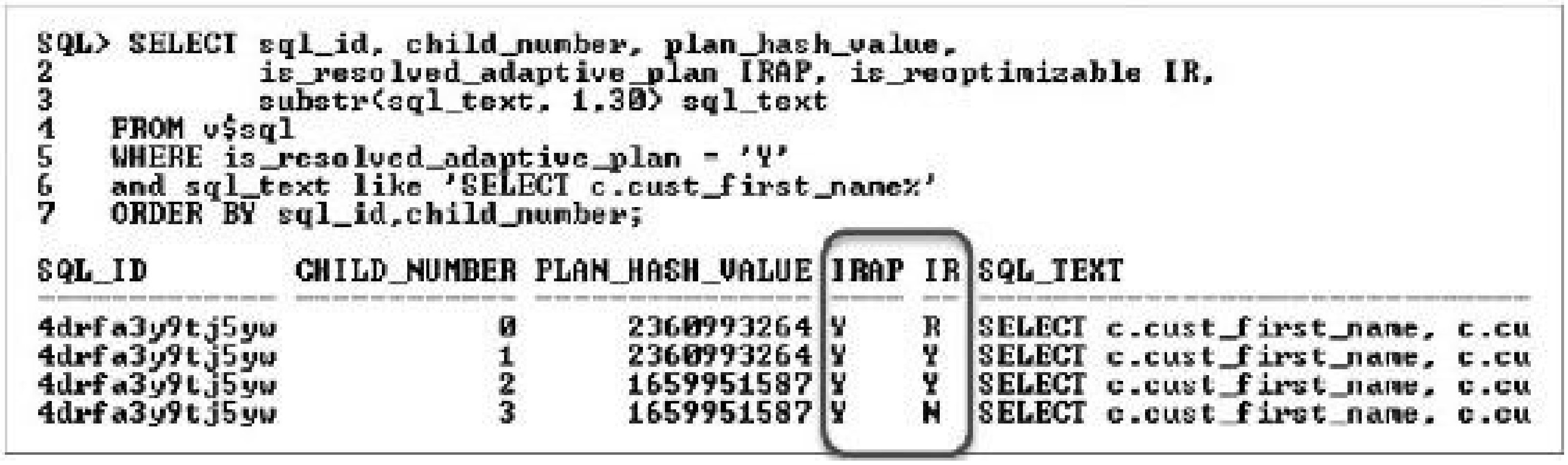
```
SELECT sql_id, child_number, plan_hash_value,
       is_resolved_adaptive_plan, is_reoptimizable,
       substr(sql text, 1,30) sql text

FROM   v$sql
WHERE  is_resolved_adaptive_plan = 'Y'
ORDER  BY sql_id,child_number;
```

In my examples, I've used the 'OE' sample schema and the following SQL statement to demonstrate how Adaptive Query Optimization works:

```
SELECT c.cust first name, c.cust last name,o.order date,
       o.order_status, o.order_mode,
       i.line_item_id, p.product_Description,
       i.unit_price * i.quantitytotal_price,
       quantityquantity_ordered,ip.total_on_hand
FROM orders o, order_itemsi, customers c, products p,
   (SELECT product_id, sum(quantity_on_hand) total_on_hand
    FROM   inventories
    GROUP  BY product_id) ip
WHERE i.order_id = o.order_id
AND   c.customer_id - o.customer_id
AND   p.product_id - i.product_id
AND   p.product_id - ip.product_id
AND   c.cust_last_name= :B1 AND o.order_status = 0
AND   o.order_date between
      to timestamp(:BEG DATE) and to timestamp(:END DATE);
```

Figure 8-4 shows that the query for a customer's order shipped status has been adapted. Notice that on the very first execution, Child Number 0 has changed from the default plan to an adapted plan. In fact, all of the child cursors have adaptive plans, identified by the 'Y' in the IS_RESOLVED_ADAPTIVE (IRAP) column. Also, notice that Child Number 0 has a value of 'R' in the IS_REOPTIMIZABLE (IR) column. The 'R' value is used to tell the optimizer that the OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter is set to TRUE. The optimizer won't use this plan, but you can see what the plan would be if the Adaptive Query Optimization features were enabled. After changing the REPORTING_ONLY parameter to FALSE, we can see that Child Number 1 has a value of 'Y' in the IS_REOPTIMIZABLE column. After the first execution, the optimizer compares default cardinality estimates with the actual number of rows for each operation. If the estimates are significantly different, the child is marked with a 'Y' so the plan won't be used again. When the IS_RESOVED_ADAPTIVE column equals 'Y', the optimizer performs a hard parse on the next execution (Child Number 2), so it can use the newly gathered statistics to find a better plan. Finally, Child Number 3 has been successfully reoptimized and no more changes are currently required. The IS_REOPTIMIZABLE column is set to 'N' on the final plan.



```
SQL> SELECT sql_id, child_number, plan_hash_value,
  2         is_resolved_adaptive_plan IRAP, is_reoptimizable IR,
  3         substr(sql_text, 1,30) sql_text
  4  FROM v$sql
  5  WHERE is_resolved_adaptive_plan = 'Y'
  6  and sql_text like 'SELECT c.cust_first_name%'
  7  ORDER BY sql_id,child_number;

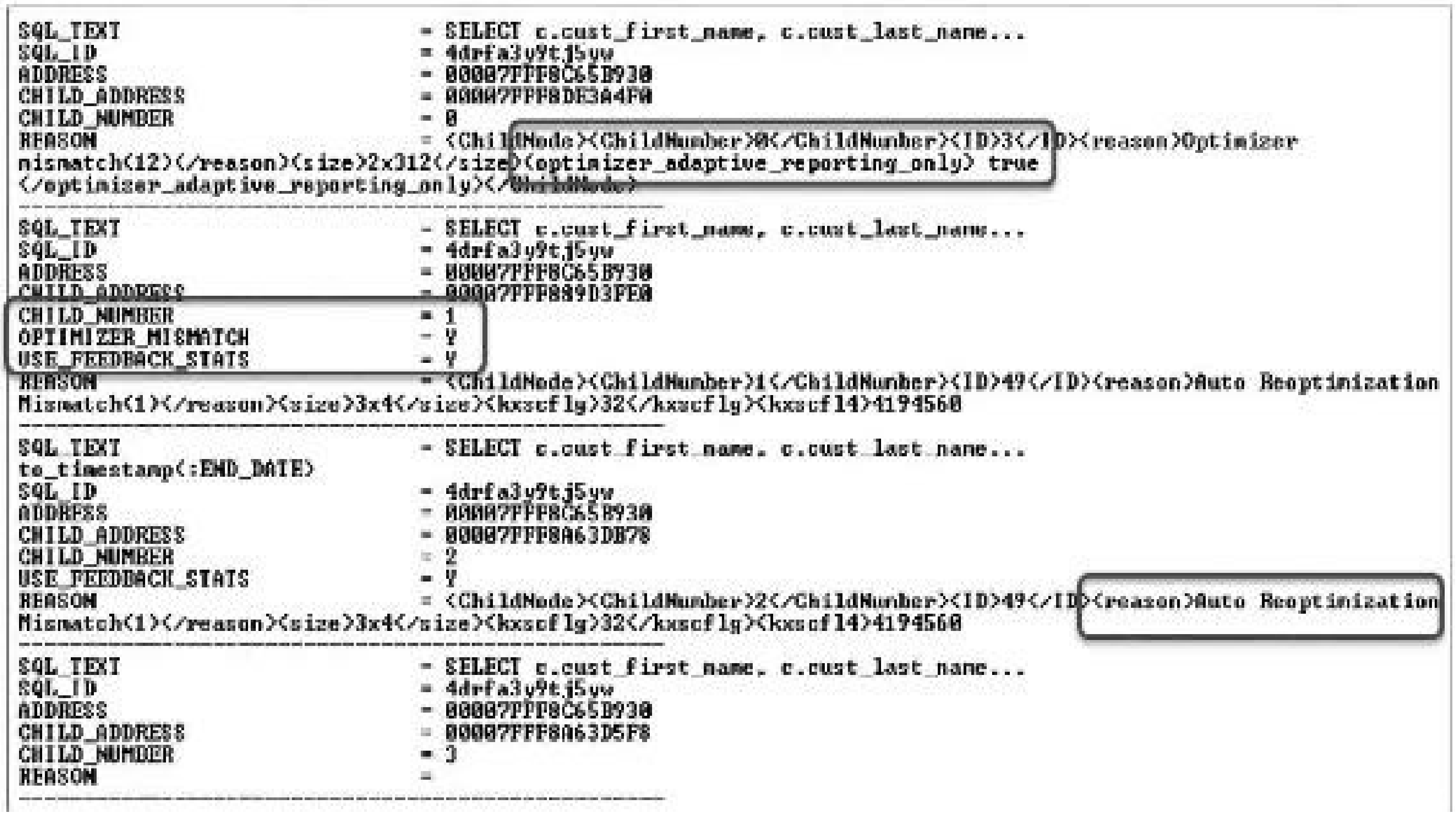
SQL_ID        CHILD_NUMBER PLAN_HASH_VALUE IRAP IR SQL_TEXT
------------- ------------ --------------- ---- -- ------------------------------
4drfa3y9tj5yw            0      2360993264 Y    R  SELECT c.cust_first_name, c.cu
4drfa3y9tj5yw            1      2360993264 Y    Y  SELECT c.cust_first_name, c.cu
4drfa3y9tj5yw            2      1659951587 Y    Y  SELECT c.cust_first_name, c.cu
4drfa3y9tj5yw            3      1659951587 Y    N  SELECT c.cust_first_name, c.cu
```

FIGURE 8-4. *Query is resolved adaptive and is reoptimizable.*

To find more information about why child cursors can't be shared and why plans change, we can query the V$SQL_SHARED_CURSOR table. This table contains 70 columns of mismatches or differences between the child cursors. Each column identifies a specific reason why the cursor cannot be shared with a 'Y' value. Viewing this table can be difficult because of all the Y and N columns. The following SQL statement can be used to report the results in a more readable format for a particular SQL_ID:

```
DECLARE c     NUMBER;
col_cnt    NUMBER;
col_rec    DBMS_SQL.DESC_TAB;
col valueVARCHAR2(4000);
ret_val    NUMBER;
BEGIN
c := DBMS_SQL.OPEN_CURSOR;
DBMS_SQL.PARSE(c,'SELECTq.sql_text, s.*
FROM V$SQL_SHARED_CURSOR S, V$SQL q
WHERE s.sql_id = q.sql_id
AND s.child number = q.child number
AND q.sql_id = ''&1''', DBMS_SQL.NATIVE);
DBMS_SQL.DESCRIBE_COLUMNS(c, col_cnt, col_rec);
FOR idx IN 1 ..col_cnt loop
DBMS_SQL.DEFINE_COLUMN(c, idx, col_value, 4000);
END LOOP;
ret_val := DBMS_SQL.EXECUTE(c);
WHILE(DBMS_SQL.FETCH_ROWS(c) > 0) LOOP
FOR idx in 1 ..col_cnt LOOP
DBMS SQL.COLUMN VALUE(c, idx, col value);
IF col_rec(idx).col_name in ('SQL_ID', 'ADDRESS',
'CHILD_ADDRESS','CHILD_NUMBER', 'SQL_TEXT', 'REASON')
THEN
DBMS_OUTPUT.PUT_LINE(RPAD(col_rec(idx).col_name, 30) || ' = ' || col_value);
ELSIF col_value = 'Y' THEN
                                DBMS_OUTPUT.PUT_LINE(RPAD(col_rec(idx).col_
name, 30) || ' = '|| col_value);
END IF;
END LOOP;
                      DBMS_OUTPUT.PUT_LINE('----------------------------------------
---------------');
END LOOP;
DBMS_SQL.CLOSE_CURSOR(c);
END;
```

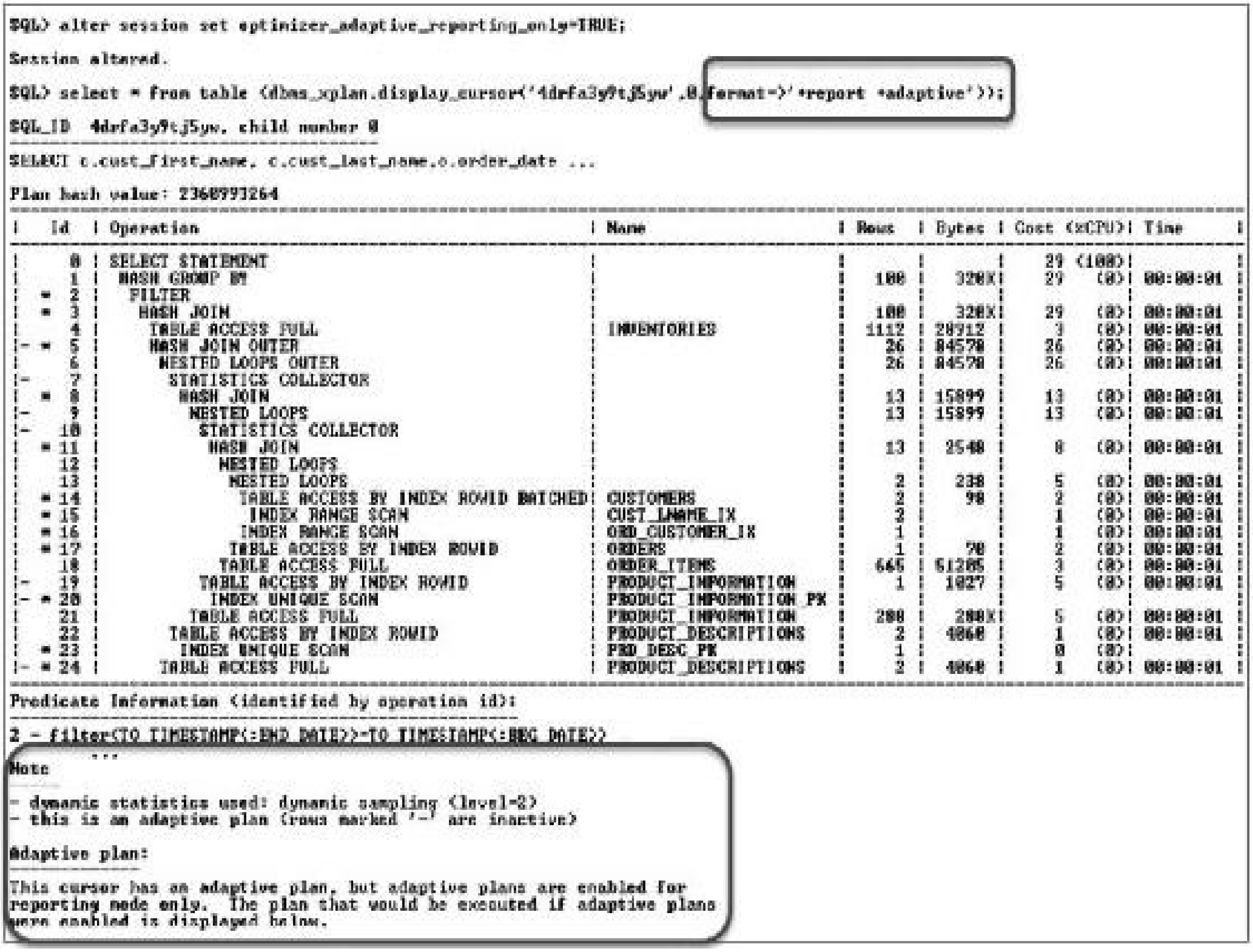
Figure 8-5 displays the results of the preceding V$SQL_SHARED_CURSOR query for our customer order query. Notice the 'Y' column names under each child number as the REASON for the change.



```
SQL_TEXT                          = SELECT c.cust_first_name, c.cust_last_name...
SQL_ID                            = 4drfa3y9tj5yw
ADDRESS                           = 00007FFF8C65B930
CHILD_ADDRESS                     = 00007FFF8DE3A4F0
CHILD_NUMBER                      = 0
REASON                            = <ChildNode><ChildNumber>0</ChildNumber><ID>3</ID><reason>Optimizer
mismatch(12)</reason><size>2x312</size><optimizer_adaptive_reporting_only> true
</optimizer_adaptive_reporting_only></ChildNode>
----------------------------------------------------
SQL_TEXT                          = SELECT c.cust_first_name, c.cust_last_name...
SQL_ID                            = 4drfa3y9tj5yw
ADDRESS                           = 00007FFF8C65B930
CHILD_ADDRESS                     = 00007FFF889D3FE0
CHILD_NUMBER                      = 1
OPTIMIZER_MISMATCH                = Y
USE_FEEDBACK_STATS                = Y
REASON                            = <ChildNode><ChildNumber>1</ChildNumber><ID>49</ID><reason>Auto Reoptimization
Mismatch(1)</reason><size>3x4</size><kxscflg>32</kxscflg><kxscf14>4194560
----------------------------------------------------
SQL_TEXT                          = SELECT c.cust_first_name, c.cust_last_name...
to_timestamp(:END_DATE)
SQL_ID                            = 4drfa3y9tj5yw
ADDRESS                           = 00007FFF8C65B930
CHILD_ADDRESS                     = 00007FFF8A63DB78
CHILD_NUMBER                      = 2
USE_FEEDBACK_STATS                = Y
REASON                            = <ChildNode><ChildNumber>2</ChildNumber><ID>49</ID><reason>Auto Reoptimization
Mismatch(1)</reason><size>3x4</size><kxscflg>32</kxscflg><kxscf14>4194560
----------------------------------------------------
SQL_TEXT                          = SELECT c.cust_first_name, c.cust_last_name...
SQL_ID                            = 4drfa3y9tj5yw
ADDRESS                           = 00007FFF8C65B930
CHILD_ADDRESS                     = 00007FFF8A63D5F8
CHILD_NUMBER                      = 3
REASON                            =
----------------------------------------------------
```

FIGURE 8-5. *V$SQL_SHARED_CURSOR example*

To view adaptive plans, there are two new format parameter values for the DBMS_XPLAN.DISPLAY_CURSOR function. The +ADAPTIVE format parameter will show all active and inactive steps of a plan. The +REPORT format parameter can be used when the OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter is set to TRUE to see how the plan would be adapted if the optimizer were running Adaptive Query Optimization. Figure 8-6 shows an example of setting the REPORTING_ONLY parameter to TRUE at session level. Then, using the +ADAPTIVE and +REPORT format parameters on the DISPLAY_CURSOR function, we can view what changes would occur if the optimizer were in non-reporting mode. Since we asked for the '+adaptive' format, the inactive steps are also listed and marked with a hyphen. Basically, the STATISTICS COLLECTOR and HASH JOIN steps have been marked inactive. Also, notice in the "Note" section that "adaptive plans are enabled for reporting mode only" and the new plan without the inactive steps is listed again.



```
SQL> alter session set optimizer_adaptive_reporting_only=TRUE;

Session altered.

SQL> select * from table (dbms_xplan.display_cursor('4drfa3y9tj5yw',0,format=>'+report +adaptive'));

SQL_ID  4drfa3y9tj5yw, child number 0
-------------------------------------
SELECT c.cust_first_name, c.cust_last_name,o.order_date ...

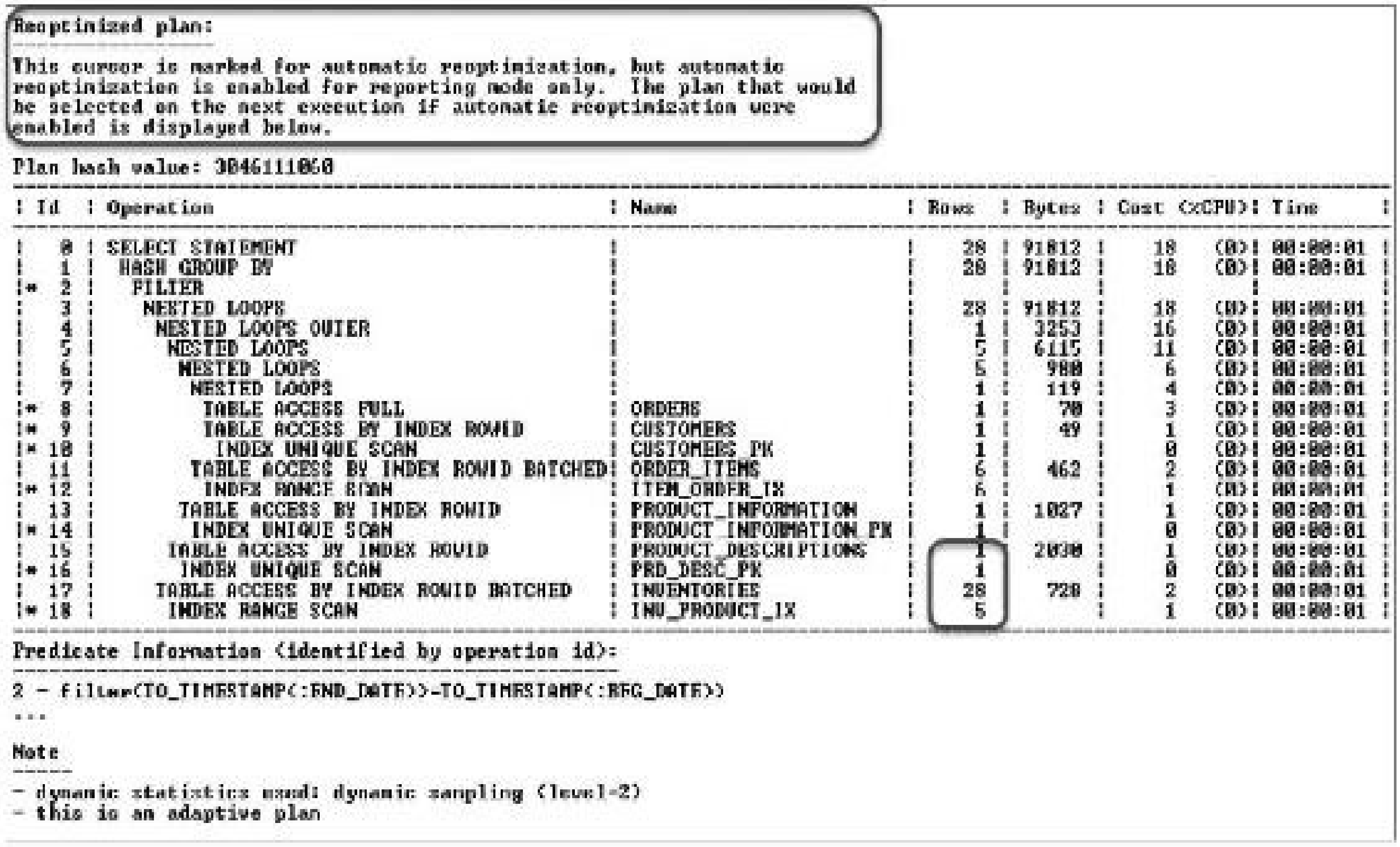
Plan hash value: 2360993264

------------------------------------------------------------------------------------------------------------------
|   Id  | Operation                                  | Name                       | Rows  | Bytes | Cost (%CPU)| Time     |
------------------------------------------------------------------------------------------------------------------
|     0 | SELECT STATEMENT                           |                            |       |       |    29 (100)|          |
|     1 |  HASH GROUP BY                             |                            |   100 |  320K|    29   (0)| 00:00:01 |
|  *  2 |   FILTER                                   |                            |       |       |            |          |
|  *  3 |    HASH JOIN                               |                            |   100 |  320K|    29   (0)| 00:00:01 |
|     4 |     TABLE ACCESS FULL                      | INVENTORIES                |  1112 | 28912 |     3   (0)| 00:00:01 |
|- *  5 |     HASH JOIN OUTER                        |                            |    26 | 84570 |    26   (0)| 00:00:01 |
|     6 |      NESTED LOOPS OUTER                    |                            |    26 | 84570 |    26   (0)| 00:00:01 |
|-    7 |       STATISTICS COLLECTOR                 |                            |       |       |            |          |
|  *  8 |        HASH JOIN                           |                            |    13 | 15899 |    13   (0)| 00:00:01 |
|-    9 |         NESTED LOOPS                       |                            |    13 | 15899 |    13   (0)| 00:00:01 |
|-   10 |          STATISTICS COLLECTOR              |                            |       |       |            |          |
|  * 11 |           HASH JOIN                        |                            |    13 |  2548 |     8   (0)| 00:00:01 |
|    12 |            NESTED LOOPS                    |                            |       |       |            |          |
|    13 |             NESTED LOOPS                   |                            |     2 |   238 |     5   (0)| 00:00:01 |
|  * 14 |              TABLE ACCESS BY INDEX ROWID BATCHED| CUSTOMERS             |     2 |    98 |     2   (0)| 00:00:01 |
|  * 15 |               INDEX RANGE SCAN             | CUST_LNAME_IX              |     2 |       |     1   (0)| 00:00:01 |
|  * 16 |              INDEX RANGE SCAN              | ORD_CUSTOMER_IX            |     1 |       |     1   (0)| 00:00:01 |
|  * 17 |             TABLE ACCESS BY INDEX ROWID    | ORDERS                     |     1 |    70 |     2   (0)| 00:00:01 |
|    18 |            TABLE ACCESS FULL               | ORDER_ITEMS                |   665 | 51205 |     3   (0)| 00:00:01 |
|-   19 |          TABLE ACCESS BY INDEX ROWID       | PRODUCT_INFORMATION        |     1 |  1027 |     5   (0)| 00:00:01 |
|- * 20 |           INDEX UNIQUE SCAN                | PRODUCT_INFORMATION_PK     |       |       |            |          |
|    21 |         TABLE ACCESS FULL                  | PRODUCT_INFORMATION        |   288 |  288K|     5   (0)| 00:00:01 |
|    22 |       TABLE ACCESS BY INDEX ROWID          | PRODUCT_DESCRIPTIONS       |     2 |  4060 |     1   (0)| 00:00:01 |
|  * 23 |        INDEX UNIQUE SCAN                   | PRD_DESC_PK                |     1 |       |     0   (0)|          |
|- * 24 |      TABLE ACCESS FULL                     | PRODUCT_DESCRIPTIONS       |     2 |  4060 |     1   (0)| 00:00:01 |
------------------------------------------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
2 - filter(TO_TIMESTAMP(:END_DATE)>=TO_TIMESTAMP(:BEG_DATE))
          ...
Note
-----
- dynamic statistics used: dynamic sampling (level=2)
- this is an adaptive plan (rows marked '-' are inactive)

Adaptive plan:
--------------
This cursor has an adaptive plan, but adaptive plans are enabled for
reporting mode only.  The plan that would be executed if adaptive plans
were enabled is displayed below.
```

FIGURE 8-6. *Format parameters +ADAPTIVE and +REPORT of DBMS_XPLAN.DISPLAY_CURSOR*

The +REPORT parameter also shows any reoptimization changes or improvements on statistics. In Figure 8-6, the default estimated rows for the INVENTORY table were at 1112. This is probably the reason for the optimizer choosing the hash join method. However, the actual statistics sampled during the execution shows that only 28 rows from the INVENTORY table will be returned, so the optimizer switched to using the nested loops join method instead, which should be substantially better (see Figure 8-7).



```
Reoptimized plan:
-----------------
This cursor is marked for automatic reoptimization, but automatic
reoptimization is enabled for reporting mode only.  The plan that would
be selected on the next execution if automatic reoptimization were
enabled is displayed below.

Plan hash value: 3046111060
---------------------------------------------------------------------------------------------------------
| Id  | Operation                               | Name                       | Rows  | Bytes | Cost (%CPU)| Time     |
---------------------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                        |                            |    28 | 91812 |    18   (0)| 00:00:01 |
|   1 |  HASH GROUP BY                          |                            |    28 | 91812 |    18   (0)| 00:00:01 |
|*  2 |   FILTER                                |                            |       |       |            |          |
|   3 |    NESTED LOOPS                         |                            |    28 | 91812 |    18   (0)| 00:00:01 |
|   4 |     NESTED LOOPS OUTER                  |                            |     1 |  3253 |    16   (0)| 00:00:01 |
|   5 |      NESTED LOOPS                       |                            |     5 |  6115 |    11   (0)| 00:00:01 |
|   6 |       NESTED LOOPS                      |                            |     5 |   980 |     6   (0)| 00:00:01 |
|   7 |        NESTED LOOPS                     |                            |     1 |   119 |     4   (0)| 00:00:01 |
|*  8 |         TABLE ACCESS FULL               | ORDERS                     |     1 |    70 |     3   (0)| 00:00:01 |
|*  9 |         TABLE ACCESS BY INDEX ROWID     | CUSTOMERS                  |     1 |    49 |     1   (0)| 00:00:01 |
|* 10 |          INDEX UNIQUE SCAN              | CUSTOMERS_PK               |     1 |       |     0   (0)| 00:00:01 |
|  11 |        TABLE ACCESS BY INDEX ROWID BATCHED| ORDER_ITEMS              |     6 |   462 |     2   (0)| 00:00:01 |
|* 12 |         INDEX RANGE SCAN                | ITEM_ORDER_IX              |     6 |       |     1   (0)| 00:00:01 |
|  13 |       TABLE ACCESS BY INDEX ROWID       | PRODUCT_INFORMATION        |     1 |  1027 |     1   (0)| 00:00:01 |
|* 14 |        INDEX UNIQUE SCAN                | PRODUCT_INFORMATION_PK     |     1 |       |     0   (0)| 00:00:01 |
|  15 |      TABLE ACCESS BY INDEX ROWID        | PRODUCT_DESCRIPTIONS       |     1 |  2030 |     1   (0)| 00:00:01 |
|* 16 |       INDEX UNIQUE SCAN                 | PRD_DESC_PK                |     1 |       |     0   (0)| 00:00:01 |
|  17 |     TABLE ACCESS BY INDEX ROWID BATCHED | INVENTORIES                |    28 |   728 |     2   (0)| 00:00:01 |
|* 18 |      INDEX RANGE SCAN                   | INV_PRODUCT_IX             |     5 |       |     1   (0)| 00:00:01 |
---------------------------------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
2 - filter(TO_TIMESTAMP(:END_DATE)>=TO_TIMESTAMP(:BEG_DATE))
...

Note
-----
- dynamic statistics used: dynamic sampling (level=2)
- this is an adaptive plan
```

FIGURE 8-7. *Reoptimized plan*

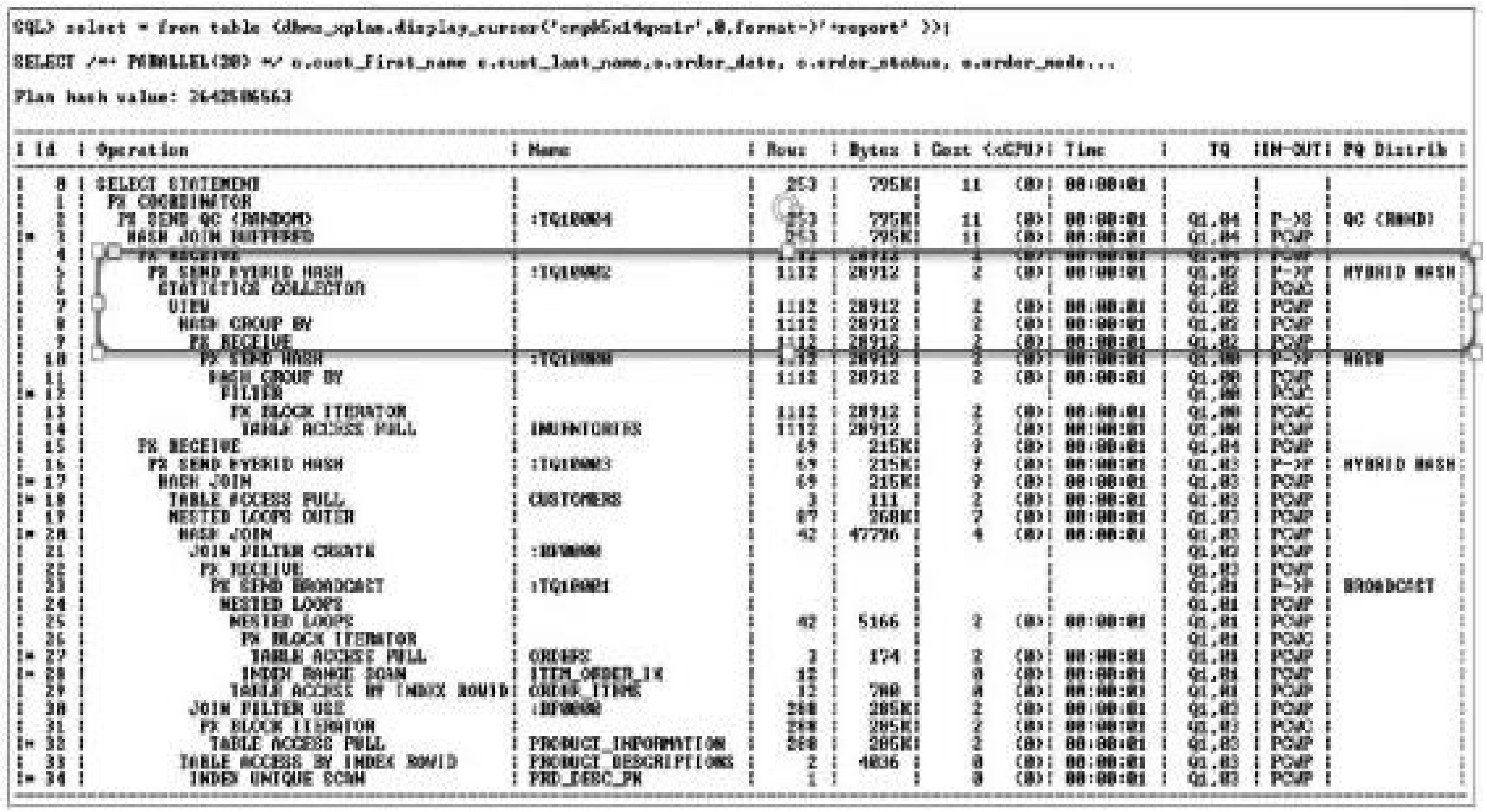
The optimizer is able to change the join method, such as changing a nested loops join to a hash join, on the fly at runtime. The only exception to this rule is when the initial join step is a sort merge join, as there will be no adaptation. This is probably due to the overhead of the sort, as the sampling would be too costly.

EXPLAIN PLAN can still be used with the DBMS_XPLAN.DISPLAY function to show estimated plans. However, you should always check the OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter value, as it may be displaying the adaptive plan when it's actually in reporting-only mode. It's important to know that when viewing adaptive plans in either the V$SQL_PLAN table or Oracle Enterprise Manager, all the steps, both active and inactive, will be shown without distinguishing which steps were actually used. You can, however, tell if the plan has been adapted by looking at the OTHER_XML column in V$SQL_PLAN. If the plan is adaptive, the OTHER_XML column will have an XML tag of `<info type="adaptive_plan">yes</info>`. The best way to see the actual plan is to use the DBMS_XPLAN.DISPLAY_CURSOR function with the +ADAPTIVE format parameter.

The other way a plan can adapt is when a SQL statement is resolved by using a parallel query. The optimizer tries to evenly distribute the number of rows across the number of processes that is has to work with. Historically, the optimizer would look at the number of rows and degree of parallelism (DOP) and then decide how to distribute the data. This often caused problems when there were only a few parallel processes trying to distribute a large number of rows. Also, any data skew could cause unequal distribution and performance issues. In 12*c*, a new Hybrid Hash distribution technique tries to fix those issues. Basically, the optimizer chooses the distribution method at execution time by inserting statistic collectors in front of the parallel processes on the producer side of the operation.

The optimizer will choose the Hybrid Hash distribution method if rows are greater than the threshold or it will choose the Broadcast distribution method if rows are less than the threshold. The threshold is defined as 2 × DOP.

Figure 8-8 shows an example of how the Hybrid Hash distribution works. A hybrid hash does not decide the final data distribution until execution time. The optimizer collects statistics in front of the parallel server processes to check the threshold. Notice that I included a hint so the DOP for our customer query is set to 20. So my threshold is 2 × 20 = 40.



```
SQL> select * from table (dbms_xplan.display_cursor('crp05xl4qpslr',0,format=>'+report' ));

SELECT /*+ PARALLEL(20) */ c.cust_first_name c.cust_last_name,o.order_date, o.order_status, o.order_mode...

Plan hash value: 2642506563

-------------------------------------------------------------------------------------------------------------------------------------------
| Id  | Operation                              | Name                  | Rows  | Bytes | Cost (%CPU)| Time     |    TQ  |IN-OUT| PQ Distrib |
-------------------------------------------------------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                       |                       |   253 |  795K|    11   (0)| 00:00:01 |        |      |            |
|   1 |  PX COORDINATOR                        |                       |       |      |            |          |        |      |            |
|   2 |   PX SEND QC (RANDOM)                  | :TQ10004              |   253 |  795K|    11   (0)| 00:00:01 |  Q1,04 | P->S | QC (RAND)  |
|*  3 |    HASH JOIN BUFFERED                  |                       |   253 |  795K|    11   (0)| 00:00:01 |  Q1,04 | PCWP |            |
|   4 |     PX RECEIVE                         |                       |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,04 | PCWP |            |
|   5 |      PX SEND HYBRID HASH               | :TQ10002              |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,02 | P->P | HYBRID HASH|
|   6 |       STATISTICS COLLECTOR             |                       |       |      |            |          |  Q1,02 | PCWC |            |
|   7 |        VIEW                            |                       |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,02 | PCWP |            |
|   8 |         HASH GROUP BY                  |                       |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,02 | PCWP |            |
|   9 |          PX RECEIVE                    |                       |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,02 | PCWP |            |
|  10 |           PX SEND HASH                 | :TQ10000              |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,00 | P->P | HASH       |
|  11 |            HASH GROUP BY               |                       |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,00 | PCWP |            |
|* 12 |             FILTER                     |                       |       |      |            |          |  Q1,00 | PCWC |            |
|  13 |              PX BLOCK ITERATOR         |                       |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,00 | PCWC |            |
|  14 |               TABLE ACCESS FULL        | INVENTORIES           |  1112 | 28912 |    2   (0)| 00:00:01 |  Q1,00 | PCWP |            |
|  15 |     PX RECEIVE                         |                       |    69 |  215K|     9   (0)| 00:00:01 |  Q1,04 | PCWP |            |
|  16 |      PX SEND HYBRID HASH               | :TQ10003              |    69 |  215K|     9   (0)| 00:00:01 |  Q1,03 | P->P | HYBRID HASH|
|* 17 |       HASH JOIN                        |                       |    69 |  215K|     9   (0)| 00:00:01 |  Q1,03 | PCWP |            |
|* 18 |        TABLE ACCESS FULL               | CUSTOMERS             |     3 |   111 |     2   (0)| 00:00:01 |  Q1,03 | PCWP |            |
|  19 |        NESTED LOOPS OUTER              |                       |    87 |  268K|     7   (0)| 00:00:01 |  Q1,03 | PCWP |            |
|* 20 |         HASH JOIN                      |                       |    42 | 47796 |     4   (0)| 00:00:01 |  Q1,03 | PCWP |            |
|  21 |          JOIN FILTER CREATE            | :BF0000               |       |      |            |          |  Q1,03 | PCWP |            |
|  22 |           PX RECEIVE                   |                       |       |      |            |          |  Q1,03 | PCWP |            |
|  23 |            PX SEND BROADCAST           | :TQ10001              |       |      |            |          |  Q1,01 | P->P | BROADCAST  |
|  24 |             NESTED LOOPS               |                       |       |      |            |          |  Q1,01 | PCWP |            |
|  25 |              NESTED LOOPS              |                       |    42 |  5166 |     3   (0)| 00:00:01 |  Q1,01 | PCWP |            |
|  26 |               PX BLOCK ITERATOR        |                       |       |      |            |          |  Q1,01 | PCWC |            |
|* 27 |                TABLE ACCESS FULL       | ORDERS                |     3 |   174 |     2   (0)| 00:00:01 |  Q1,01 | PCWP |            |
|* 28 |               INDEX RANGE SCAN         | ITEM_ORDER_IX         |    12 |      |     0   (0)| 00:00:01 |  Q1,01 | PCWP |            |
|  29 |              TABLE ACCESS BY INDEX ROWID| ORDER_ITEMS          |    12 |   780 |     0   (0)| 00:00:01 |  Q1,01 | PCWP |            |
|  30 |          JOIN FILTER USE               | :BF0000               |   288 |  285K|     2   (0)| 00:00:01 |  Q1,03 | PCWP |            |
|  31 |           PX BLOCK ITERATOR            |                       |   288 |  285K|     2   (0)| 00:00:01 |  Q1,03 | PCWC |            |
|* 32 |            TABLE ACCESS FULL           | PRODUCT_INFORMATION   |   288 |  285K|     2   (0)| 00:00:01 |  Q1,03 | PCWP |            |
|  33 |         TABLE ACCESS BY INDEX ROWID    | PRODUCT_DESCRIPTIONS  |     2 |  4036 |     0   (0)| 00:00:01 |  Q1,03 | PCWP |            |
|* 34 |          INDEX UNIQUE SCAN             | PRD_DESC_PK           |     1 |      |     0   (0)| 00:00:01 |  Q1,03 | PCWP |            |
-------------------------------------------------------------------------------------------------------------------------------------------
```

FIGURE 8-8. *Hybrid Hash, a new parallel distribution method*

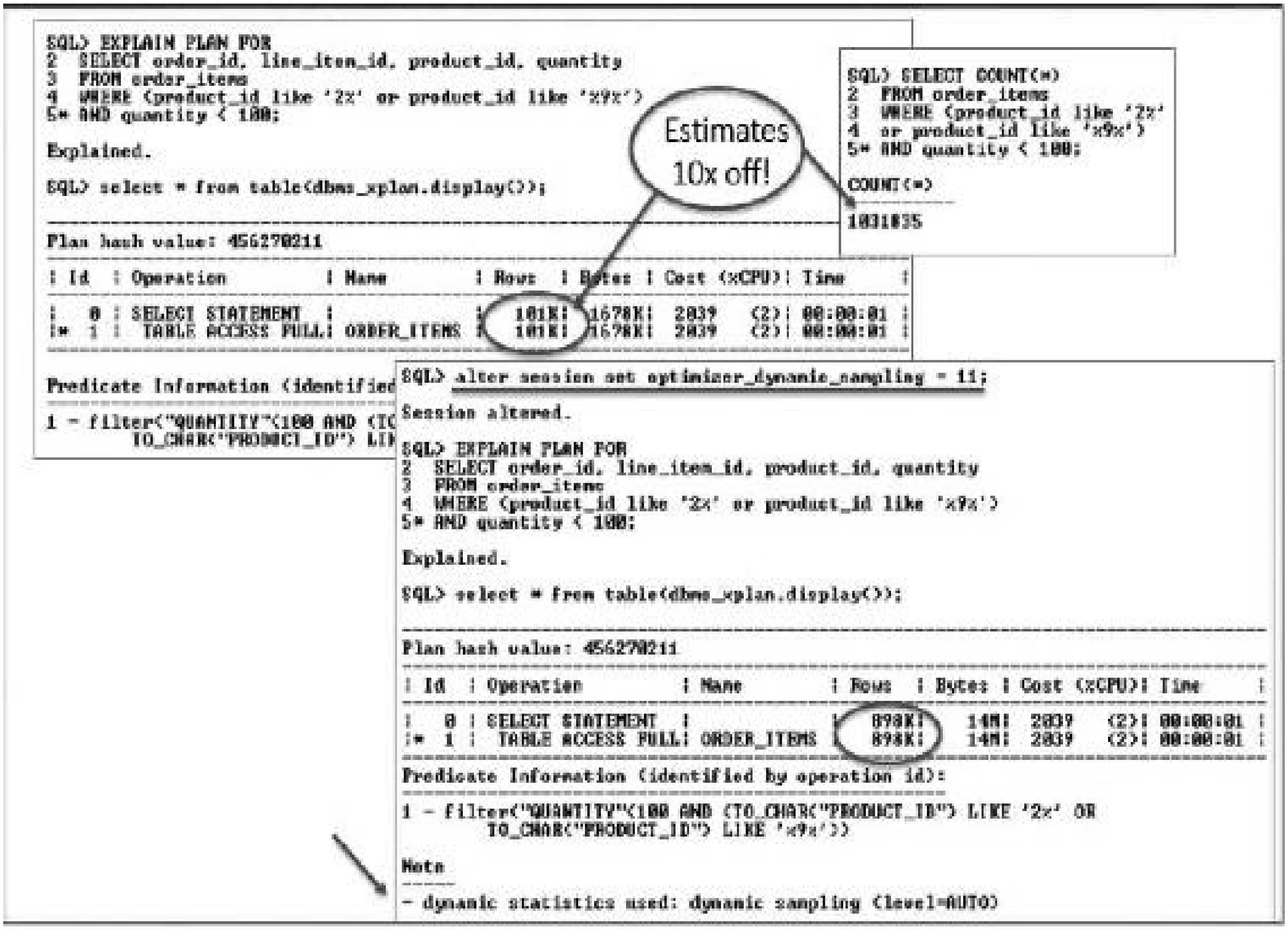
The optimizer chose to use the Hybrid Hash distribution method on the INVENTORIES table because the rows accessed were well over my threshold of 40. Likewise, it chose the Broadcast distribution method when accessing ORDERS and ORDER_ITEMS because they had rows below the threshold.

Adaptive Statistics

The other piece to the Adaptive Query Optimizer is adaptive statistics (refer to Figure 8-2 shown earlier). I've already presented some examples of the optimizer using them, but I'll dive further into all the different aspects of adaptive statistics, including dynamic statistics, automatic reoptimization, and SQL plan directives.

Dynamic Statistics

Dynamic sampling is not a new feature in 12*c*. However, the name has been changed to dynamic statistics because you can instruct the optimizer to automatically decide when to use dynamic statistics for any SQL statement. Historically, if statistics were missing, the optimizer would first sample a few random blocks to get more information. In 12*c*, you can set the initialization parameter OPTIMIZER_DYNAMIC_SAMPLING to a new level, 11. This new level, which can be set either at system or session level, will allow the optimizer to decide whether to use dynamic statistics even if there are base table statistics. The optimizer considers the base table statistics, the complexity of the statement, and the total execution time in order to decide whether to use dynamic statistics or not. This feature could be really useful if your data is rapidly growing and changing at such a pace that statistics get stale very quickly. Figure 8-9 shows a good example of why you would want to use dynamic statistics.



```
SQL> EXPLAIN PLAN FOR
2  SELECT order_id, line_item_id, product_id, quantity
3  FROM order_items
4  WHERE (product_id like '2%' or product_id like '%9%')
5* AND quantity < 100;

Explained.

SQL> select * from table(dbms_xplan.display());

----------------------------------------------------------------------------------
Plan hash value: 456270211
----------------------------------------------------------------------------------
| Id  | Operation          | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
----------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |             |  101K|  1678K|  2039   (2)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| ORDER_ITEMS |  101K|  1678K|  2039   (2)| 00:00:01 |
----------------------------------------------------------------------------------

Predicate Information (identified
-----------------------------------
1 - filter("QUANTITY"<100 AND (TO
       TO_CHAR("PRODUCT_ID") LIK
```

```
SQL> SELECT COUNT(*)
2  FROM order_items
3  WHERE (product_id like '2%'
4  or product_id like '%9%')
5* AND quantity < 100;

COUNT(*)
----------
1031035
```

```
SQL> alter session set optimizer_dynamic_sampling = 11;

Session altered.

SQL> EXPLAIN PLAN FOR
2  SELECT order_id, line_item_id, product_id, quantity
3  FROM order_items
4  WHERE (product_id like '2%' or product_id like '%9%')
5* AND quantity < 100;

Explained.

SQL> select * from table(dbms_xplan.display());

----------------------------------------------------------------------------------
Plan hash value: 456270211
----------------------------------------------------------------------------------
| Id  | Operation          | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
----------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |             |  898K|    14M|  2039   (2)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| ORDER_ITEMS |  898K|    14M|  2039   (2)| 00:00:01 |
----------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
1 - filter("QUANTITY"<100 AND (TO_CHAR("PRODUCT_ID") LIKE '2%' OR
       TO_CHAR("PRODUCT_ID") LIKE '%9%'))

Note
-----
- dynamic statistics used: dynamic sampling (level=AUTO)
```

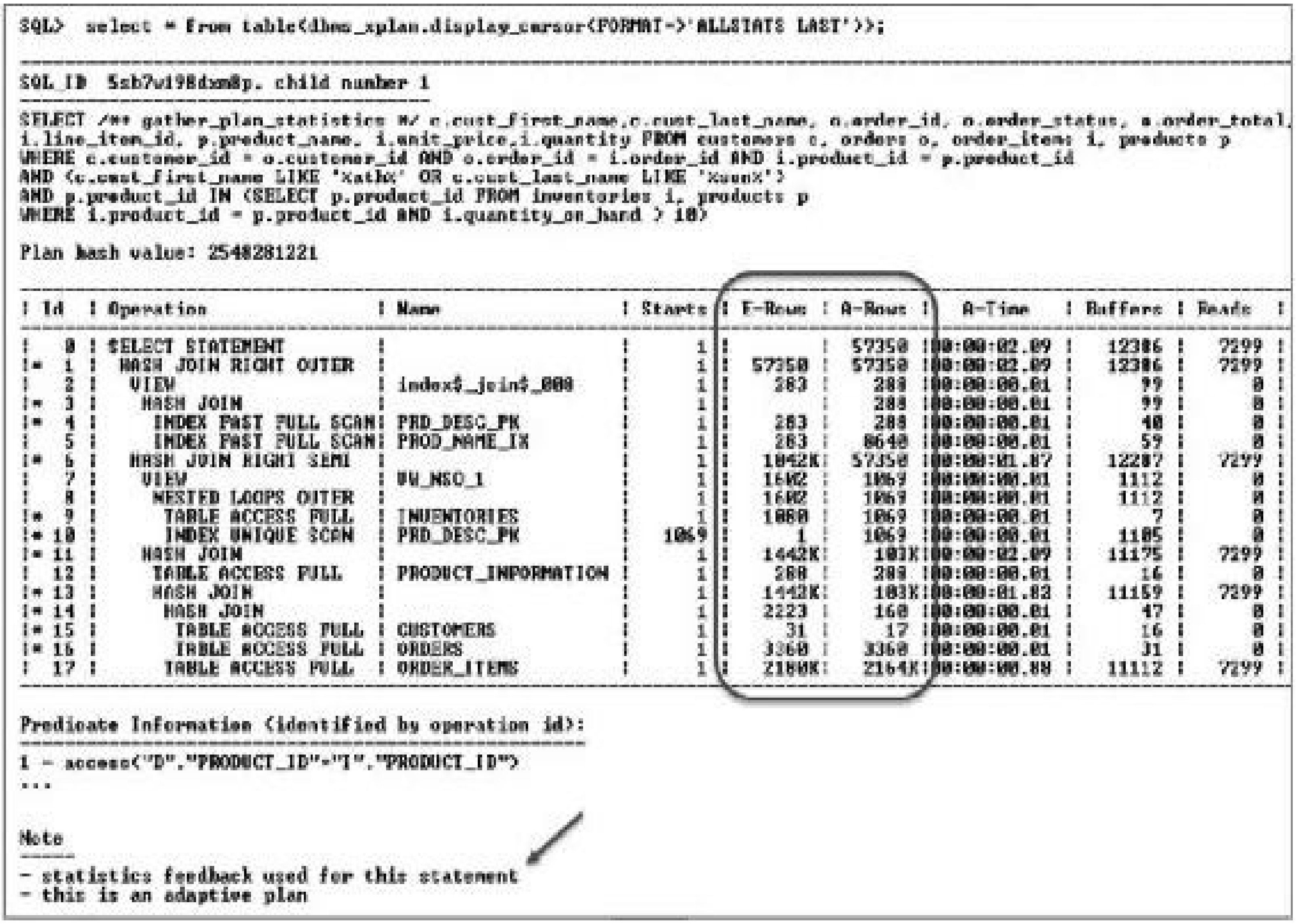
FIGURE 8-9. *Dynamic statistics*

In the example in the upper portion of Figure 8-9, the SELECT statement shows the number of rows returned will be over 1 million. My EXPLAIN PLAN shows that the default plan estimated a little over 101K rows will be returned. This is almost ten times off what is really going to be returned from the table. The bottom of the figure shows how to set the dynamic sampling to level 11. Notice now the optimizer has better statistics at 898K and the sampling level is set to AUTO. It is important to know that parse time will take longer when you have dynamic sampling set to AUTO or level 11. However, the results are often persisted in cache as dynamic statistics or as a SQL plan directive that can be used for other "like" or similar queries. We'll get into more detail on SQL plan directives in a few pages.

Automatic Reoptimization

I briefly discussed automatic reoptimization in the context of adaptive plans. However, automatic reoptimization differs from adaptive plans in that reoptimization changes the plan after the first execution, not during it. The optimizer uses the information gathered during the execution and compares it with the default estimates. If they differ significantly, then the plan will be reoptimized on the next run. Sometimes, the optimizer will store the new information gathered as a 'SQL plan directive' so other similar queries can benefit from the information. Or it will store an OPT_ESTIMATE hint in V$SQL_REOPTIMIZATION_HINTS for future reference. The optimizer can reoptimize a query several times by using statistics feedback or performance feedback to change the plan.

Statistics Feedback Statistics feedback is used when estimated cardinalities are wrong. This can be due to missing or inaccurate statistics or complex predicates, or if there are multiple (and/or) filter predicates on a table. Also, the optimizer will use statistics feedback if the predicates contain complex operations for which the optimizer can't compute any estimates. Figure 8-10 shows an example of how statistics feedback works. For this example, the DBMS_XPLAN format parameter ALLSTATS LAST is used in conjunction with the GATHER_PLAN_STATISTICS hint to show the estimated rows versus the actual rows returned in each step.



```
SQL>  select * from table(dbms_xplan.display_cursor(FORMAT=>'ALLSTATS LAST'));

----------------------------------------------------------------------------------------------------------------
SQL_ID  5sb7wi98dxm8p, child number 1
-------------------------------------
SELECT /*+ gather_plan_statistics */ c.cust_first_name,c.cust_last_name, o.order_id, o.order_status, o.order_total,
i.line_item_id, p.product_name, i.unit_price,i.quantity FROM customers c, orders o, order_items i, products p
WHERE c.customer_id = o.customer_id AND o.order_id = i.order_id AND i.product_id = p.product_id
AND (c.cust_first_name LIKE '%ath%' OR c.cust_last_name LIKE '%son%')
AND p.product_id IN (SELECT p.product_id FROM inventories i, products p
WHERE i.product_id = p.product_id AND i.quantity_on_hand > 10)

Plan hash value: 2548281221

----------------------------------------------------------------------------------------------------------------
| Id  | Operation                 | Name                | Starts | E-Rows | A-Rows |   A-Time   | Buffers | Reads  |
----------------------------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT          |                     |      1 |        |  57350 |00:00:02.09 |   12386 |   7299 |
|*  1 |  HASH JOIN RIGHT OUTER    |                     |      1 |  57350 |  57350 |00:00:02.09 |   12386 |   7299 |
|   2 |   VIEW                    | index$_join$_008    |      1 |    283 |    288 |00:00:00.01 |      99 |      0 |
|*  3 |    HASH JOIN              |                     |      1 |        |    288 |00:00:00.01 |      99 |      0 |
|*  4 |     INDEX FAST FULL SCAN| PRD_DESC_PK         |      1 |    283 |    288 |00:00:00.01 |      40 |      0 |
|   5 |     INDEX FAST FULL SCAN| PROD_NAME_IX        |      1 |    283 |   8640 |00:00:00.01 |      59 |      0 |
|*  6 |   HASH JOIN RIGHT SEMI    |                     |      1 |  1042K |  57350 |00:00:01.87 |   12287 |   7299 |
|   7 |    VIEW                   | VW_NSO_1            |      1 |   1602 |   1069 |00:00:00.01 |    1112 |      0 |
|   8 |     NESTED LOOPS OUTER    |                     |      1 |   1602 |   1069 |00:00:00.01 |    1112 |      0 |
|*  9 |      TABLE ACCESS FULL    | INVENTORIES         |      1 |   1080 |   1069 |00:00:00.01 |       7 |      0 |
|* 10 |      INDEX UNIQUE SCAN    | PRD_DESC_PK         |   1069 |      1 |   1069 |00:00:00.01 |    1105 |      0 |
|* 11 |    HASH JOIN              |                     |      1 |  1442K |   103K|00:00:02.09 |   11175 |   7299 |
|  12 |     TABLE ACCESS FULL     | PRODUCT_INFORMATION |      1 |    288 |    288 |00:00:00.01 |      16 |      0 |
|* 13 |     HASH JOIN             |                     |      1 |  1442K |   103K|00:00:01.83 |   11159 |   7299 |
|* 14 |      HASH JOIN            |                     |      1 |   2223 |    160 |00:00:00.01 |      47 |      0 |
|* 15 |       TABLE ACCESS FULL   | CUSTOMERS           |      1 |     31 |     17 |00:00:00.01 |      16 |      0 |
|* 16 |       TABLE ACCESS FULL   | ORDERS              |      1 |   3360 |   3360 |00:00:00.01 |      31 |      0 |
|  17 |      TABLE ACCESS FULL    | ORDER_ITEMS         |      1 |  2180K |  2164K|00:00:00.88 |   11112 |   7299 |
----------------------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

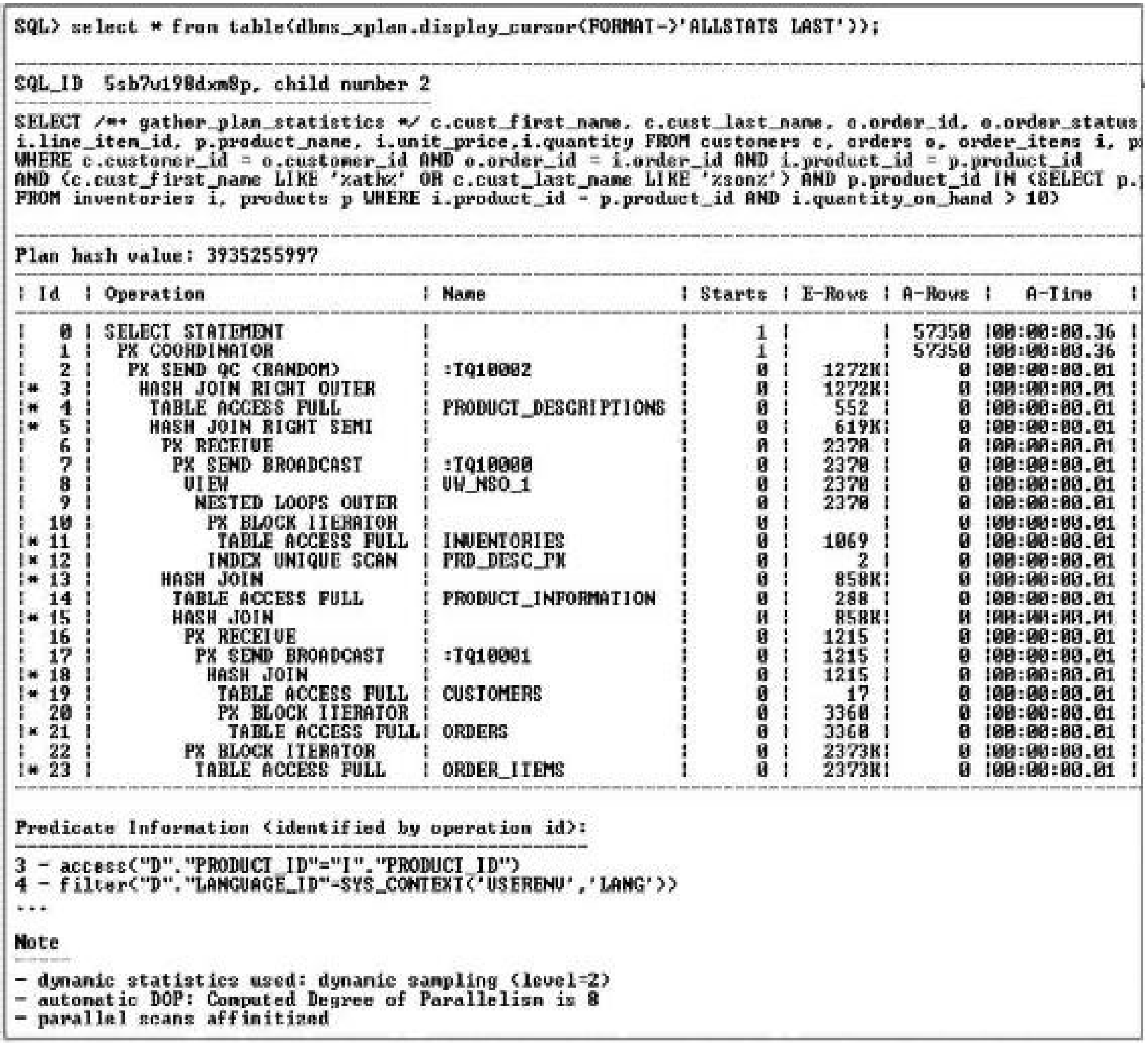
1 - access("D"."PRODUCT_ID"="I"."PRODUCT_ID")
...

Note
-----
- statistics feedback used for this statement
- this is an adaptive plan
```

FIGURE 8-10. *Statistics feedback*

In this example, notice how far off the default estimates are. In step 6 alone, the estimated number of rows read is 1042K, when in reality only 57,350 rows are needed. The optimizer realizes this discrepancy and uses statistics feedback to further optimize it.

Performance Feedback Performance feedback is another part of reoptimization that deals with parallel queries. The initialization parameter PARALLEL_DEGREE_POLICY needs to be set to ADAPTIVE before the optimizer will use this feature. On the first execution, the optimizer decides whether to execute the statement in parallel and then decides the degree of parallelism (DOP) based on estimates. After the first run, the optimizer compares the DOP chosen with the DOP based on the actual execution. If they differ significantly, the statement will be marked for reparse and the actual performance statistics (e.g., CPU time) will be stored as feedback for subsequent executions. Basically, the optimizer looks at the CPU time it took and compares that with the value of the parameter PARALLEL_MIN_TIME_THRESHOLD. If the PARALLEL_DEGREE_POLICY parameter is not set to ADAPTIVE, statistics feedback can still be used to change the DOP. Figure 8-11 shows an example of performance feedback. Notice that the notes section shows that it computed the degree of parallelism.



```
SQL> select * from table(dbms_xplan.display_cursor(FORMAT->'ALLSTATS LAST'));

------------------------------------------------------------------------------------------------
SQL_ID  5sb7u190dxm8p, child number 2
-------------------------------------
SELECT /*+ gather_plan_statistics */ c.cust_first_name, c.cust_last_name, o.order_id, o.order_status
i.line_item_id, p.product_name, i.unit_price,i.quantity FROM customers c, orders o, order_items i, p
WHERE c.customer_id = o.customer_id AND o.order_id = i.order_id AND i.product_id = p.product_id
AND (c.cust_first_name LIKE '%ath%' OR c.cust_last_name LIKE '%son%') AND p.product_id IN (SELECT p.
FROM inventories i, products p WHERE i.product_id = p.product_id AND i.quantity_on_hand > 10)

------------------------------------------------------------------------------------------------
Plan hash value: 3935255997
------------------------------------------------------------------------------------------------
| Id  | Operation                   | Name                 | Starts | E-Rows | A-Rows |   A-Time   |
------------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT            |                      |      1 |        |  57350 |00:00:00.36 |
|   1 |  PX COORDINATOR             |                      |      1 |        |  57350 |00:00:00.36 |
|   2 |   PX SEND QC (RANDOM)       | :TQ10002             |      0 |   1272K|      0 |00:00:00.01 |
|*  3 |    HASH JOIN RIGHT OUTER    |                      |      0 |   1272K|      0 |00:00:00.01 |
|*  4 |     TABLE ACCESS FULL       | PRODUCT_DESCRIPTIONS |      0 |    552 |      0 |00:00:00.01 |
|*  5 |     HASH JOIN RIGHT SEMI    |                      |      0 |    619K|      0 |00:00:00.01 |
|   6 |      PX RECEIVE             |                      |      0 |   2370 |      0 |00:00:00.01 |
|   7 |       PX SEND BROADCAST     | :TQ10000             |      0 |   2370 |      0 |00:00:00.01 |
|   8 |        VIEW                 | VW_NSO_1             |      0 |   2370 |      0 |00:00:00.01 |
|   9 |         NESTED LOOPS OUTER  |                      |      0 |   2370 |      0 |00:00:00.01 |
|  10 |          PX BLOCK ITERATOR  |                      |      0 |        |      0 |00:00:00.01 |
|* 11 |           TABLE ACCESS FULL | INVENTORIES          |      0 |   1069 |      0 |00:00:00.01 |
|* 12 |          INDEX UNIQUE SCAN  | PRD_DESC_PK          |      0 |      2 |      0 |00:00:00.01 |
|* 13 |      HASH JOIN              |                      |      0 |    858K|      0 |00:00:00.01 |
|  14 |       TABLE ACCESS FULL     | PRODUCT_INFORMATION  |      0 |    288 |      0 |00:00:00.01 |
|* 15 |       HASH JOIN             |                      |      0 |    858K|      0 |00:00:00.01 |
|  16 |        PX RECEIVE           |                      |      0 |   1215 |      0 |00:00:00.01 |
|  17 |         PX SEND BROADCAST   | :TQ10001             |      0 |   1215 |      0 |00:00:00.01 |
|* 18 |          HASH JOIN          |                      |      0 |   1215 |      0 |00:00:00.01 |
|* 19 |           TABLE ACCESS FULL | CUSTOMERS            |      0 |     17 |      0 |00:00:00.01 |
|  20 |           PX BLOCK ITERATOR |                      |      0 |   3360 |      0 |00:00:00.01 |
|* 21 |            TABLE ACCESS FULL| ORDERS               |      0 |   3360 |      0 |00:00:00.01 |
|  22 |        PX BLOCK ITERATOR    |                      |      0 |   2373K|      0 |00:00:00.01 |
|* 23 |         TABLE ACCESS FULL   | ORDER_ITEMS          |      0 |   2373K|      0 |00:00:00.01 |
------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

3 - access("D"."PRODUCT_ID"="I"."PRODUCT_ID")
4 - filter("D"."LANGUAGE_ID"=SYS_CONTEXT('USERENV','LANG'))
...

Note
-----
- dynamic statistics used: dynamic sampling (level=2)
- automatic DOP: Computed Degree of Parallelism is 8
- parallel scans affinitized
```

FIGURE 8-11. *Performance feedback*

SQL Plan Directives

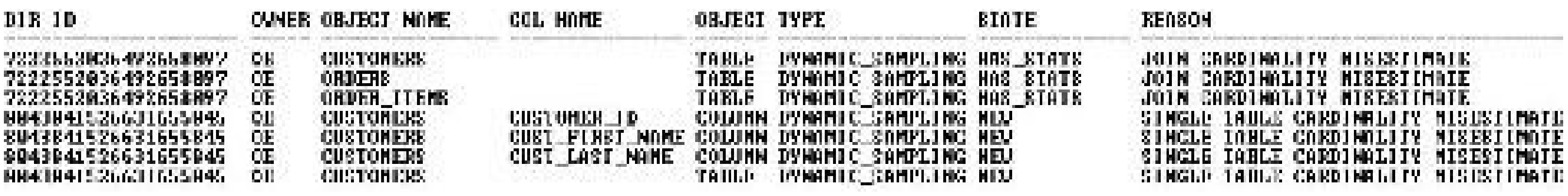
As mentioned earlier, automatic reoptimization sometimes stores additional discovered statistics so the optimizer can use that extra information for other queries. It stores them in two new tables, DBA_SQL_PLAN_DIRECTIVES and DBA_SQL_PLAN_DIR_OBJECTS. The tables contain additional instructions for missing column group statistics (i.e., extended statistics) or data skew in join columns. Column group statistics are used for related columns, such as the CITY, STATE, and ZIP columns in a CUSTOMER table, for example. The optimizer can make much more intelligent choices if it knows only a few column combinations can occur. A SQL plan directive will direct the optimizer to gather dynamic statistics for better cardinality estimates and, hopefully, a better plan.

Other queries that contain the same query expression can also benefit from the SQL plan directive. In my example, a SQL plan directive on the CUSTOMER table for CITY, STATE, and ZIP would direct the optimizer to gather dynamic statistics on every SQL statement that references those columns in the WHERE clause. It's important to note that the directive will be used until there is a supported column group statistic or histogram created with DBMS_STATS. If the optimizer finds significant data skew within the combination of columns, it will automatically create the column group statistic or histogram.

However, I think it's important to keep an eye on the number of directives you have in your database, as they can give clues to problems with current statistics-gathering methods. The following query can be used to view all the directives under the example schema of 'OE':

```
SELECT TO_CHAR(d.directive_id) dir_id,
       o.owner, o.object_name, o.subobject_namecol_name,
       o.object_type, d.type,d.state,d.reason
FROM   dba_sql_plan_directives d, dba_sql_plan_dir_objects o
WHERE  d.directive_id = o.directive_id
AND    o.owner IN ('OE', 'HR') ORDER BY 1,2,3,4,5;
```

The SQL plan directive 7222552036492658097 in Figure 8-12 has identified a join cardinality misestimate for the CUSTOMERS, ORDERS, and ORDER_ITEMS tables. The optimizer will use dynamic statistics when these three tables are joined. The next directive, 8043841522631655845, has identified a column group of CUSTOMER_ID, CUST_FIRST_NAME, and CUST_LAST_NAME. We could create extended statistics for this column group using DBMS_STATS so this directive is no longer needed.



```
DIR_ID              OWNER OBJECT_NAME    COL_NAME        OBJECT TYPE             STATE       REASON
------------------- ----- -------------- --------------- ------ ---------------- ----------- ------------------------------------
7222552036492658097 OE    CUSTOMERS                      TABLE  DYNAMIC_SAMPLING HAS_STATS   JOIN CARDINALITY MISESTIMATE
7222552036492658097 OE    ORDERS                         TABLE  DYNAMIC_SAMPLING HAS_STATS   JOIN CARDINALITY MISESTIMATE
7222552036492658097 OE    ORDER_ITEMS                    TABLE  DYNAMIC_SAMPLING HAS_STATS   JOIN CARDINALITY MISESTIMATE
8043841522631655845 OE    CUSTOMERS      CUSTOMER_ID     COLUMN DYNAMIC_SAMPLING NEW         SINGLE TABLE CARDINALITY MISESTIMATE
8043841522631655845 OE    CUSTOMERS      CUST_FIRST_NAME COLUMN DYNAMIC_SAMPLING NEW         SINGLE TABLE CARDINALITY MISESTIMATE
8043841522631655845 OE    CUSTOMERS      CUST_LAST_NAME  COLUMN DYNAMIC_SAMPLING NEW         SINGLE TABLE CARDINALITY MISESTIMATE
8043841522631655845 OE    CUSTOMERS                      TABLE  DYNAMIC_SAMPLING NEW         SINGLE TABLE CARDINALITY MISESTIMATE
```

FIGURE 8-12. *SQL plan directives*

The database manages SQL plan directives in a shared pool and periodically writes them (every 15 minutes) to the SYSAUX tablespace. If a directive is not used for 53 weeks, it is deleted from the tables by default. A new system package, DBMS_SPD, can be used to manually manage SQL plan directives. Please note that you can't manually create directives; you can only alter, drop, change settings, or stage them for moving to other databases. There is also a command to flush the directives out of the SGA. This can be especially useful when testing.

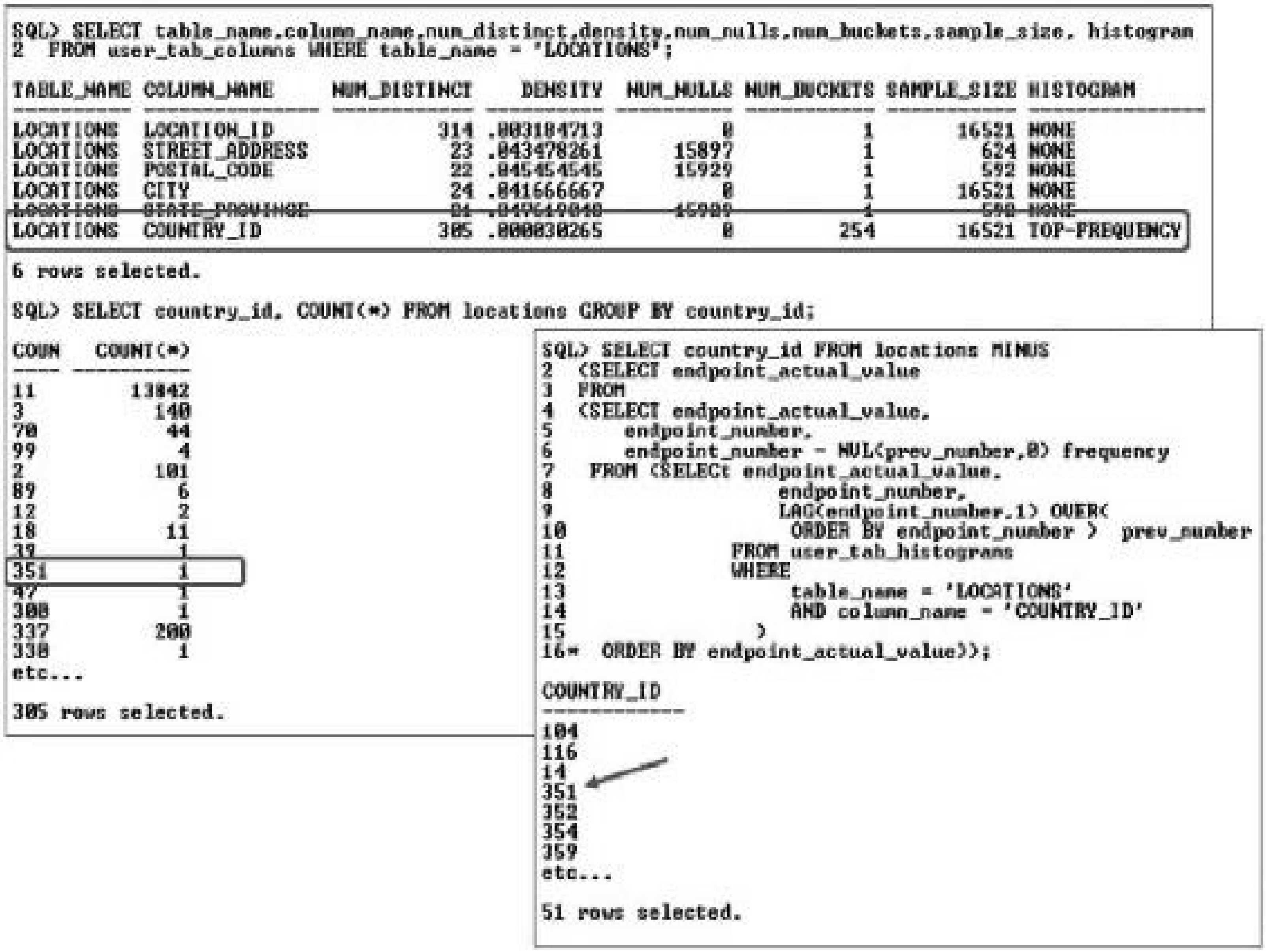
Following is an example of dropping all directives for the example schema OE. The PL/SQL loops through all the directives in the two tables and runs the DBMS_SPD.DROP_SQL_PLAN_DIRECTIVE procedure.

```
BEGIN
FOR get_rec in (SELECT distinct TO_CHAR(d.directive_id) dir_id
                FROM dba_sql_plan_directives d, dba_sql_plan_dir_objects o
                WHERE d.directive_id = o.directive_id
                AND o.owner in ('OE')) LOOP
DBMS_SPD.DROP_SQL_PLAN_DIRECTIVE(get_rec.dir_id);
END LOOP;
END;
```

Oracle 12*c* Changes in Statistics Gathering and Two New Histograms

In Oracle 12*c*, basic statistics are now gathered during index CREATE TABLE AS (CTAS) and INSERT AS SELECT (IAS) operations. During these operations, the optimizer has to read the data anyway, so it might as well capture the statistics at the same time. Statistics are also gathered for global temporary tables at the session level to improve costing information.

In addition, there are two new types of histograms, Top-Frequency and Hybrid. In previous versions, there were only two types of histograms: Frequency, where the number of distinct values (NDVs) had to be less than or equal to 254, and Height Balanced, where NDVs were greater than 254. These histograms didn't work very well if you had some values that were more popular than others. The Top-Frequency histogram fixes this if you have greater than 254 NDVs but only a few of these values take up most of the rows. Top-Frequency will ignore the unpopular values and store only the popular values in the histogram. Figure 8-13 shows that the table, LOCATIONS, has a Top-Frequency histogram on the COUNTRY_ID column.



```
SQL> SELECT table_name,column_name,num_distinct,density,num_nulls,num_buckets,sample_size, histogram
2  FROM user_tab_columns WHERE table_name = 'LOCATIONS';

TABLE_NAME COLUMN_NAME      NUM_DISTINCT    DENSITY  NUM_NULLS NUM_BUCKETS SAMPLE_SIZE HISTOGRAM
---------- ---------------- ------------ ---------- ---------- ----------- ----------- ---------------
LOCATIONS  LOCATION_ID               314 .003184713          0           1       16521 NONE
LOCATIONS  STREET_ADDRESS             23 .043478261      15897           1         624 NONE
LOCATIONS  POSTAL_CODE                22 .045454545      15929           1         592 NONE
LOCATIONS  CITY                       24 .041666667          0           1       16521 NONE
LOCATIONS  STATE_PROVINCE             21 .047619048      15909           1         598 NONE
LOCATIONS  COUNTRY_ID                305 .000030265          0         254       16521 TOP-FREQUENCY

6 rows selected.

SQL> SELECT country_id, COUNT(*) FROM locations GROUP BY country_id;

COUN   COUNT(*)
---- ----------
11        13842
3           140
70           44
99            4
2           101
89            6
12            2
18           11
39            1
351           1
47            1
300           1
337         200
338           1
etc...

305 rows selected.
```

```
SQL> SELECT country_id FROM locations MINUS
2  (SELECT endpoint_actual_value
3  FROM
4  (SELECT endpoint_actual_value,
5      endpoint_number,
6      endpoint_number - NVL(prev_number,0) frequency
7   FROM (SELECT endpoint_actual_value,
8                endpoint_number,
9                LAG(endpoint_number,1) OVER(
10                 ORDER BY endpoint_number )  prev_number
11           FROM user_tab_histograms
12           WHERE
13                 table_name = 'LOCATIONS'
14                 AND column_name = 'COUNTRY_ID'
15           )
16*  ORDER BY endpoint_actual_value));

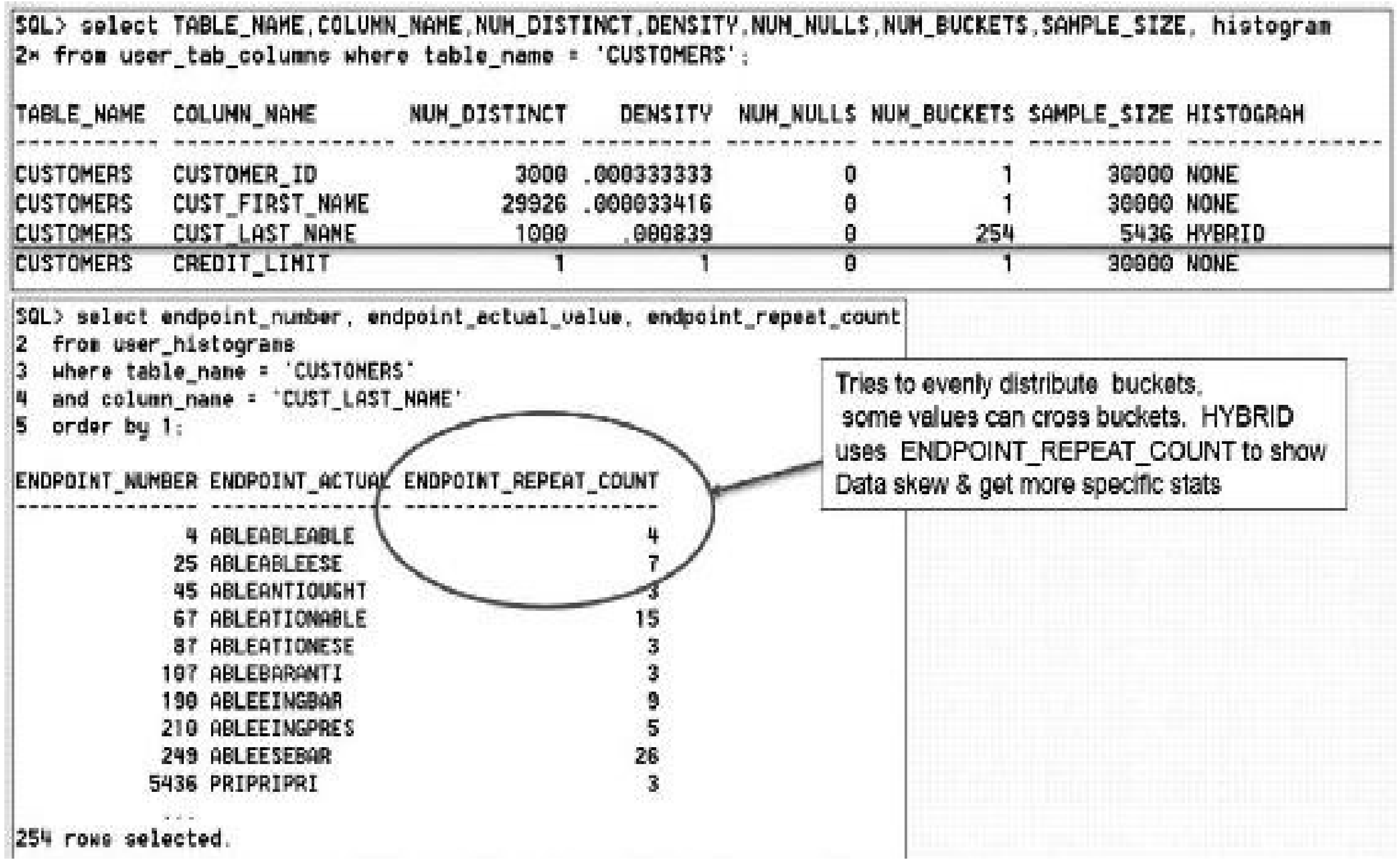
COUNTRY_ID
------------
104
116
14
351
352
354
359
etc...

51 rows selected.
```

FIGURE 8-13. *Top-Frequency histogram*

On further inspection, we can see that there are 305 distinct values for COUNTRY_ID, but many of them are unpopular. Therefore, the Top-Frequency histogram can fit the popular values into 254 buckets and ignore the 51 rows that statistically won't make a difference. Notice that by selecting the COUNTRY_ID values from the LOCATION table that are *not* in the histogram, we can see that value 351 is being ignored.

The Hybrid histogram is similar to the Height Balanced histogram (which is deprecated in 12*c*) in that it deals with NDVs that are far greater than 254 buckets. In the Height Balanced histogram, endpoints often crossed buckets, especially if you had a mix of popular values and unpopular values. This often led to many different distinct values in one bucket, which rendered the histogram ineffective. The new Hybrid histogram (see Figure 8-14) stores the frequency of the endpoints instead of letting the endpoints run over into multiple buckets. It can get more endpoints into the buckets, thus giving the optimizer more information about the data skew.



```
SQL> select TABLE_NAME,COLUMN_NAME,NUM_DISTINCT,DENSITY,NUM_NULLS,NUM_BUCKETS,SAMPLE_SIZE, histogram
2* from user_tab_columns where table_name = 'CUSTOMERS';

TABLE_NAME  COLUMN_NAME        NUM_DISTINCT    DENSITY  NUM_NULLS NUM_BUCKETS SAMPLE_SIZE HISTOGRAM
----------- ------------------ ------------ ---------- ---------- ----------- ----------- ---------------
CUSTOMERS   CUSTOMER_ID                3000 .000333333          0           1       30000 NONE
CUSTOMERS   CUST_FIRST_NAME           29926 .000033416          0           1       30000 NONE
CUSTOMERS   CUST_LAST_NAME             1000    .000839          0         254        5436 HYBRID
CUSTOMERS   CREDIT_LIMIT                  1          1          0           1       30000 NONE
```

```
SQL> select endpoint_number, endpoint_actual_value, endpoint_repeat_count
2  from user_histograms
3  where table_name = 'CUSTOMERS'
4  and column_name = 'CUST_LAST_NAME'
5  order by 1;

ENDPOINT_NUMBER ENDPOINT_ACTUAL ENDPOINT_REPEAT_COUNT
--------------- --------------- ---------------------
              4 ABLEABLEABLE                        4
             25 ABLEABLEESE                         7
             45 ABLEANTIOUGHT                       3
             67 ABLEATIONABLE                      15
             87 ABLEATIONESE                        3
            107 ABLEBARANTI                         3
            190 ABLEEINGBAR                         9
            210 ABLEEINGPRES                        5
            249 ABLEESEBAR                         26
           5436 PRIPRIPRI                           3
            ...
254 rows selected.
```

Tries to evenly distribute buckets, some values can cross buckets. HYBRID uses ENDPOINT_REPEAT_COUNT to show Data skew & get more specific stats

FIGURE 8-14. *Hybrid histogram*

Figure 8-14 shows an example of a Hybrid histogram on the CUST_LAST_NAME column with 1000 distinct values stored in 254 buckets. Notice that ENDPOINT_REPEAT_COUNT contains the number of rows containing the same last name.

It's important to note that the new histograms will only be created if you use DBMS_STATS.GATHER_*_STATS with AUTO_SAMPLE_SIZE (the default) turned on.

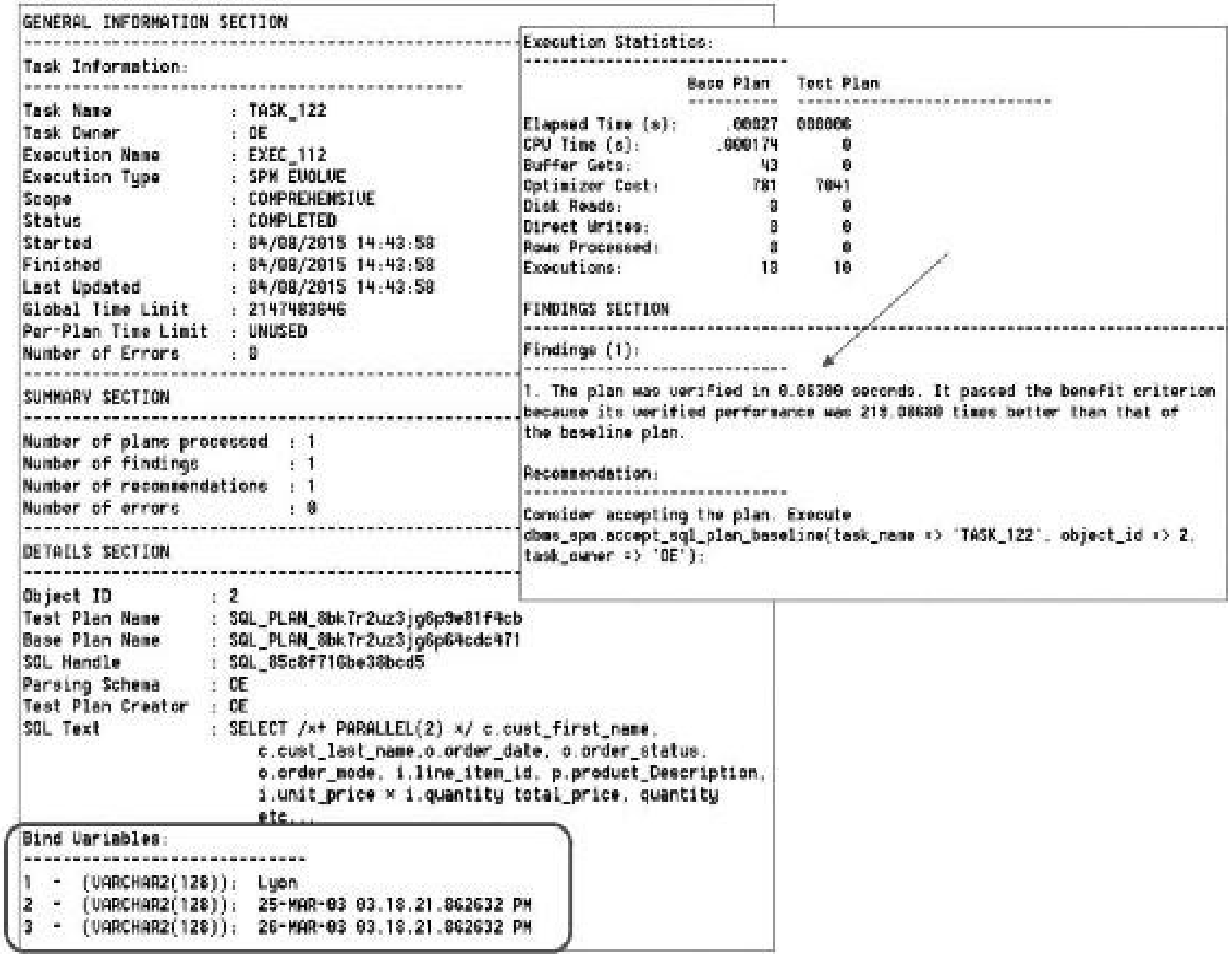
Oracle 12*c* Changes in SQL Plan Management

SQL Plan Management (SPM) was introduced to help stop performance regression caused by bad plan changes. Basically it involves using baselines to compare any new plan against the existing baseline to make sure that only new plans that perform better (1.5 times greater) can be used. The only change in 12*c* is there is now a nightly task called SYS_AUTO_SPM_EVOLVE_TASK that will automatically run against nonaccepted plans and decide whether to evolve them or not. The DBA can then view a report of the automatic changes via a new function in DBMS_SPM called REPORT_AUTO_EVOLVE_TASK. Please note that the old way of evolving plans has been deprecated…although it's still listed in the package and still works.

The following example shows the new way to manually evolve a plan using tasks. The CREATE_EVOLVE_TASK function takes the SQL_HANDLE in DBA_SQL_PLAN_BASELINES and creates a task name. The EXECUTE_EVOLVE_TASK function then evaluates the new plan and the IMPLEMENT_EVOLVE_TASK function marks it as accepted or not. Notice that I forced this plan to be accepted. The optimizer doesn't automatically evolve plans where the performance isn't 1.5 times greater than the existing baseline. I found that some plans, while not meeting this criteria, can and do improve performance, so careful consideration should be given when forcing a plan to be accepted.

```
var task varchar2(1000);
var evolve varchar2(100);
varimple varchar2(1000);
varrptclob;
exec :task := DBMS_SPM.CREATE_EVOLVE_TASK(sql_handle=>'&sql_handle');
exec :evolve := DBMS_SPM.EXECUTE_EVOLVE_TASK(task_name=>:task);
exec :imple:=DBMS_SPM.IMPLEMENT_EVOLVE_TASK
(task_name=>:task,FORCE=>true);
exec :rpt :=DBMS_SPM.REPORT_EVOLVE_TASK
(task name=>:task,type=>'TEXT', execution name=>:evolve);
print
```

The REPORT_EVOLVE_TASK function lists information about the evolution and whether it passed or failed in accepting the plan as a new baseline. In Figure 8-15, we can see the values of the bind variables and review its findings and recommendations. Since I forced this plan to be accepted, the recommendation already happened.



```
GENERAL INFORMATION SECTION
---------------------------------------------------------
Task Information:
---------------------------------------------
Task Name              : TASK_122
Task Owner             : OE
Execution Name         : EXEC_112
Execution Type         : SPM EVOLVE
Scope                  : COMPREHENSIVE
Status                 : COMPLETED
Started                : 04/08/2015 14:43:58
Finished               : 04/08/2015 14:43:58
Last Updated           : 04/08/2015 14:43:58
Global Time Limit      : 2147483646
Per-Plan Time Limit    : UNUSED
Number of Errors       : 0
---------------------------------------------------------
SUMMARY SECTION
---------------------------------------------------------
Number of plans processed  : 1
Number of findings         : 1
Number of recommendations  : 1
Number of errors           : 0
---------------------------------------------------------
DETAILS SECTION
---------------------------------------------------------
Object ID            : 2
Test Plan Name       : SQL_PLAN_8bk7r2uz3jg6p9e81f4cb
Base Plan Name       : SQL_PLAN_8bk7r2uz3jg6p64cdc471
SQL Handle           : SQL_85c8f716be38bcd5
Parsing Schema       : OE
Test Plan Creator    : OE
SQL Text             : SELECT /*+ PARALLEL(2) */ c.cust_first_name,
                          c.cust_last_name,o.order_date, o.order_status,
                          o.order_mode, i.line_item_id, p.product_Description,
                          i.unit_price * i.quantity total_price, quantity
                          etc...
Bind Variables:
-----------------------------
1  -  (VARCHAR2(128)):  Lyon
2  -  (VARCHAR2(128)):  25-MAR-03 03.18.21.862632 PM
3  -  (VARCHAR2(128)):  26-MAR-03 03.18.21.862632 PM
```

```
Execution Statistics:
-----------------------------
                      Base Plan   Test Plan
                      ---------   ----------------------------
Elapsed Time (s):        .00027   000006
CPU Time (s):           .000174        0
Buffer Gets:                 43        0
Optimizer Cost:             781     7041
Disk Reads:                   0        0
Direct Writes:                0        0
Rows Processed:               0        0
Executions:                  10       10

FINDINGS SECTION
---------------------------------------------------------------------------------
Findings (1):
-----------------------------
1. The plan was verified in 0.06300 seconds. It passed the benefit criterion
because its verified performance was 219.08680 times better than that of
the baseline plan.

Recommendation:
-----------------------------
Consider accepting the plan. Execute
dbms_spm.accept_sql_plan_baseline(task_name => 'TASK_122', object_id => 2,
task_owner => 'OE');
```

FIGURE 8-15. *SQL Plan Management evolution report*

To turn off the nightly automated task to automatically evolve and accept new baselines, you can run the following commands:

```
SELECT parameter_name,parameter_value
FROM   dba_advisor_parameters
WHERE  task_name ='SYS_AUTO_SPM_EVOLVE_TASK'
AND    parameter_name = 'ACCEPT_PLANS';

execdbms_spm.set_evolve_task_parameter  ('SYS_AUTO_SPM_EVOLVE_TASK','ACCEPT_
PLANS','false');
```

Oracle Automatic SQL Tuning

Oracle introduced the SQL Tuning Advisor to help DBAs and developers improve the performance of

SQL statements (note that you must purchase the Diagnostics Pack). A component of the SQL Tuning Advisor is the Automatic SQL Tuning Adviser, which includes statistics analysis, SQL profiling, access path analysis, and SQL structure analysis. The SQL Tuning Advisor uses input from the ADDM, from resource-intensive SQL statements captured by the AWR, from the cursor cache, or from SQL Tuning Sets. Oracle has extended the SQL Tuning Advisor by adding additional features such as SQL Replay (also a cost option), Automatic SQL Tuning, SQL Statistics Management, and SQL Plan Management.

Since this chapter is focused on query tuning, I'll describe how to pass specific SQL to the SQL Tuning Advisor in the form of a SQL Tuning Set, and then I'll cover the Automatic SQL Tuning Advisor and SQL Performance Analysis (SQL Replay). The Oracle recommended interface for the SQL Tuning Advisor is Oracle Enterprise Manager (see Chapter 5), but you can use the Application Programming Interfaces (APIs) via the command line in SQL*Plus. I cover the command-line session so you can better understand the analysis procedure for a single query. This section is only a small glance into the functionality of the SQL Tuning Advisor. You also have the capability to create SQL Tuning Sets and SQL profiles and to transport SQL Tuning Sets from one database to another.

Ensuring the Tuning User Has Access to the APIs

The following privileges needed to access the API should be restricted to authorized users in a production environment (with proper licensing). The privileges are granted by SYS. The ADMINISTER SQL TUNING SET privilege allows a user to access only his or her own tuning sets.

```
GRANT ADMINISTER SQL TUNING SET to &TUNING_USER;  -- or
GRANT ADMINISTER ANY SQL TUNING SET to &TUNING_USER;
GRANT ADVISOR TO &TUNING USER;
GRANT CREATE ANY SQL PROFILE TO &TUNING_USER;
GRANT ALTER ANY SQL PROFILE TO &TUNING_USER;
GRANT DROP ANY SQL PROFILE TO &TUNING USER;
```

Creating the Tuning Task

If you want to tune a single SQL statement, for example,

```
select COUNT(*)
from   t2
where  UPPER(owner) = 'RIC';
```

you must first create a tuning task using the DBMS_SQLTUNE package:

```
DECLARE
tuning_task_name VARCHAR2(30);
tuning sqltext CLOB;
BEGIN
tuning_sqltext :='SELECT COUNT(*) '  ||
                 'FROM t2 '  ||
                 'WHERE UPPER(owner) = :owner';
tuning_task_name := DBMS_SQLTUNE.CREATE_TUNING_TASK(
          sql_text =>tuning_sqltext,
        bind list  =>sql binds(anydata.ConvertVarchar2(100)),

         user_name => 'RIC',
           scope   => 'COMPREHENSIVE',
      time_limit  => 60,
       task_name  => 'first_tuning_task13',
      description => 'Tune T2 count');
END;
/
```

Making Sure the Task Can Be Seen in the Advisor Log

To see the task, query the USER_ADVISOR log:

```
select task_name
from   user_advisor_log;

TASK_NAME
--------------------
first_tuning_task13
```

Executing the SQL Tuning Task

To execute the tuning task, you use the DBMS_SQLTUNE package, as shown here:

```
BEGIN
DBMS_SQLTUNE.EXECUTE_TUNING_TASK(task_name => 'first_tuning_task13' );
END;
/
```

Checking Status of the Tuning Task

To see the specific tuning task, query the USER_ADVISOR log:

```
select status
from   user_advisor_tasks
where  task_name = 'first_tuning_task13';

STATUS
---------
COMPLETED
```

Displaying the SQL Tuning Advisor Report

To see the SQL Tuning Advisor Report, you also use the DBMS_SQLTUNE package:

```
SET LONG 8000
SET LONGCHUNKSIZE 8000
SET LINESIZE 100
SET PAGESIZE 100

select dbms_sqltune.report_tuning_task('first_tuning_task13')
from   dual;
```

Reviewing the Report Output

The report output shown next is lengthy, but it essentially recommends creating a function-based index on the OWNER column of table T2. Had the SQL Tuning Advisor recommended the use of a SQL profile, this could have been accepted by using the DBMS_SQLTUNE.ACCEPT_SQL_PROFILE package.

```
DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
------------------------------------------------------------------------------
GENERAL INFORMATION SECTION
------------------------------------------------------------------------------
Tuning Task Name                  : first_tuning_task13
Tuning Task Owner                 : RIC
Workload Type                     : Single SQL Statement
Scope                             : COMPREHENSIVE
Time Limit(seconds)               : 60
Completion Status                 : COMPLETED
Started at                        : 11/20/2010 20:49:56
Completed at                      : 11/20/2010 20:49:56
Number of Index Findings          : 1
Number of SQL Restructure Findings: 1

DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Schema Name: RIC
SQL ID     : 8ubrqzjkkyj3g
SQL Text   : SELECT COUNT(*) FROM t2 WHERE UPPER(owner) = 'RIC'
--------------------------------------------------------------------------------
FINDINGS SECTION (2 findings)
--------------------------------------------------------------------------------
1- Index Finding (see explain plans section below)

DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
--------------------------------------------------------------------------------
---------------------------------------------------------
The execution plan of this statement can be improved by creating one or more
indices.

Recommendation (estimated benefit: 100%)
-----------------------------------------
Consider running the Access Advisor to improve the physical schema design
or creating the recommended index.
create index RIC.IDX$$_00CF0001 on RIC.T2(UPPER('OWNER'));

Rationale
```

```
DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
--------------------------------------------------------------------------------
  Creating the recommended indexes significantly improves the execution plan
  of this statement. However, it might be preferable to run "Access Advisor"
  using a representative SQL workload as opposed to a single statement. This
  will allow Oracle to get comprehensive index recommendations which takes into
  account index maintenance overhead and additional space consumption.

2- Restructure SQL finding (see plan 1 in explain plans section)
----------------------------------------------------------------
The predicate UPPER("T2"."OWNER")='RIC' used at line ID 2 of the execution
plan contains an expression on indexed column "OWNER". This expression

DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
--------------------------------------------------------------------------------
prevents the optimizer from selecting indices on table "RIC"."T2".

Recommendation
--------------
- Rewrite the predicate into an equivalent form to take advantage of
indices. Alternatively, create a function-based index on the expression.

Rationale
---------
The optimizer is unable to use an index if the predicate is an inequality
condition or if there is an expression or an implicit data type conversion

DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
--------------------------------------------------------------------------------
on the indexed column.

--------------------------------------------------------------------------------
EXPLAIN PLANS SECTION
--------------------------------------------------------------------------------
1- Original
-----------
Plan hash value: 1374435053
--------------------------------------------------------------------------------
DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
--------------------------------------------------------------------------------
| Id | Operation            | Name  | Rows  | Bytes | Cost (%CPU) |Time     |
--------------------------------------------------------------------------------
|  0 | SELECT STATEMENT     |       |   1   |  6    |  4049   (3)  |00:00:49 |
|  1 |  SORT AGGREGATE      |       |   1   |  6    |              |         |
|* 2 |  INDEX FAST FULL SCAN| T2_I1 | 26097 | 152K  |  4049   (3)  |00:00:49 |
--------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
2 - filter(UPPER("OWNER")='RIC')

DBMS_SQLTUNE.REPORT_TUNING_TASK('FIRST_TUNING_TASK13')
```

```
-------------------------------------------------------------------------------

2- Using New Indices
--------------------
Plan hash value: 2206416184

-------------------------------------------------------------------------------------
| Id | Operation          | Name             | Rows    Bytes |Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT   |                  |   1       6   |524   (2)  | 00:00:07|
|  1 |  SORT AGGREGATE    |                  |   1       6   |
|* 2 |  INDEX RANGE SCAN  | IDX$$_0JCF0001   |  237K   1390K|524   (2)  | 00:00:07|
```

Tuning SQL Statements Automatically Using SQL Tuning Advisor

Oracle’s Automatic SQL Tuning Advisor analyzes Automatic Workload Repository data to find high-load SQL statements that have been executed repeatedly. Oracle then uses the SQL Tuning Advisor to tune those statements, creates SQL profiles, if needed, and tests them thoroughly. If the advisor thinks implementing the SQL profile is beneficial, it automatically implements those profiles. No intervention is needed. The Automatic SQL Tuning Advisor runs during the normal maintenance window. The DBA can then run reports against those recommendations and validate those SQL profiles.

Enabling Automatic SQL Tuning Advisor

The following procedure is used to enable the Automatic SQL Tuning Advisor:

```
BEGIN
DBMS_AUTO_TASK_ADMIN.ENABLE(client_name => 'sql tuning advisor',  operation =>
  NULL,  window_name => NULL);
END;
/
```

Configuring Automatic SQL Tuning Advisor

To query what is currently set for the Automatic SQL Tuning Advisor, run the following query:

```
select parameter_name, parameter_value
from   dba_advisor_parameters
where  task_name = 'SYS_AUTO_SQL_TUNING_TASK'
and    parameter_name IN ('ACCEPT_SQL_PROFILES',
                   'MAX_SQL_PROFILES_PER_EXEC',
                   'MAX_AUTO_SQL_PROFILES');

PARAMETER_NAME                 PARAMETER_VALUE
------------------------------ ------------------------------
ACCEPT_SQL_PROFILES            FALSE
MAX_SQL_PROFILES_PER_EXEC      20
MAX_AUTO_SQL_PROFILES          10000
```

Now change SQL_PROFILE parameters as follows:

```
SQL> CONNECT / AS SYSDBA

BEGIN
 DBMS_SQLTUNE.set_tuning_task_parameter(
 task_name => 'SYS_AUTO_SQL_TUNING_TASK',
 parameter => 'ACCEPT_SQL_PROFILES',
 value    => 'TRUE');
END;
/
```

The next step is to force the execution of the task so you see the results immediately:

```
exec dbms_sqltune.execute_tuning_task(task_name=>'SYS_AUTO_SQL_TUNING_TASK');
```

Viewing Automatic SQL Tuning Results

The following procedure reports the most recent run of the Automatic SQL Tuning Advisor:

```
VARIABLE p_report CLOB;
BEGIN
 :p_report :=DBMS_SQLTUNE.report_auto_tuning_task(
  begin_exec   => NULL,
  end_exec     => NULL,
   type        => DBMS_SQLTUNE.type_text,      -- 'TEXT'
  level        => DBMS_SQLTUNE.level_typical, -- 'TYPICAL'
   section     => DBMS_SQLTUNE.section_all,   -- 'ALL'
  object_id    => NULL,
  result_limit => NULL);
END;
```

Print :p_report prints the report and recommendation:

```
Set long 1000000
PRINT :p_report

GENERAL INFORMATION SECTION
-------------------------------------------------------------------------------
Tuning Task Name                 : SYS_AUTO_SQL_TUNING_TASK
Tuning Task Owner                : SYS
Workload Type                    : Automatic High-Load SQL Workload
Execution Count                  : 14
Current Execution                : EXEC_1259
Execution Type                   : TUNE SQL
```

```
Scope                              : COMPREHENSIVE
Global Time Limit(seconds)         : 3600
Per-SQL Time Limit(seconds)        : 1200
Completion Status                  : COMPLETED
Started at                         : 02/03/2011 17:14:17
Completed at                       : 02/03/2011 17:14:27
Number of Candidate SQLs               : 3
Cumulative Elapsed Time of SQL (s)   : 50

-------------------------------------------------------------------------------
SUMMARY SECTION
-------------------------------------------------------------------------------
                 Global SQL Tuning Result Statistics
-------------------------------------------------------------------------------

Number of SQLs Analyzed                      : 3
Number of SQLs in the Report                 : 3
Number of SQLs with Findings                 : 3
Number of SQLs with Statistic Findings       : 3

-------------------------------------------------------------------------------
  SQLs with Findings Ordered by Maximum (Profile/Index) Benefit, Object ID
-------------------------------------------------------------------------------
object ID  SQL ID  statistics profile(benefit) index(benefit) restructure
---------- ------------- ---------- ----------- ----------- ----------- --------
    42 4q8yn4bngw19s    1
    43 fvzwdtr0ywagd    1
     44 5sp4ugqbs4ms8   1

----------------------------------------------------------------------------------
  Objects with Missing/Stale Statistics (ordered by schema, object, type)
----------------------------------------------------------------------------------
Schema Name          Object Name        Type       State Cascade
---------------------------- ---------------------------- ----- ------- -------
               SYS OBJECT_TAB          TABLE MISSING NO

------------------------------------------------------------------------------------
DETAILS SECTION
----------------------------------------------------------------------------------
 Statements with Results Ordered by Maximum (Profile/Index) Benefit, Object ID
----------------------------------------------------------------------------------
Object ID   : 42
Schema Name : SYS
SQL ID      : 4q8yn4bngw19s
SQL Text    : insert into object_tab select * from object_tab

----------------------------------------------------------------------------------
FINDINGS SECTION (1 finding)

1- Statistics Finding
----------------------
 Table "SYS"."OBJECT_TAB" was not analyzed.
 Recommendation
 --------------
 - Consider collecting optimizer statistics for this table.
```

```
   executedbms_stats.gather_table_stats(ownname => 'SYS', tabname =>
           'OBJECT_TAB', estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE,
            method_opt => 'FOR ALL COLUMNS SIZE AUTO');

 Rationale
 ---------
   The optimizer requires up-to-date statistics for the table in order to
   select a good execution plan.

-------------------------------------------------------------------------------
EXPLAIN PLANS SECTION
-------------------------------------------------------------------------------

1- Original
-----------
Plan hash value: 622691728

| Id  | Operation                | Name       | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------
|   0 | INSERT STATEMENT         |            | 4674K|   419M|  7687  (1)| 00:01:33 |
|   1 |  LOAD TABLE CONVENTIONAL | OBJECT_TAB |       |       |            |          |
|   2 |   TABLE ACCESS FULL      | OBJECT_TAB | 4674K|   419M|  7687  (1)| 00:01:33 |
-------------------------------------------------------------------------------------

-------------------------------------------------------------------------------
Object ID  : 43
Schema Name: SYS
SQL ID     : fvzwdtr9ywagd
SQL Text   : select count(*) from object_tab where UPPER(owner)='SYS'

-------------------------------------------------------------------------------
FINDINGS SECTION (1 finding)
-------------------------------------------------------------------------------

1- Statistics Finding
---------------------
 Table "SYS"."OBJECT_TAB" was not analyzed.

 Recommendation
 --------------
 - Consider collecting optimizer statistics for this table.
  executedbms_stats.gather_table_stats(ownname => 'SYS', tabname =>
           'OBJECT_TAB', estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE,
           method_opt => 'FOR ALL COLUMNS SIZE AUTO');

 Rationale
 ---------
   The optimizer requires up-to-date statistics for the table in order to
   select a good execution plan.

-----------------------------------------------------------------------------
EXPLAIN PLANS SECTION
-----------------------------------------------------------------------------

1- Original
-----------
Plan hash value: 2592930531
```

```
--------------------------------------------------------------------------------
-
| Id  | Operation           | Name       | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT    |            |     1 |    17 |  7703   (1)| 00:01:33 |
|   1 |  SORT AGGREGATE     |            |     1 |    17 |            |          |
|*  2 |   TABLE ACCESS FULL| OBJECT_TAB|  2000K|   32M |  7703   (1)| 00:01:33 |
--------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
  2 - filter(UPPER("OWNER")='SYS')

---------------------------------------------------------------------------
Object ID  : 44
Schema Name: SYS
SQL ID     : 5sp4uggbs4ms6
SQL Text   : select count(*) from object_tab where UPPER(owner)='SCOTT'

--------------------------------------------------------------------------
FINDINGS SECTION (1 finding)
--------------------------------------------------------------------------

1- Statistics Finding
---------------------
 Table "SYS"."OBJECT_TAB" was not analyzed.

 Recommendation
 --------------
 - Consider collecting optimizer statistics for this table.
  executedbms_stats.gather_table_stats(ownname => 'SYS', tabname =>
         'OBJECT_TAB', estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE,
       method_opt => 'FOR ALL COLUMNS SIZE AUTO');
 Rationale
 ---------
   The optimizer requires up-to-date statistics for the table in order to
  select a good execution plan.

-----------------------------------------------------------------------------
EXPLAIN PLANS SECTION
-----------------------------------------------------------------------------
1- Original
-----------
Plan hash value: 2592930531
--------------------------------------------------------------------------------
| Id  | Operation           | Name       | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT    |            |     1 |    17 |  7703   (1)| 00:01:33 |
|   1 |  SORT AGGREGATE     |            |     1 |    17 |            |          |
|*  2 |   TABLE ACCESS FULL| OBJECT_TAB|   311 |  5287 |  7703   (1)| 00:01:33 |
--------------------------------------------------------------------------------
Predicate Information (identified by operation id):
---------------------------------------------------
  2 - filter(UPPER("OWNER")='SCOTT')
```

Check the Recommendation sections. The SQL Tuning Advisor has recommended that you collect statistics. Just by running the following statement, you would improve the performance of the problem SQL listed in the SQL Tuning Advisor report:

```
execute dbms_stats.gather_table_stats(ownname => 'SYS', tabname => -
       'OBJECT_TAB', estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE,  -
       method_opt => 'FOR ALL COLUMNS SIZE AUTO');
```

Using SQL Performance Analyzer (SPA)

The concept of SQL Tuning Sets and the SQL Tuning Advisor were introduced in 10*g*. Oracle makes use of SQL Tuning Sets with the SQL Performance Analyzer, often referred to as SPA. The SPA compares the performance of specific SQL statements defined in a particular SQL Tuning Set, before and after a database change. The database change could be a major upgrade, an initialization parameter change, or simply an index or statistics collection change. Chapter 5 covers how to do this in Enterprise Manager. Because this chapter focuses on SQL tuning, this section looks at what the SQL Performance Analyzer can do with queries before and after creating an index. In Chapter 9, I cover more uses for the SPA, especially in database and application upgrades, as well as Real Application Testing and Database Replay. The SPA is a part of Real Application Testing and is not available in the database by default. The use of the SPA and Database Replay requires the Oracle Real Application Testing licensing.

Step 1: Set Up the Testing Environment

For this test, a table is created called OBJECT_TAB, and the table is populated to simulate a decent workload:

```
create table object_tab as
 select *
 from   dba_objects;

insert into object_tab
 select *
 from   object_tab;

commit;
```

The OBJECT_TAB table does not have any indexes; statistics are collected (as displayed here):

```
execdbms stats.gather table stats(USER,'OBJECT TAB',cascade=>TRUE);
```

Next, the shared pool is flushed to clear out SQL statements in memory to get a new workload:

```
alter system flush shared_pool;
```

Step 2: Execute the Queries

Execute the following testing queries:

```
select count(*)
from   object_tab
where  object_id=100;

select  count(*)
from    object_tab
where   object_id<100;

select count(*)
from   object_tab
where  object_id=1000;

select count(*)
from   object_tab
where  object_id<=1000;
```

Later you'll create an index for the OBJECT_ID column and compare the performance of the SQL statement before and after the index is created.

Step 3: Create a SQL Tuning Set

Creating a SQL Tuning Set is done by collecting many SQL statements that you would like to tune into one set. Create a SQL Tuning Set with the following command:

```
execDBMS SQLTUNE.create sqlset(sqlset name=>'sql replay test');
```

Step 4: Load the SQL Tuning Set

The following procedure loads the Tuning Set by obtaining SQL statements from the CURSOR_CACHE that query the OBJECT_TAB table:

```
DECLARE
 l_cursor DBMS_SQLTUNE.sqlset_cursor;
BEGIN
  OPEN l_cursor FOR
  SELECT VALUE(a)
  FROM   TABLE(DBMS_SQLTUNE.select_cursor_cache(
   basic_filter => 'sql_text LIKE ''%object_tab%'' and parsing_schema_name =
   ''SYS''',
    attribute_list => 'ALL')
  ) a;
DBMS_SQLTUNE.load_sqlset(sqlset_name => 'sql_replay_test',populate_cursor=>
l_cursor);
END;
/
```

Step 5: Query from the SQL Tuning Set

Run the following query:

```
select sql_text
from   dba_sqlset_statements
where  sqlset_name = 'sql_replay_test';

SQL_TEXT
-----------------------------------------------------------------
Select count(*) from object_tab where object_id=100;
Select count(*) from object_tab where object_id<100;
Select count(*) from object_tab where object_id=1000;
Select count(*) from object_tab where object_id<=1000;
```

Step 6: Print from the SQL Tuning Set

Print from the SQL Tuning Set and note the TASK ID (record it somewhere for later use):

```
VARIABLE v_task VARCHAR2(64);
EXEC :v_task := DBMS_SQLPA.create_analysis_task(sqlset_name=>'sql_replay_test');
print :v_task
V_TASK

TASK_832
```

Step 7: Execute Before Analysis Task

Execute the contents of the Tuning Set before the database change to gather performance information:

```
BEGIN
  DBMS_SQLPA.execute_analysis_task(task_name => :v_task,execution_type => 'test
 execute',
    execution_name => 'before_change');
END;
/
```

Step 8: Make the Necessary Changes

Add an index that you already know you need to improve performance of the queries in the Tuning Set (and regather statistics):

```
create index object_tab_indx_id on object_tab(object_id);
exec dbms_stats.gather_table_stats(USER,'OBJECT_TAB',cascade=>TRUE);
```

Step 9: Execute after Create Index Analysis Task

```
VARIABLE v_taskVARCHAR2(64);
BEGIN
  DBMS_SQLPA.execute_analysis_task(task_name => 'TASK_832',execution_type =>
 'test execute',
    execution_name => 'after_change');
END;
/
```

Step 10: Execute Compare Analysis Task

```
VARIABLE v_task VARCHAR2(64);
--EXEC :v_task := DBMS_SQLPA.create_analysis_task(sqlset_name =>
'sql_replay_test');
BEGIN
  DBMS_SQLPA.execute_analysis_task( task_name   => 'TASK_832', execution_type  =>
'compare performance',
   execution_params  =>dbms_advisor.arglist(
           'execution_name1',
              'before_change',
              'execution_name2',
              'after_change'));
END;
/
```

Step 11: Print the Final Analysis

```
SET LONG 100000000
SET PAGESIZE 0
SET LINESIZE 200
SET LONGCHUNKSIZE 200
SET TRIMSPOOL ON
spool /tmp/report.txt

SELECT DBMS_SQLPA.report_analysis_task('TASK_832')
from   dual;

spool off
```

Report Output

```
General Information
---------------------------------------------------------------------------------------------

 Task Information:                          Workload Information:
-----------------------------------------  -------------------------------------
 Task Name     : TASK_832                    SQL Tuning Set Name   sql_replay_test
 Task Owner    : SYS                         SQL Tuning Set Owner        : SYS
 Description   :                             Total SQL Statement Count    : 7

Execution Information:
---------------------------------------------------------------------------------------------
 Execution Name        : EXEC_847
 Started               : 02/04/2010 15:57:00
 Execution Type        : COMPARE PERFORMANCE
 Last Updated          : 02/04/2010 15:57:00
 Description           :
 Global Time Limit     : UNLIMITED
 Scope                  : COMPREHENSIVE
 Per-SQL Time Limit : UNUSED
 Status                 : COMPLETED
 Number of Errors    : 0
 Number of Unsupported SQL  : 1

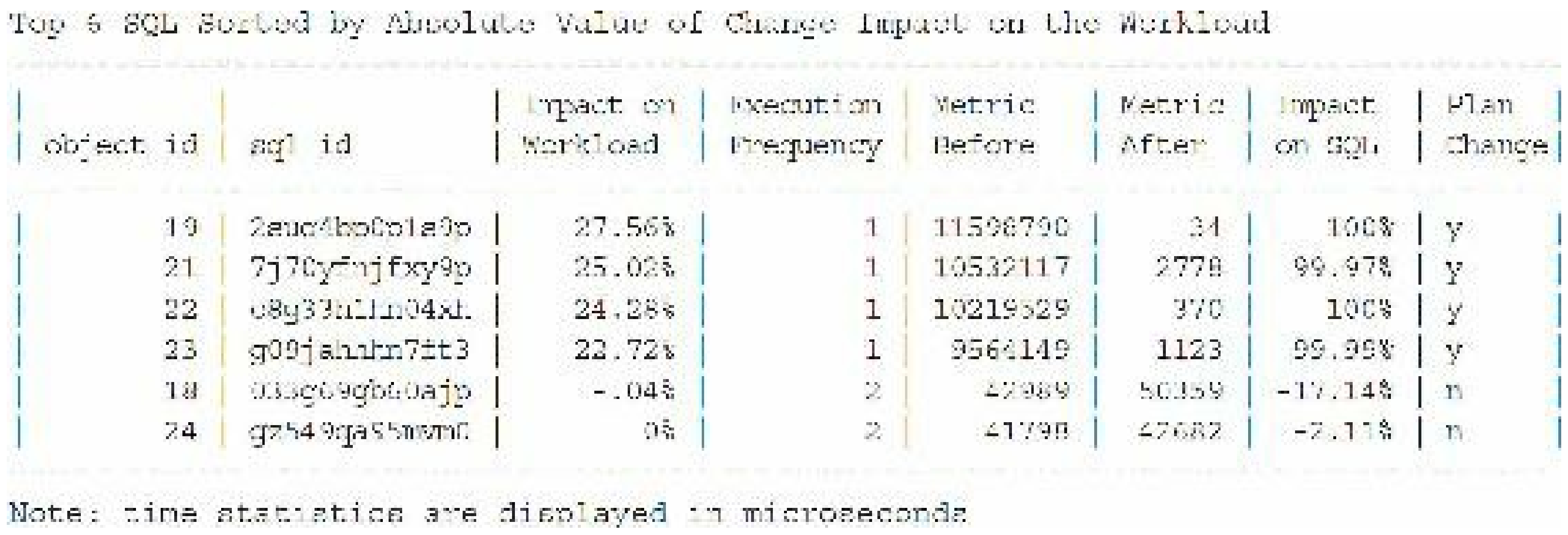
Analysis Information:
------------------------------------------------------------------------------------
---------
 Before Change Execution:                       After Change Execution:
 ---------------------------------------  -----------------------------------
---------
 Execution Name      : before_change        Execution Name      : after_change
 Execution Type      : TEST EXECUTE         Execution Type      : TEST EXECUTE
 Scope               : COMPREHENSIVE        Scope               : COMPREHENSIVE
 Status              : COMPLETED            Status              : COMPLETED
 Started             : 02/04/2010 15:50:08 Started             : 02/04/2010 15:56:13
 Last Updated        : 02/04/2010 15:51:41 Last Updated        : 02/04/2010 15:56:15
 Global Time Limit   : UNLIMITED            Global Time Limit   : UNLIMITED
 Per-SQL Time Limit : UNUSED               Per-SQL Time Limit : UNUSED
 Number of Errors    : 0                    Number of Errors    : 0

 ----------------------------------------------
 Comparison Metric: ELAPSED_TIME
 ----------------------------------------------
 Workload Impact Threshold: 1%
 ----------------------------------------------
 SQL Impact Threshold: 1%
 ----------------------------------------------

Report Summary
------------------------------------------------------------------------------------

Projected Workload Change Impact:
--------------------------------------------
 Overall Impact       :  99.59%
 Improvement Impact  :  99.59%
 Regression Impact   :  0%

SQL Statement Count
--------------------------------------------
 SQL Category  SQL Count  Plan Change Count
 Overall            7              4
 Improved           4              4
 Unchanged          2              0
 Unsupported        1              0
```



```
Top 6 SQL Sorted by Absolute Value of Change Impact on the Workload
------------------------------------------------------------------------------------------------
|           |               | Impact on | Execution | Metric    | Metric | Impact  | Plan   |
| object id | sql id        | Workload  | Frequency | Before    | After  | on SQL  | Change |
------------------------------------------------------------------------------------------------
|        19 | 2auc4bo0o1a9p |    27.56% |         1 |  11598790 |     34 |    100% | y      |
|        21 | 7j70yfnjfxy9p |    25.02% |         1 |  10532117 |   2778 |  99.97% | y      |
|        22 | c8y33h1ln04xh |    24.28% |         1 |  10219329 |    370 |    100% | y      |
|        23 | g09jahhhn7tt3 |    22.72% |         1 |   9564149 |   1123 |  99.99% | y      |
|        18 | 03sg69gb60ajp |     -.04% |         2 |     42989 |  50359 | -17.14% | n      |
|        24 | gz549qa55mvn6 |        0% |         2 |     41798 |  42682 |  -2.11% | n      |
------------------------------------------------------------------------------------------------
Note: time statistics are displayed in microseconds
```

Wow! Overall impact is a positive 99.59 percent! Having viewed the queries, this makes sense. The query accessed a 1.1-million row table, yet only 16 rows satisfied the OBJECT_ID = 100 condition. By adding an index on the OBJECT_ID column, performance is drastically improved!

Tips Review

- In 12*c*, Oracle introduced Adaptive Query Optimization. Now Oracle can change execution plans on the fly from, say, a hash join to a nested loops join based on the dynamic statistics it is collecting as it is executing. It can also use the better execution plan for future executions as well using automatic reoptimization. You can also tune and direct future executions using SQL plan directives.
- Query V$SQLAREA and V$SQL to find problem queries that need to be tuned.
- You can also query V$SQL to find your problem queries that need to be tuned.
- When a small number of rows ("small" is version and hardware dependent, but almost always less than 5 percent and even less than 1 percent at times) are returned to meet a condition in a query, you generally want to use an index on that condition (column), given that the small number of rows also returns a small number of individual blocks (usually the case).
- The first tip concerning slow queries is that you will have a lot of them if you don't index restrictive columns (return a small percentage of the table). Building indexes on restrictive columns is the first step toward better system performance.
- Bad indexes (indexing the wrong columns) can cause as much trouble as forgetting to use indexes on the correct columns. While Oracle's cost-based optimizer generally suppresses poor indexes, problems can still develop when a bad index is used at the same time as a good index. The cost of each index for INSERTs and DELETEs must also be considered when adding many indexes.
- For crucial queries on your system, consider concatenated indexes on the columns contained in both the SELECT and the WHERE clauses so only the index is accessed.
- The INDEX_FFS hint processes *only* the index and does not access the table. All columns that

are used and retrieved by the query *must* be contained in the index.

- When running a query multiple times in succession, it becomes faster because you have now cached the data in memory (although full table scans are aged out of memory quicker than indexed scans). At times, people are tricked into believing that they have actually made a query faster, when in actuality they are accessing data stored in memory. Flushing the buffer cache or restarting the test system can help you get accurate tuning results for comparisons. The next time a user calls and says a query was too slow, just say: *Really? Try running it again*.
- Caching an often-used but relatively small table into memory ensures that the data is not pushed out of memory by other data. Be careful, however—cached tables can alter the execution path normally chosen by the optimizer, leading to an unexpected execution order for the query (for instance, affecting the driving table in nested loop joins).
- If you are executing the same queries over and over (especially grouping or calculation functions), using the RESULT_CACHE hint often makes subsequent queries run faster (at times *very* much faster).
- When multiple indexes on a single table can be used for a query, use the most restrictive index when you need to override an optimizer choice. While Oracle's cost-based optimizer generally forces the use of the most restrictive index, variations will occur, depending on the version of Oracle used, the structure of the query structure, and the initialization parameters that you may use. Fix the larger issue (get rid of bad indexes) if you see this as a trend.
- Bitmap indexes usually behave differently because they are usually much smaller. See Chapter 2 for more information on the differences between bitmap indexes and other indexes.
- At times, modifying the column side of the query can result in the index being suppressed unless a function-based index is used. Oracle *may* also fix this issue during parsing. The more complex the query, the less likely Oracle will fix it.
- Function-based indexes can lead to dramatic performance gains when used to create indexes on functions often used on selective columns in the WHERE clause.
- Oracle has improved the way that it performs the OR clause. The NO_EXPAND hint can still be helpful, as it prevents the optimizer from using OR expansion, as described in Chapter 7.
- Using the nested subquery with an EXISTS clause may make queries dramatically faster, depending on the data being retrieved from each part of the query. Oracle 12*c* *often* makes this translation internally, saving you time and giving you performance gains!
- In 12*c*, adaptive plans help the optimizer make the final plan choice on the first execution of a SQL statement. It accomplishes this by instrumenting the default execution plan with statistic collectors that will be used during execution or on future executions.
- The 12*c* optimizer might change the execution plan during the execution phase if the SQL is long running and the statistic collector exceeds the threshold it expects. This is known as dynamic statistics and the execution plan could change from a nested loops to a hash join based on the new statistics collected while the query is running.
- Most importantly, ensure that you are correctly licensed. Many tuning packs are an extra cost.

Check DBA_FEATURE_USAGE_TABLE to confirm which features you are using.

References

*Oracle Database Performance Tuning Guide 12*c *Release 2 (12.2)* (Oracle Corporation).

Deb Dudek, *DBA Tips, or a Job Is a Terrible Thing to Waste* (TUSC).

*Query Optimization in Oracle9*i*, An Oracle Whitepaper* (Oracle Corporation).

Janis Griffin did the great 12*c* update and additions to this chapter. In the prior edition, Rama Balaji added several new sections and helped with the update for 11*g*. Thanks to Connor McDonald for his feedback on V$SQLAREA. Rob Christensen contributed the major portion of a previous update to this chapter.

CHAPTER

9

Table Joins and Other Advanced Tuning (Advanced DBA and Developer)

With Oracle Database 11*g* and available in 12*c*, Oracle introduced a new option called Real Application Testing. Real Application Testing allows you to capture a complete database workload on one database and replay it on another database. You can replay the exact workload and you even have the option to synchronize workload timing. This tool is very valuable for load testing on a new application release, database patch, or database upgrade. If you need to tune a specific object or set of queries, 12*c* also offers the SQL Performance Analyzer (SPA). This tool provides the ability to examine a SQL workload on a database, record a portion of it based on what you want collected/tested, and then take that workload and examine it in another environment. The new environment can include any database changes (including initialization parameter changes), hardware changes, or environment changes. SPA not only offers a powerful new way to examine the potential impact of change with more predictable results, but also allows the targeting of a specific change while measuring its potential impact.

This chapter was originally the most painful to write due to the complexities of Oracle joins and block level tuning. I've included many examples from Oracle and other products over the years to show different possible tuning patterns and how to solve future patterns. This chapter includes a section that shows how to link tuning to mathematical equations so that you can develop your own tuning theory and compare results for your unique system. This chapter is not *strictly* 12*c* related; rather, it is focused on advanced query tuning concepts, showing the evolution of the Oracle database. Oracle is growing much faster and is truly more of a platform than a database these days.

The driving table or the first table accessed in a query is an important aspect of superior performance. Using the Enterprise Manager Cloud Control Tuning Pack and Automatic Workload Repository (AWR) statistics, Oracle can do a lot to help you tune things (see Chapter 5 for more information). If the optimizer has designated the wrong table as the driving table in a query, the optimizer's choice can be the difference between hours and seconds. Usually, the cost-based optimizer chooses the correct table, but your indexing on tables affects how this works. If you need to change the driving table using a hint on the same table over and over, this symptom often indicates an indexing plan that still needs work. When you have to tune multiple tables using hints, tuning increasing numbers of tables gets progressively harder. With only two or three tables, it's easy enough to use an ORDERED hint (guaranteeing the order of the tables) and then to try variations of the table order until you achieve the fastest outcome. However, a ten-table join has 3,628,800 possible combinations, which makes trying all these combinations slightly time-consuming. Using a LEADING hint (you specify the first or leading table to drive the query with) simplifies this chore, but it is still far more daunting than building the correct indexing scheme in the first place.

One of the greatest challenges of this book was trying to put driving tables into a helpful format for readers, using the EXPLAIN PLAN, AUTOTRACE, and TKPROF. The optimizer's complexity and all the potential paths for joining and optimizing a query can be mind-boggling. Suppressing a single index in a query can affect the driving table, how Oracle joins tables in a query, and how Oracle uses or suppresses other indexes. This chapter focuses on helping you make better decisions when choosing a driving table. Although I have a good understanding of how Oracle performs these complexities, putting that understanding into words was the challenging task for the first half of this chapter. The challenge for the second half was relating performance tuning to mathematical equations.

The tips covered in this chapter include the following:

- Real Application Testing
- Database Replay
- SQL Performance Analyzer
- Join methods
- Table join initialization parameters
- A two-table join: equal-sized tables (cost-based)
- A two-table INDEXED join: equal-sized tables (cost-based)
- Forcing a specific join method
- Eliminating join records (candidate rows) in multitable joins
- A two-table join between a large table and a small table
- Three table joins: not as much fun (cost-based)
- Bitmap join indexes
- Third-party product tuning
- Tuning distributed queries
- When you have everything tuned
- Miscellaneous tuning snippets
- Tuning at the block level (advanced)
- Tuning using Simple Mathematical Techniques

Database Replay (capture/replay)

Database Replay (often referred to as Real Application Testing or capture/replay) is used to capture a database workload on one system and replay it later on a different system and is very useful when comparing two different systems or different versions of Oracle. You can perform Real Application Testing in text mode (covered in this section only as an overview—use the Oracle documentation as your guide if you choose to use this) or through Oracle Enterprise Manager Cloud Control 12c or 13c. It's a great way to test your upgrade to 12*c* (capture on your 10*g*R2+ system and then test it against 12*c*). There is a screenshot of Enterprise Manager Cloud Control running Database Replay in Chapter 5.

To perform Real Application Testing, the basic steps are as follows:

1. Capture workload on a database, from 10*g*R2 or higher.
2. Restore the database on a test system to the SCN when capture begins.
3. Perform the upgrade and make changes to the test system as needed.
4. Preprocess the captured workload if it is not preprocessed.
5. Configure the test system for replay.
6. Replay the workload on the test system (can be synchronized or unsynchronized).
7. Create a report that shows Data, Error, and Performance divergences.

Database Replay is used to replay a workload in a manner that you would like to test. You can have a replay that executes exactly as it was captured or use other Oracle options to replay it in a different manner. Database Replay can be used in command-line mode or through Oracle Enterprise Manager.

Set Up Source Database for Database Replay Capture

As stated earlier, you can utilize database releases prior to 11*g* for capturing a workload for replay on a 12*c* database (as early as 10*g*R2). First, however, some setup is required (see the Oracle notes on this that come with the product).

Prepare to Capture Workload

You need to prepare the source database where you will be capturing the workload for replay.

To create a directory location where the workload capture file can be written:

```
c:\oracle>mkdir dbcapture
```

To create a directory within the source database where the workload will be captured:

```
SQL> create directory dbcapture as 'c:\oracle\dbcapture';
```

Capture the Workload

Prior to executing the workload, you need to initiate the capture.

1. Start the capture process:
```
SQL> exec dbms workload capture.start capture('NRML ACTIVITY', 'DBCAPTURE');
```
2. Run the workload.
3. When complete, or when you have captured the desired workload, stop the capture process:
```
SQL> exec dbms workload capture.finish capture();
```
4. Execute a report on the capture:
```
-- Capture Report
DECLARE
  cap_id              NUMBER;
  cap_rpt             CLOB;
  buffer              VARCHAR2(32767);
  buffer_size         CONSTANT BINARY_INTEGER := 32767;
  amount              BINARY_INTEGER;
  offset              NUMBER(38);
  file_handle         UTL_FILE.FILE_TYPE;
  directory_name      CONSTANT VARCHAR2(80) := 'DBCAPTURE';
  v filename          CONSTANT VARCHAR2(80) := 'Capture.html';
```

```
BEGIN
  cap_id  := DBMS_WORKLOAD_CAPTURE.GET_CAPTURE_INFO(dir=>directory_name);
  cap_rpt := DBMS_WORKLOAD_CAPTURE.REPORT(capture_id => cap_id,
                              format => DBMS_WORKLOAD_CAPTURE.TYPE_HTML);

   -- Write Report to file
   DBMS_OUTPUT.ENABLE(100000);

   -- --------------------------------
   -- OPEN NEW XML FILE IN WRITE MODE
   -- --------------------------------
   file_handle := UTL_FILE.FOPEN(location     => directory_name,
                                 filename     => v_filename,
                                 open mode    => 'w',
                                 max_linesize => buffer_size);

   amount := buffer_size;
   offset := 1;

    WHILE amount >= buffer_size
    LOOP
        DBMS_LOB.READ(lob_loc    => cap_rpt,
                      amount     => amount,
                      offset     => offset,
                      buffer     => buffer);

        offset := offset + amount;

        UTL_FILE.PUT(file      => file_handle,
                     buffer    => buffer);

        UTL_FILE.FFLUSH(file => file_handle);
    END LOOP;

    UTL_FILE.FCLOSE(file => file_handle);
END;
/
```

Prepare the Workload for Replay

The following steps show how to prepare the workload for replay:

1. Create a directory location for the captured workload to be placed in for processing and replay on both the processing database and the replay database if the processing and replay databases are different. Best practice is to process the workload on the same database that will execute the replay.

```
c:\oracle> mkdir replay
```

2. Copy the captured workload files to another directory if on the same host as the database where the workload was captured or to the destination system location to be processed:

```
copy c:\oracle\dbcapture\* c:\oracle\Replay
```

3. Create a directory in the Oracle database that will process the captured workload:

```
SQL> create directory REPLAY as 'c:\oracle\replay';
```

Process the Workload for Replay

This process is resource-intensive. It should, therefore, be done on a nonproduction system. If you capture the workload on your production system, move the capture files to a test or development system to prepare them for replay.

Process the captured workload:

```
SQL> exec dbms_workload_replay.process_capture ('REPLAY');
```

The process creates the following files in the REPLAY directory (and a few others) during the processing of the captured workload (you may also have a subdirectory, which you would need to add to any of the directory locations):

```
wcr_login.pp
WCR_SCN_ORDER.EXTB
WCR_SEQ_DATA.EXTB
WCR_CONN_DATA.EXTB
wcr_process.wmd
```

Prepare to Replay the Workload

Next, you need to prepare the replay database. In the following steps, you prepare the replay database. Keep in mind this is version/system dependent, and there may be variations needed for your system.

1. Go to the database where the replay will be executed if different from the database that processed the workload. If the replay database is the same as the database that processed the workload, skip to Step 3; otherwise, proceed to Step 2.
2. If you have not done so already, go to the "Prepare the Workload for Replay" section, earlier in this chapter, and execute the steps on the database that will replay the workload.
3. Initialize the replay:

```
SQL> exec dbms_workload_replay.initialize_replay ('TEST_REPLAY','REPLAY');
```

4. Prepare for workload replay:

   ```
   SQL> exec dbms_workload_replay.prepare_replay(synchronization=>TRUE);
   ```

5. Calibrate the workload to determine the number of workload replay clients. At the command line, change to the REPLAY directory and calibrate:

   ```
   cd c:\oracle\replay
   c:\oracle\replay> wrc mode=calibrate
   ```

Execute the Workload Replay

Now that the workload has been captured and processed, the workload is ready to be replayed. I suggest using Oracle Enterprise Manager Cloud Control if possible. Follow these steps to execute the workload on the new system:

1. Note the number of workload replay clients indicated in the previous section that you need to execute the processed workload.
2. Open a window for each workload replay client that you will need, as these will each be separate executions. As indicated in the previous step, you only need one client.
3. From the command line, enter the `replay` command with the `wrc` utility for the number of workload replay clients needed, with one command in each window:

   ```
   c:\oracle\proccapture>wrc system/xxxxx@orcl12c replaydir=c:\oracle\replay
   ```

4. Repeat for each of the replay clients needed.
5. AWR information will be available for the time period in which the workload replay was executed. Oracle recommends that the executed workload replay cover at least one complete snap period to provide the most useful data. You can take a snapshot prior to beginning and immediately after the workload execution (this is optional):

   ```
   SQL> execute DBMS_WORKLOAD_REPOSITORY.CREATE_SNAPSHOT ();
   ```

6. From another window, log in to the database where the workload replay will be executed and start the workload replay process. An indication that the workload has been started will appear:

   ```
   SQL> exec dbms_workload_replay.start_replay ;

   PL/SQL procedure successfully completed.
   ```

7. Monitor the workload replay until it is completed.
8. Once the workload replay is complete, take another AWR snapshot (optional):

   ```
   SQL> execute DBMS_WORKLOAD_REPOSITORY.CREATE_SNAPSHOT ();
   ```

9. Execute workload replay report extraction, and evaluate the results from the report:

   ```
   SQL> execute DBMS WORKLOAD REPOSITORY.CREATE SNAPSHOT ();
   ```

```
  buffer_size        CONSTANT BINARY_INTEGER := 32767;
  amount             BINARY_INTEGER;
  offset             NUMBER(38);
  file_handle        UTL_FILE.FILE_TYPE;
  directory_name     CONSTANT VARCHAR2(80) := 'PROCCAPTURE';
  v_filename         CONSTANT VARCHAR2(80) := 'Replay.html';

BEGIN
   cap_id := DBMS_WORKLOAD_REPLAY.GET_REPLAY_INFO(dir => 'PROCCAPTURE');

   select max(id)
   into rep_id
   from dba_workload_replays
   where capture_id = cap_id ;

   rep_rpt := DBMS_WORKLOAD_REPLAY.REPORT(replay_id => rep_id,
                                 format => DBMS_WORKLOAD_REPLAY.TYPE_HTML);

    -- Write Report to file
   DBMS_OUTPUT.ENABLE(100000);

   -- --------------------------------
   -- OPEN NEW XML FILE IN WRITE MODE
   -- --------------------------------
   file_handle := UTL_FILE.FOPEN(location     => directory_name,
                                filename     => v_filename,
                                open_mode    => 'w',
                                max_linesize => buffer_size);

   amount := buffer_size;
   offset := 1;

    WHILE amount >= buffer_size
    LOOP
        DBMS_LOB.READ(lob_loc    => rep_rpt,
                      amount     => amount,
                      offset     => offset,
                      buffer     => buffer);

        offset := offset + amount;

        UTL_FILE.PUT(file      => file_handle,
                     buffer    => buffer);

        UTL_FILE.FFLUSH(file => file_handle);
    END LOOP;

    UTL_FILE.FCLOSE(file => file_handle);
END;
```

10. Go to the directory used in the script, C:\oracle\replay, and view the `Replay.html` file.

SQL Performance Analyzer

The SQL Performance Analyzer (SPA) is a great tool for measuring and reporting on performance before and after instituting a change. The SPA uses the DBMS_SQLTUNE package to accomplish its analysis. In Chapter 8, you learned how to use the SPA for a simple tuning issue in which the SPA recommended an index that improved performance by over 99 percent. But the SPA is much broader. This tool is one of the most powerful ways to answer some of the most common performance questions:

- What will be the impact of removing this index?
- What will be the impact of adding an index to this table?
- What will be the impact of changing an index from a b-tree to a bitmap?
- What will be the impact of reorganizing and ordering this table?
- What will be the impact of partitioning this table?
- What will be the impact of changing a table to an index-organized table?
- What will be the impact of regathering the cost-based optimizer stats?
- What will be the impact of updating the database patch level?
- What will be the impact of upgrading the database to the next version?
- What will be the impact of changing this database initialization parameter?
- What will happen if I change the database from using file systems to ASM?

Create a SQL Tuning Set

To make a comparison using the SPA, the first step is to create a SQL Tuning Set. The first execution of the SQL Tuning Set is the one to use as a baseline; use the second to make the comparison. Create a SQL Tuning Set (as shown here) prior to making any changes, and then create a second Tuning Set after you've made the changes. You can also do this in Enterprise Manager (see Chapter 5 for additional information).

```
---------------------------------------------------------------------------
-- Script: spa_create_sts.sql
-- Setup a SQL Tuning Set for the SQL Performance Analyzer.
---------------------------------------------------------------------------
set feedback on
---------------------------------------------------------------------------
-- Set up the SQL Set and what sql we want to make part of the sql tuning set
---------------------------------------------------------------------------
BEGIN
    -- Create the sql set
    DBMS_SQLTUNE.CREATE_SQLSET(sqlset_name => 'STS_SPA_1');
    -- Limit the sql in the set to Just on the ORDERS and ORDER_ITEMS
    -- The CAPTURE_CURSOR_CACHE_SQLSET will collect SQL statements
    -- over a period of time.  This helps build a more realistic
    -- set of SQL load from the system
    DBMS_SQLTUNE.CAPTURE_CURSOR_CACHE_SQLSET(
         sqlset_name => 'STS_SPA_1'
        ,basic_filter=> q'#UPPER(sql_text) LIKE '%ORDER%' #'
        ,time_limit  => 300
        ,repeat_interval => 2
    );
END;
/
```

Note that this procedure runs for 5 minutes, capturing SQL statements every 2 seconds.

Create an Analysis Task

After creating a SQL Tuning Set with the SQL workload execution, you create an analysis task:

```
dbms_sqlpa.create_analysis_task(sqlset_name => 'my_sts',
task_name => 'my_spa_task',
description => 'test index changes');
```

Execute Analysis Task

After creating the analysis task, you need to execute the task for a baseline tuning set. After executing the analysis task, you can make your changes for comparison against the baseline. This requires creating a second SQL Tuning Set, a second analysis task, and then executing that task. Then you can generate a comparison.

Pre-change:

```
dbms_sqlpa.execute_analysis_task(task_name => 'my_spa_task',
execution_type => 'test execute',
execution_name => 'before index change');
```

Post-change:

```
dbms_sqlpa.execute_analysis_task(task_name => 'my_spa_task',
execution_type -> 'test execute',
execution_name => 'after index change');
```

Now you have two SQL Tuning Sets and are ready to generate a comparison.
To generate a comparison:

```
dbms_sqlpa.execute_analysis_task(
task_name => 'my_spa_task',
execution_type => 'compare performance',
execution_name => 'analysis_results',
execution_params => dbms_advisor.arglist('execution_name1','before index change',
'execution_name2', 'after_index_change',
'comparison_metric','buffer_gets'));

-------------------------------------------------------------------------------
-- Script: spa_compare.sql
-- Executes a SQL Tuning Set Comparison and then outputs a report from SPA
-------------------------------------------------------------------------------
spool SPA_COMPARE_REPORT.out

-- Get the whole report for the single statement case.
SELECT DBMS_SQLPA.REPORT_ANALYSIS_TASK('my_spa_task') from dual;

-- Show me the summary for the sts case.
SELECT DBMS_SQLPA.REPORT_ANALYSIS_TASK('my_spa_task', 'TEXT', 'TYPICAL', 'SUMMARY')
FROM   DUAL;

-- Show me the findings for the statement I'm interested in.
SELECT DBMS_SQLPA.REPORT_ANALYSIS_TASK('my_spa_task', 'TEXT', 'TYPICAL', 'FINDINGS', 5)
FROM   DUAL;

spool off
```

Query SQL Performance Analyzer Advisor Tasks

You can show the Advisor tasks using the DBA_ADVISOR_TASKS view or

USER_ADVISOR_TASKS view:

```
select owner, task_name, status
from   dba_advisor_tasks
where  owner <> 'SYS' ;

OWNER                          TASK_NAME                      STATUS
------------------------------ ------------------------------ ----------
SCOTT                          TASK_1949                      COMPLETED
SCOTT                          TASK_1950                      COMPLETED
SCOTT                          TASK_1948                      INITIAL
SCOTT                          TASK_1943                      INITIAL
SCOTT                          TASK_2700                      INITIAL
SCOTT                          TASK_1946                      INITIAL
SCOTT                          TASK_1923                      INITIAL
SCOTT                          TASK_1945                      INITIAL
SCOTT                          TASK_1944                      INITIAL
SCOTT                          TASK_1947                      INITIAL
```

Cancel an Executing SQL Performance Analyzer Analysis Task

If a SQL Performance Analyzer analysis task is in the process of executing, you can cancel it manually at any time. You may need to do this for tasks you wish to interrupt due to resource issues, database performance impact issues, and so on.

Syntax

```
DBMS_SQLPA.CANCEL_ANALYSIS_TASK ('my_spa_task') ;
```

Remove SQL Performance Analyzer Analysis Task

After you have utilized the information from the SQL Performance Analyzer analysis, you may no longer need the analysis task. To clear space and remove unused or unneeded analysis tasks, it is best to drop them. Oracle provides a procedure within the DBMS_SQLPA package to remove an analysis task.

Syntax

```
DBMS_SQLPA.DROP_ANALYSIS_TASK ('my_spa_task') ;
```

Example

```
SQL> exec DBMS_SQLPA.DROP_ANALYSIS_TASK ('TASK_1923') ;

PL/SQL procedure successfully completed
```

Determine Active SQL Tuning Sets

Before you can drop a SQL Tuning Set, you must remove all references to the SQL Tuning Set, including SPA analysis tasks as well as SQL Tuning Advisor tasks. You can determine references to SQL Tuning Sets via the DBA_SQLSET_REFERENCES view. Having the reference ID is critical to being able to inactivate a SQL set reference.

```
SQL> select id, sqlset_owner, sqlset_name, description from DBA_SQLSET_REFERENCES;

 ID SQLSET_OWNER SQLSET_NAME Description
--- ------------ ----------- ---------------------------------------------------
  2 SCOTT        STS_SPA_1   created by: SQL Tuning Advisor - task: TASK_1926
  3 SCOTT        STS_SPA_1   created by: SQL Tuning Advisor - task: TASK_1927
  5 SCOTT        STS_SPA_1   created by: SQL Tuning Advisor - task: TASK_1929
  8 SCOTT        STS_SPA_1   created by: SQL Tuning Advisor - task: TASK_1932
  7 SCOTT        STS_SPA_1   created by: SQL Tuning Advisor - task: TASK_1931
  4 SCOTT        STS_SPA_1   created by: SQL Tuning Advisor - task: TASK_1928
  6 SCOTT        STS_SPA_1   created by: SQL Tuning Advisor - task: TASK_1930

7 rows selected.
```

Remove SQL Tuning Set

After you have finished the SQL Performance Analyzer analysis, to conserve space and remove unneeded results from SQL Performance Analyzer activities, you may want to remove SQL Tuning Sets. You can only remove inactive SQL Tuning Sets. To remove an active SQL Tuning Set, you have to first remove the SPA analysis tasks that reference the SQL Tuning Set. After removing all analysis tasks, you must remove the SQL Tuning Set references; otherwise, an ORA-13757 error will result indicating the SQL Tuning Set is still active.

Remove SQL Tuning Set Reference

Syntax

```
DBMS SQLTUNE.REMOVE SQLSET REFERENCE ('<tuning set name>') ;
```

Example

```
SQL> exec DBMS SQLTUNE.REMOVE SQLSET REFERENCE ('STS SPA 1', 2) ;

PL/SQL procedure successfully completed.
```

Drop SQL Tuning Set

Ensure all references to the SQL Tuning Set being dropped have first been removed, and then you can drop the SQL Tuning Set itself.

Syntax

```
DBMS_SQLTUNE.DROP_SQLSET ('<tuning set name>') ;
```

Example (references have not been removed)

```
SQL> exec DBMS SQLTUNE.DROP SQLSET ('STS SPA 1');

BEGIN DBMS_SQLTUNE.DROP_SQLSET ('STS_SPA_1') ; END;
*
ERROR at line 1:
ORA-13757: "SQL Tuning Set" "STS_SPA_1" owned by user "SCOTT" is active.
ORA-06512: at "SYS.DBMS_SQLTUNE_INTERNAL", line 8597
ORA-06512: at "SYS.DBMS_SQLTUNE", line 3015
ORA-06512: at line 1
```

Example (references have been removed):

```
SQL> exec DBMS_SQLTUNE.DROP_SQLSET ('STS_SPA_1');

PL/SQL procedure successfully completed.
```

Join Methods

Since the days of Oracle 6, the optimizer has used three primary ways to join row sources together: the NESTED LOOPS join, the SORT-MERGE join, and the CLUSTER join. (There is also the favorite of the ad hoc query user—the Cartesian join.) Oracle 7.3 introduced the HASH join, and Oracle8*i* introduced the INDEX join, making for a total of five primary join methods. Each method has a unique set of features and limitations. Before you attack a potential join issue, you need to know the answers to the following questions:

- Which table will drive the query (first table accessed), and when will other tables be accessed given the path that is chosen for the query? What are the alternate driving paths?
- What are the Oracle join possibilities (described in this section)? Remember, each join possibility for Oracle can yield different results, depending on the join order, the selectivity of indexes, and the available memory for sorting and/or hashing.
- Which indexes are available, and what is the selectivity of the indexes? The selectivity of an index not only can cause the optimizer to use or suppress an index, but can also change the way the query drives and may determine the use or suppression of other indexes in the query.
- Which hints provide alternate paths, and which hints suppress or force an index to be used? These hints change the driving order of the tables, and they change how Oracle performs the join and which indexes it uses or suppresses.
- Which version of Oracle are you using? Your choices vary, depending on the version and release of Oracle you are using. The optimizer also works differently, depending on the version.

NESTED LOOPS Joins

Suppose somebody gave you a telephone book and a list of 20 names to look up, and then asked you to write down each person's name and corresponding telephone number. You would probably go down the list of names, looking up each one in the telephone book one at a time. This task would be pretty easy because the telephone book is alphabetized by name. Moreover, somebody looking over your shoulder could begin calling the first few numbers you write down while you are still looking up the rest. This scene describes a NESTED LOOPS join.

In a NESTED LOOPS join, Oracle reads the first row from the first row source and then checks the second row source for matches. All matches are then placed in the result set and Oracle goes on to the next row from the first row source. This continues until all rows in the first row source have been processed. The first row source is often called the outer or *driving* table, whereas the second row source is called the *inner* table. Using a NESTED LOOPS join is one of the fastest methods of receiving the first records back from a join.

NESTED LOOPS joins are ideal when the driving row source (the records you are looking for) is small and the joined columns of the inner row source are uniquely indexed or have a highly selective nonunique index. NESTED LOOPS joins have an advantage over other join methods in that they can quickly retrieve the first few rows of the result set without having to wait for the entire result set to be determined. This situation is ideal for query screens where an end user can read the first few records retrieved while the rest are being fetched. NESTED LOOPS joins are also flexible in that any two-row sources can always be joined by NESTED LOOPS—regardless of join condition and schema definition.

However, NESTED LOOPS joins can be very inefficient if the inner row source (second table accessed) does not have an index on the joined columns or if the index is not highly selective. If the driving row source (the records retrieved from the driving table) is quite large, other join methods may be more efficient.

Figure 9-1 illustrates the method of executing the query shown next where the DEPT table is accessed first and the result is then looped through the EMP table with a NESTED LOOPS join. The type of join performed can be forced with a hint and will vary due to different variables on your system.

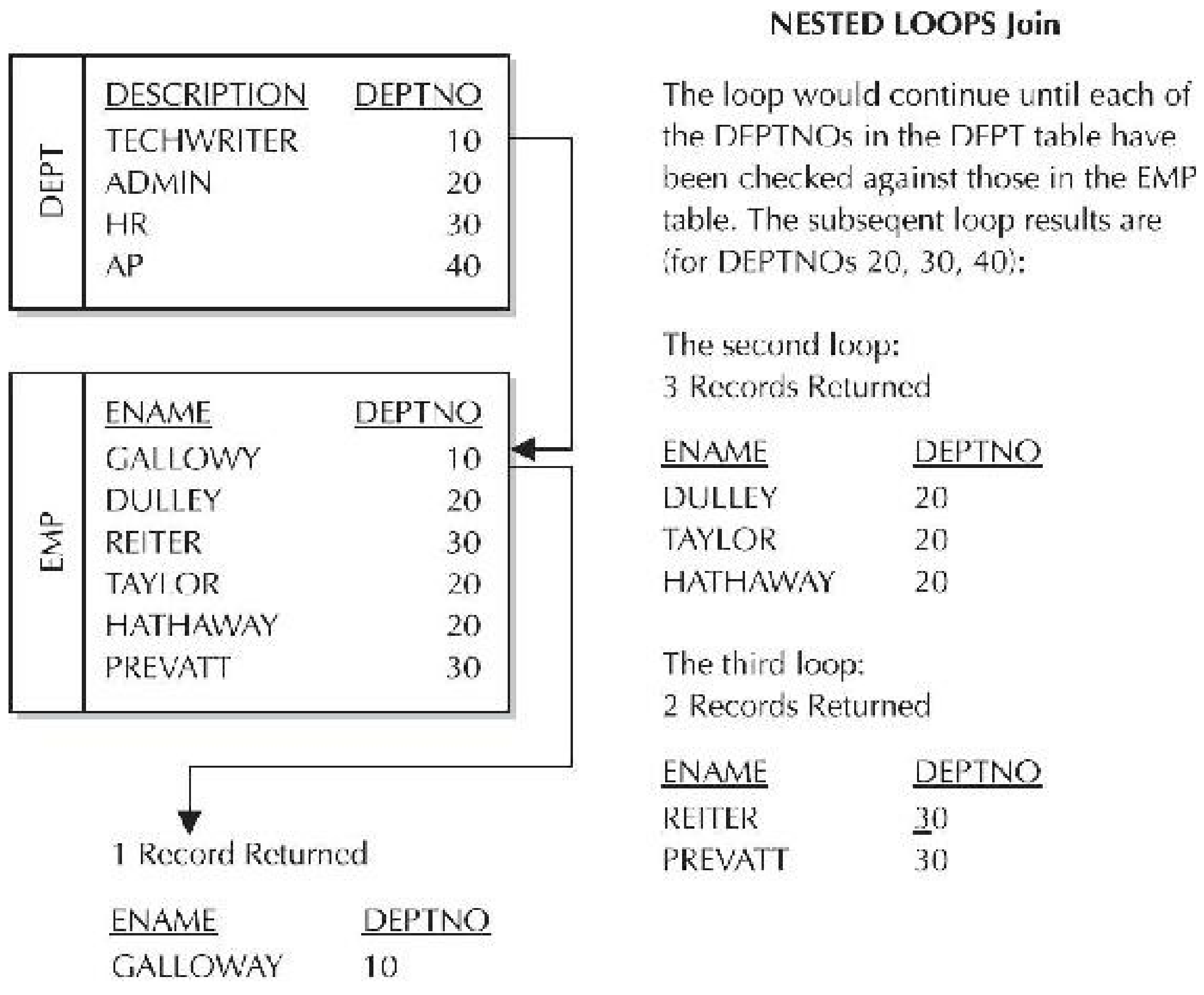
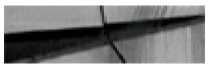


FIGURE 9-1. *NESTED LOOPS join (DEPT is the driving table)*



```
select   /*+ ordered */ ename, dept.deptno
from     dept, emp
where    dept.deptno = emp.deptno;
```

SORT-MERGE Joins

Suppose two salespeople attend a conference and each collects over 100 business cards from potential new customers. They now each have a pile of cards in random order, and they want to see how many cards are duplicated in both piles. The salespeople alphabetize their piles, and then they call off names one at a time. Because both piles of cards have been sorted, it becomes much easier to find the names that appear in both piles. This example describes a SORT-MERGE join.

In a SORT-MERGE join, Oracle sorts the first row source by its join columns, sorts the second row source by its join columns, and then merges the sorted row sources together. As matches are found, they are put into the result set.

SORT-MERGE joins can be effective when lack of data selectivity or useful indexes renders a NESTED LOOPS join inefficient, or when both of the row sources are quite large (greater than 5 percent of the blocks accessed). Also, SORT-MERGE joins can be used only for inequalities, whereas HASH joins can be used only for equijoins (`WHERE D.deptno = E.deptno`, as opposed to `WHERE D.deptno >= E.deptno`). SORT-MERGE joins require temporary segments for sorting (if SORT_AREA_SIZE or the automatic memory parameters like MEMORY_TARGET are set too small). This can lead to extra memory utilization and/or extra disk I/O in the temporary tablespace.

Figure 9-2 illustrates the method of executing the query shown next when a SORT-MERGE join is performed.

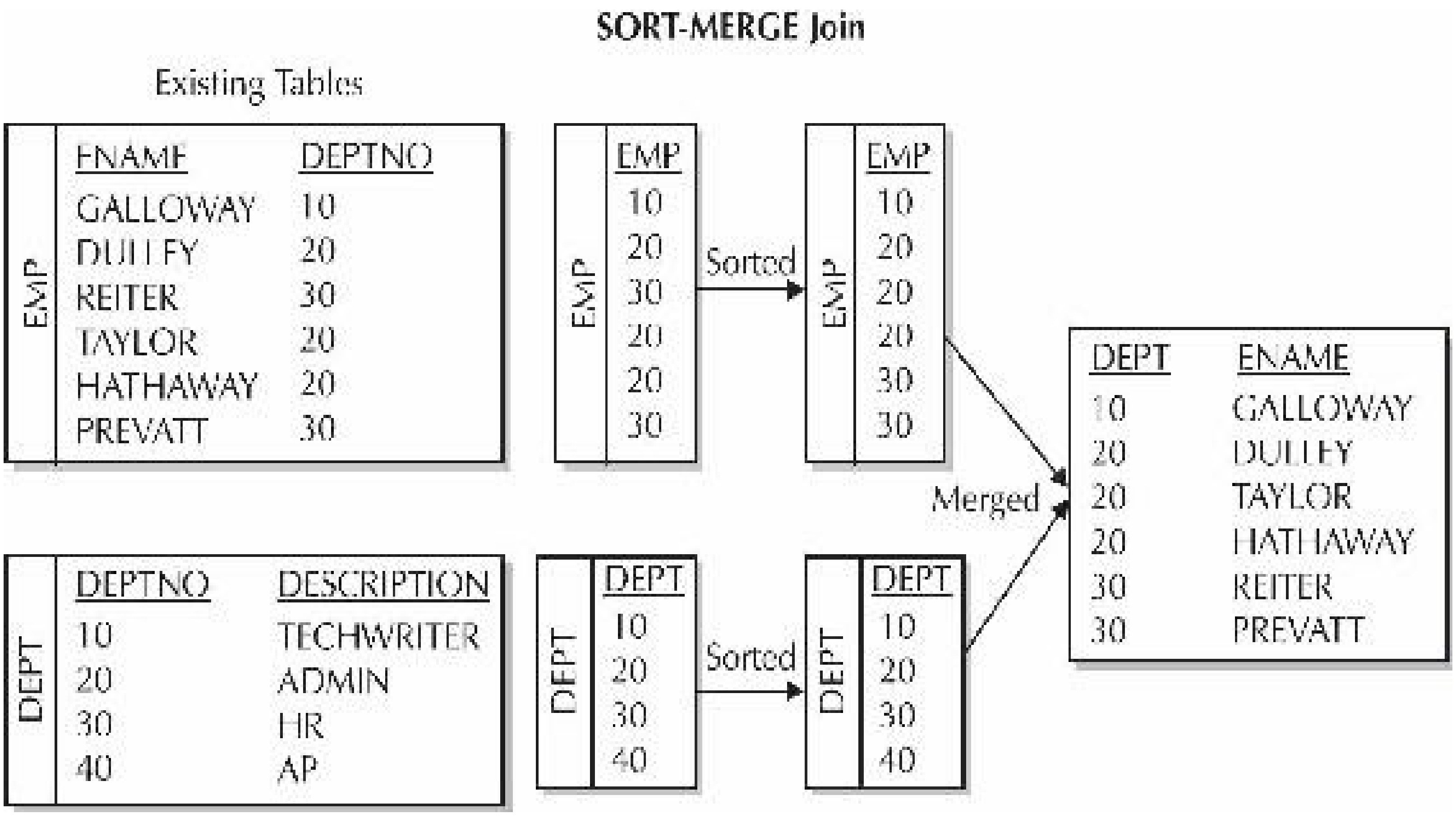


FIGURE 9-2. *SORT-MERGE join*

```
select   /*+ ordered */ ename, dept.deptno
from     emp, dept
where    dept.deptno = emp.deptno;
```

CLUSTER Joins

A CLUSTER join is really just a special case of the NESTED LOOPS join that is not used very often. If the two row sources being joined are actually tables that are part of a cluster, and if the join is an equijoin between the cluster keys of the two tables, then Oracle can use a CLUSTER join. In this case, Oracle reads each row from the first row source and finds all matches in the second row source by using the CLUSTER index.

CLUSTER joins are extremely efficient because the joining rows in the two row sources will actually be located in the same physical data block. However, clusters carry certain caveats of their own, and you cannot have a CLUSTER join without a cluster. Therefore, CLUSTER joins are not very commonly used.

HASH Joins

HASH joins are the usual choice of the Oracle optimizer when the memory is set up to accommodate them. In a HASH join, Oracle accesses one table (usually the smaller of the joined results) and builds a hash table on the join key in memory. It then scans the other table in the join (usually the larger one) and probes the hash table for matches to it. Oracle uses a HASH join efficiently only if the parameter PGA_AGGREGATE_TARGET is set to a large enough value. If MEMORY_TARGET is used, the PGA_AGGREGATE_TARGET is included in the MEMORY_TARGET, but you may still want to set a minimum (see Chapter 4 for additional information). If you set the SGA_TARGET, you must set the PGA_AGGREGATE_TARGET as the SGA_TARGET does not include the PGA (unless you use MEMORY_TARGET as just described). The HASH join is similar to a NESTED LOOPS join in the sense that there is a nested loop that occurs—Oracle first builds a hash table to facilitate the operation and then loops through the hash table. When using an ORDERED hint, the first table in the FROM clause is the table used to build the hash table.

HASH joins can be effective when the lack of a useful index renders NESTED LOOPS joins inefficient. The HASH join might be faster than a SORT-MERGE join, in this case, because only one row source needs to be sorted, and it could possibly be faster than a NESTED LOOPS join because probing a hash table in memory can be faster than traversing a b-tree index. As with SORT-MERGE joins and CLUSTER joins, HASH joins work only on equijoins. As with SORT-MERGE joins, HASH joins use memory resources and can drive up I/O in the temporary tablespace if the sort memory is not sufficient (which can cause this join method to be extremely slow). Finally, HASH joins are available only when cost-based optimization is used (which should be 100 percent of the time for your application running on Oracle 11*g*).

Figure 9-3 illustrates the method of executing the query shown in the listing that follows when a HASH join is used.

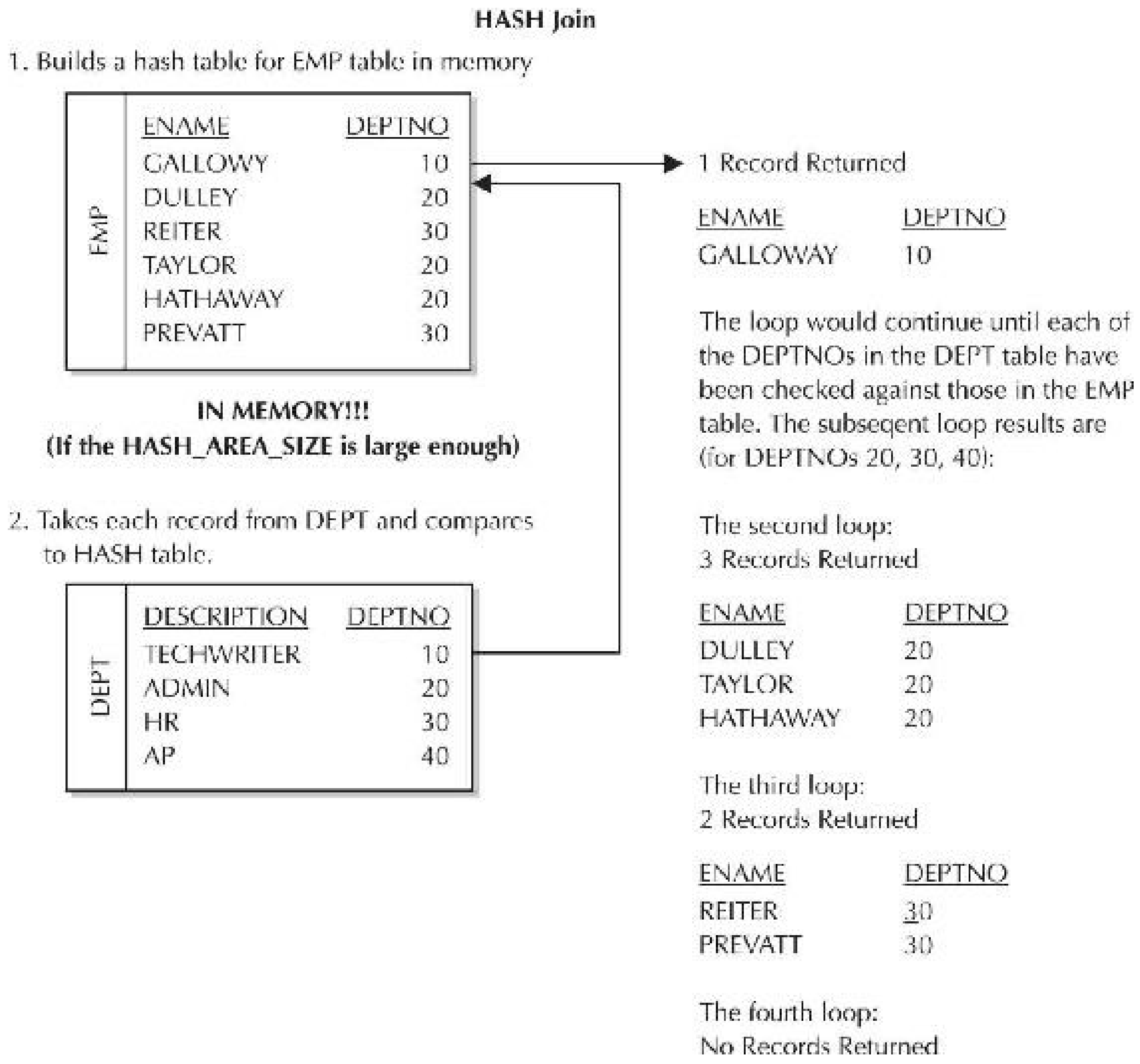


FIGURE 9-3. *HASH join*

```
select   /*+ ordered */ ename, dept.deptno
from     emp, dept
where    dept.deptno = emp.deptno;
```

INDEX-MERGE Joins

Prior to Oracle8*i*, you always had to access the table unless the index contained all of the information required. As of Oracle8*i*, if a set of indexes exists that contains all of the information required by the query, then the optimizer can choose to generate a sequence of HASH joins between the indexes. Each of the indexes is accessed using a range scan or fast full scan, depending on the conditions available in the WHERE clause. This method is extremely efficient when a table has a large number of columns but you want to access only a limited number of those columns. The more limiting the conditions in the WHERE clause, the faster the execution of the query. The optimizer evaluates this as an option when looking for the optimal path of execution.

You must create indexes on the appropriate columns (those that will satisfy the entire query) to ensure that the optimizer has the INDEX-MERGE join as an available choice. This task usually involves adding indexes on columns that may not be indexed or on columns that were not indexed together previously. The advantage of INDEX-MERGE joins over fast full scans is that fast full scans have a *single* index satisfying the entire query. INDEX-MERGE joins have multiple indexes satisfying the entire query.

Two indexes (one on ENAME and one on DEPTNO) have been created prior to the execution of the corresponding query in this next listing. The query does not need to access the table! Figure 9-4 shows this INDEX-MERGE join in graphical format.

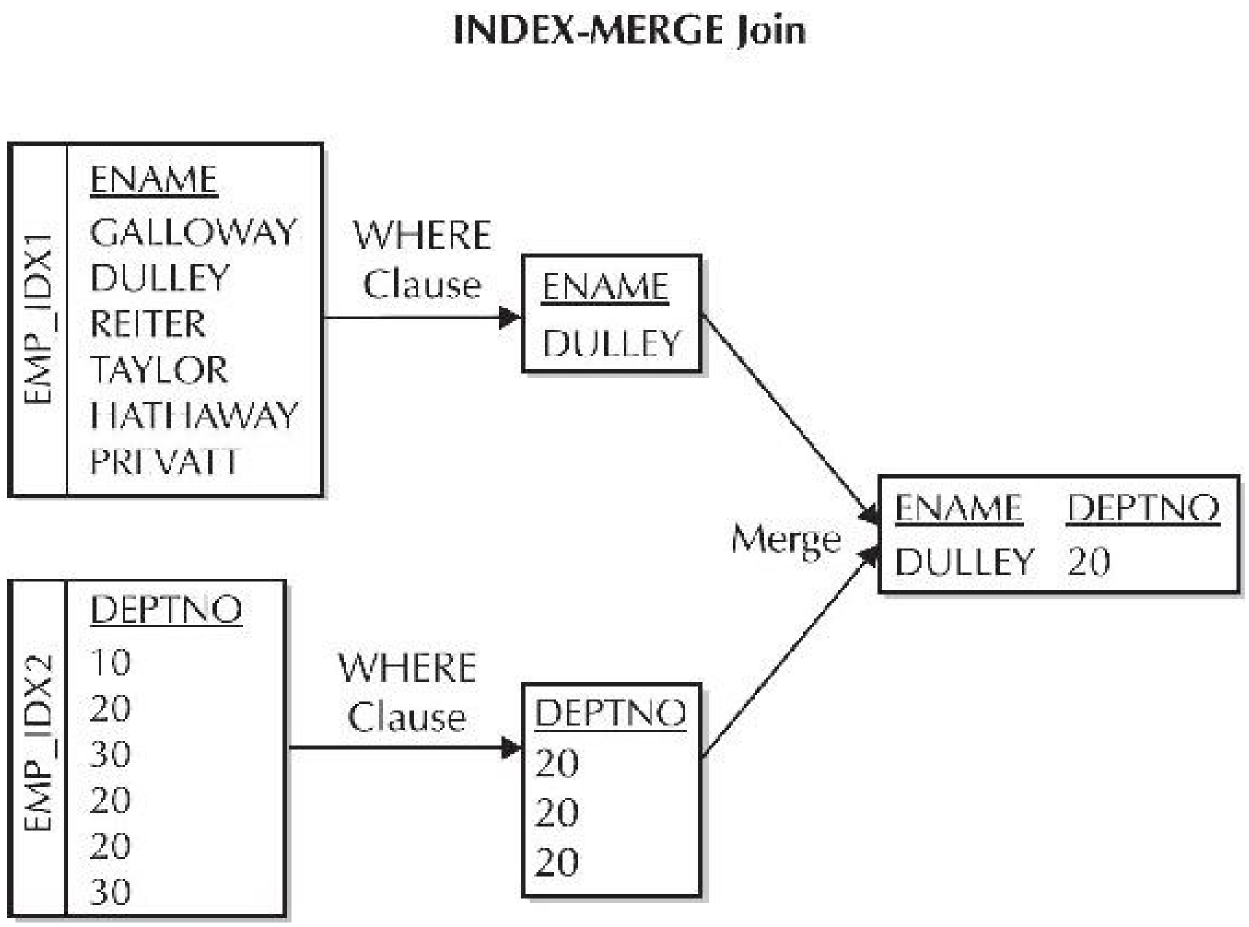
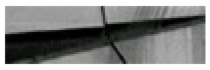


FIGURE 9-4. *An INDEX MERGE join of EMP_IDX1 and EMP_IDX2*



```
select   ENAME, DEPTNO
from     EMP
where    DEPTNO = 20
and      ENAME = 'DULLY';
```

To show the improved efficiency, consider this example that uses the TEST2 table. The TEST2 table has 1 million rows and is 210M in size. First, you create the indexes:

```
create   index doby on test2   ( doby );
create   index state on test2   ( state );
create   index dobmsy on test2  (state, doby );
```

Neither DOBY nor STATE is very limiting when queried individually; consequently, the first indication is to execute a full table scan, as shown in this listing:

```
select   /*+ FULL(test2) */  state, doby
from     test2
where    doby = 1972
and      state = 'MA';

SELECT STATEMENT
TABLE ACCESS (FULL) OF 'TEST2'

Elapse time: 12.6 seconds
```

Using a single index on DOBY is slower than the full table scan:

```
select   /*+ index(test2 doby) */ state, doby
from     test2
where    doby = 1972
and      state = 'MA';

SELECT STATEMENT
TABLE ACCESS (BY INDEX ROWID) OF 'TEST2'
INDEX (RANGE SCAN) OF 'DOBY' (NON-UNIQUE)

Elapsed time: 13:45 seconds
```

Using a single index on STATE is also slower than a full table scan:

```
select   /*+ index(test2 state) */ state, doby
from     test2
where    doby = 1972
and      state = 'MA';

SELECT STATEMENT
TABLE ACCESS (BY INDEX ROWID) OF 'TEST2'
INDEX (RANGE SCAN) OF 'STATE' (NON-UNIQUE)

Elapsed time: 23.50 seconds
```

However, using an INDEX-MERGE join of DOBY and STATE is quicker than a full table scan because the table does not need to be accessed, as in this listing:

```
select   /*+ index_join(test2 doby state) */ state, doby
from     test2
where    doby = 1972

and      state = 'MA';

SELECT STATEMENT
VIEW OF 'index$_join$_001'
HASH JOIN
INDEX (RANGE SCAN) OF 'DOBY' (NON-UNIQUE)
INDEX (RANGE SCAN) OF 'STATE' (NON-UNIQUE)

Elapsed time: 4.76 seconds
```

However, the INDEX_FFS (if a single index on all needed columns exists) is still the most efficient method, as shown here:

```
select   /*+ index_ffs(test2 dobmsy) */ state, doby
from     test2
where    doby = 1972
and      state = 'MA';

SELECT STATEMENT
INDEX (FAST FULL SCAN) OF 'DOBMSY' (NON-UNIQUE)

Elapsed time: 3.6 seconds
```

Although fast full scan is the most efficient option in this case, the INDEX join accommodates more situations. Also, an INDEX_FFS is *often* a problem as it scans through many index blocks and shows up as a severe amount of `'db file sequential read'` waits (so try to tune it by using a better index or having a more selective query so it doesn't need to scan the whole index). Your mileage will vary; this example is only to show how to tune. Which solution is best will be clearer on your unique system after detailed testing.

Table Join Initialization Parameters

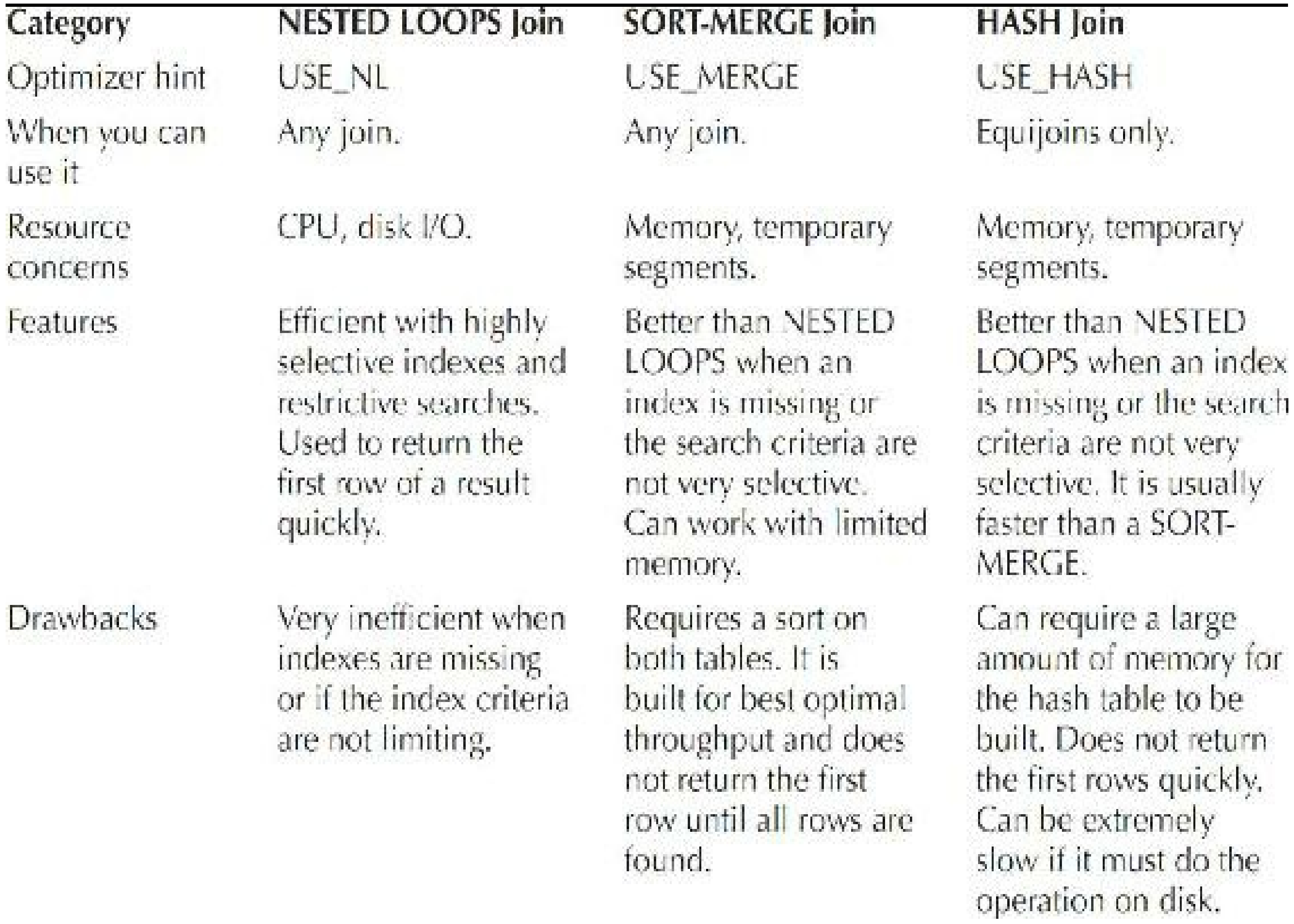
Performance of SORT-MERGE joins and HASH joins is strongly impacted by certain initialization parameters. Join performance can be crippled if certain parameters are not set properly.

SORT-MERGE and HASH Join Parameters

The initialization parameter DB_FILE_MULTIBLOCK_READ_COUNT specifies how many blocks Oracle should read at a time from disk when performing a scattered read such as a full table scan. In 11*g*, my default was 128 (128 * 8192 = 1048576, or 1M; but this is platform dependent and 1M for most platforms), which should be more than sufficient. Because SORT-MERGE joins often involve full table scans, setting this parameter correctly reduces overhead when scanning large tables.

The initialization parameter PGA_AGGREGATE_TARGET (this can be part of the memory allocated with MEMORY_TARGET, if used, as described earlier) specifies how much memory can be used for sorting, which has a strong impact on performance of all sorts. Because SORT-MERGE joins require sorting of both row sources, the amount of memory allocated for sorting can greatly impact SORT-MERGE join performance. If an entire sort cannot be completed in the amount of memory specified, then a temporary segment in the temporary tablespace is allocated. In this case, the sort is performed in memory one part at a time, and partial results are stored on disk in the temporary segment. If memory allocated for sorting is set very small, then excessive disk I/O is required to perform even the smallest of sorts. If it is set too high, then the operating system may run out of physical memory and resort to swapping. The same is true for HASH joins. If the HASH table can’t be built because of insufficient memory, a HASH join could be excessively slow using disk I/O instead.

Table 9-1 provides a quick view of the primary join types.



Category	NESTED LOOPS Join	SORT-MERGE Join	HASH Join
Optimizer hint	USE_NL	USE_MERGE	USE_HASH
When you can use it	Any join.	Any join.	Equijoins only.
Resource concerns	CPU, disk I/O.	Memory, temporary segments.	Memory, temporary segments.
Features	Efficient with highly selective indexes and restrictive searches. Used to return the first row of a result quickly.	Better than NESTED LOOPS when an index is missing or the search criteria are not very selective. Can work with limited memory.	Better than NESTED LOOPS when an index is missing or the search criteria are not very selective. It is usually faster than a SORT-MERGE.
Drawbacks	Very inefficient when indexes are missing or if the index criteria are not limiting.	Requires a sort on both tables. It is built for best optimal throughput and does not return the first row until all rows are found.	Can require a large amount of memory for the hash table to be built. Does not return the first rows quickly. Can be extremely slow if it must do the operation on disk.

TABLE 9-1. *Primary Join Methods*

A Two-Table Join: Equal-Sized Tables (Cost-Based)

Consider the following tables (they have been analyzed) that will be used for this example:

```
SMALL1   10000 rows   No Indexes
SMALL2   10000 rows   No Indexes
```

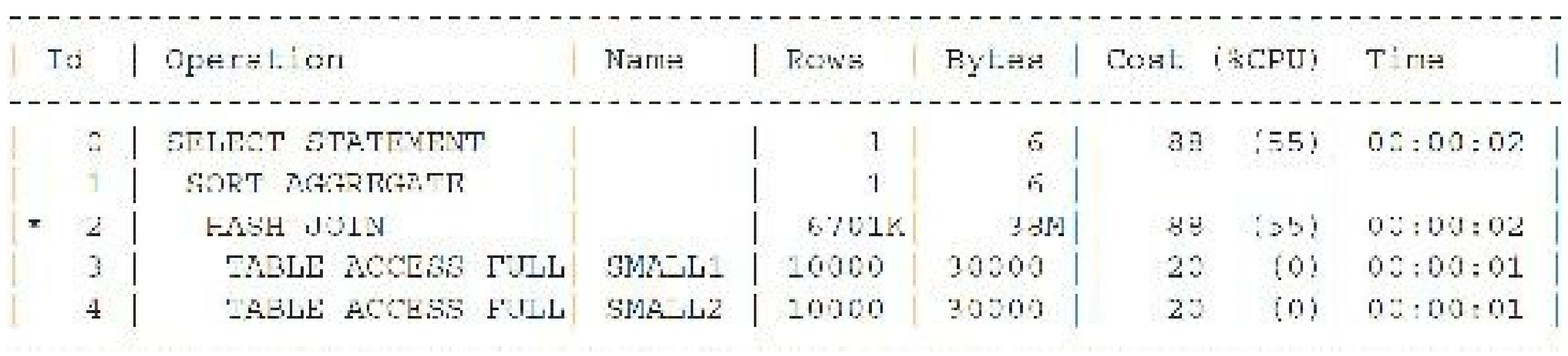
This section of examples is important as you learn more about how the cost-based optimizer works, with all conditions being equal in a join (same size tables/no indexes).

Example 1

Neither table has an index and there aren't any other noteworthy conditions on the tables. Oracle uses a HASH join if the initialization parameters have been set up to allow a HASH join; otherwise, it uses a SORT-MERGE join. In this example, both tables are equal, so the first one in the FROM clause is used and Oracle uses a HASH join:

```
select  small1.col1, small2.col1
from    small1, small2
where   small1.col1 = small2.col1;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL1 table is accessed first and used to build a hash table. Oracle accesses the SMALL1 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL2 and probes the hash table for matches to SMALL2.



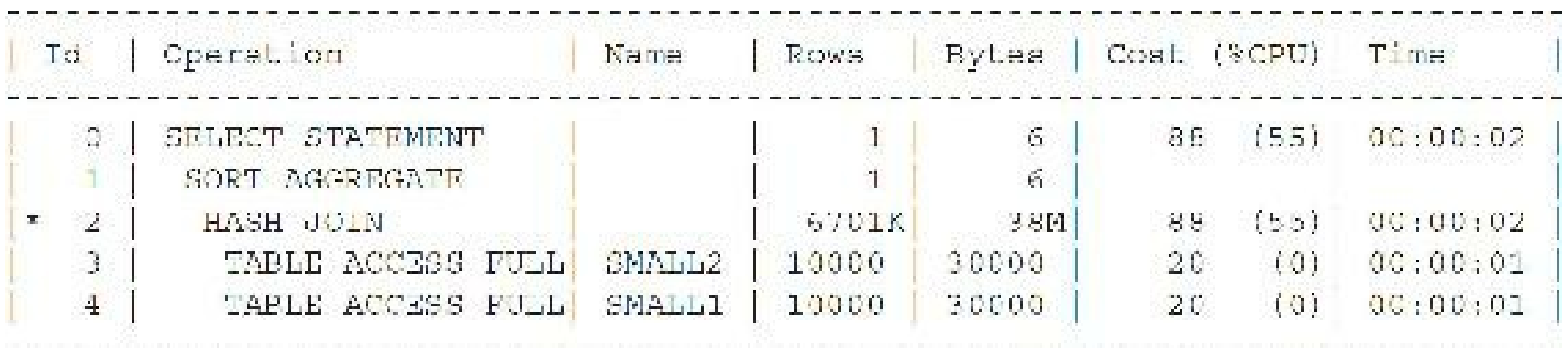
```
-------------------------------------------------------------------------------------
| Id  | Operation            | Name   | Rows  | Bytes | Cost (%CPU)  Time     |
-------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT     |        |     1 |     6 |    88  (55)  00:00:02 |
|   1 |  SORT AGGREGATE      |        |     1 |     6 |                       |
|*  2 |   HASH JOIN          |        | 6701K |   38M|    88  (55)  00:00:02 |
|   3 |    TABLE ACCESS FULL| SMALL1 | 10000 | 30000 |    23   (0)  00:00:01 |
|   4 |    TABLE ACCESS FULL| SMALL2 | 10000 | 30000 |    23   (0)  00:00:01 |
-------------------------------------------------------------------------------------
```

Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up) Although SMALL1 would normally be the driving table (because it is first in the FROM clause and this example uses cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL1 table is *accessed* first for this operation (an EXPLAIN or AUTOTRACE shows this).

Now change the order of the tables in the FROM clause. The SMALL2 table is listed first and is also accessed first as the driving table. A HASH join is performed. A full table scan is needed on both tables, and the order in the FROM clause has no impact on the driving table, as shown here:

```
select  small1.col1, small2.col1
from    small2, small1
where   small1.col1 = small2.col1;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL2 table is accessed first and used to build a hash table. Oracle accesses the SMALL2 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL1 and probes the hash table for matches to SMALL1.



```
------------------------------------------------------------------------------------
| Id  | Operation            | Name   | Rows  | Bytes | Cost (%CPU)| Time     |
------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT     |        |     1 |     6 |    88  (55)| 00:00:02 |
|   1 |  SORT AGGREGATE      |        |     1 |     6 |            |          |
|*  2 |   HASH JOIN          |        | 6701K |   38M|    88  (55)| 00:00:02 |
|   3 |    TABLE ACCESS FULL| SMALL2 | 10000 | 30000 |    20   (0)| 00:00:01 |
|   4 |    TABLE ACCESS FULL| SMALL1 | 10000 | 30000 |    20   (0)| 00:00:01 |
```

Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up) Although SMALL2 would normally be the driving table (because it is first in the FROM clause and using cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL2 table is *accessed* first for this operation (an EXPLAIN or AUTOTRACE will show this).

Example 1 Outcomes

If you have set up the initialization parameters for hashing, Oracle builds a hash table from the join values of the *first* table (accessed first), and then it probes that table for values from the second table. Forcing a USE_MERGE hint *always* causes the first table to be accessed first in my testing regardless of the order in the FROM clause.

Finally, if neither table is analyzed in Example 1, Oracle accesses what it believes to be the smallest table first (very important point here). Before I ran the ANALYZE, it listed SMALL2 as slightly less than 10,000 rows, and it *always* accessed it first regardless of the order in the FROM clause. Once I ran an ANALYZE on both tables, they both were listed at 10,000 rows, and the *first table listed in the FROM clause was always accessed first as the driving table*.

Example 2

Neither table has an index, and you will use the ORDERED hint, as in this listing:

```
select  /*+ ORDERED */ small1.col1, small2.col1
from    small1, small2
where   small1.col1 = small2.col1;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL1 table is accessed first and used to build a hash table. Oracle accesses the SMALL1 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL2 and probes the hash table for matches to SMALL2.

```
--------------------------------------------------------------------------------------------
| Id  | Operation            | Name   | Rows  | Bytes | Cost (%CPU)  Time     |
--------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT     |        |     1 |     6 |    88  (55)  00:00:02 |
|   1 |  SORT AGGREGATE      |        |     1 |     6 |                       |
|*  2 |   HASH JOIN          |        | 6700K|    38M|    88  (55)  00:00:02 |
|   3 |    TABLE ACCESS FULL| SMALL1 | 10000 | 30000 |    20   (0)  00:00:01 |
|   4 |    TABLE ACCESS FULL| SMALL2 | 10000 | 30000 |    20   (0)  00:00:01 |
--------------------------------------------------------------------------------------------
```

Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up) Although SMALL1 would normally be the driving table (because it is first in the FROM clause and using cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL1 table is *accessed* first for this operation (an EXPLAIN or AUTOTRACE will show this).

Now change the order of the tables in the FROM clause:

```
select   /*+ ORDERED */ small1.col1, small2.col1
from     small2, small1
where    small1.col1 = small2.col1;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL2 table is accessed first and used to build a hash table. Oracle accesses the SMALL2 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL1 and probes the hash table for matches to SMALL1.

```
--------------------------------------------------------------------------------------------
| Id  | Operation            | Name   | Rows  | Bytes | Cost (%CPU)  Time     |
--------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT     |        |     1 |     6 |    88  (55)  00:00:02 |
|   1 |  SORT AGGREGATE      |        |     1 |     6 |                       |
|*  2 |   HASH JOIN          |        | 6700K|    38M|    88  (55)  00:00:02 |
|   3 |    TABLE ACCESS FULL| SMALL2 | 10000 | 30000 |    20   (0)  00:00:01 |
|   4 |    TABLE ACCESS FULL| SMALL1 | 10000 | 30000 |    20   (0)  00:00:01 |
--------------------------------------------------------------------------------------------
```

Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up) Although SMALL2 would normally be the driving table (because it is first in the FROM clause and using cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL2 table is *accessed* first for this operation (an EXPLAIN or AUTOTRACE will show this).

Example 2 Outcomes

If hash initialization parameters are set up, Oracle builds a hash table from the join values of the *first* table listed and then probes that hash table for values from the *second* table listed. If hash initialization parameters are not set up, the *first* table in the FROM clause in cost-based optimization *is* accessed first and is the driving table when an ORDERED hint is used; but in a SORT-MERGE join, this has no impact because each table must be sorted and then all tables must be merged together.

TIP

Using cost-based optimization, the first table in the FROM clause is the driving table when the ORDERED hint is used. This overrides the optimizer from choosing the driving table. If a SORT-MERGE join is used, then the order of the tables has no impact because neither will drive the query (although the first listed table is accessed first for the operation and is the driving table). Knowing which table is generally the driving table when using an ORDERED hint in small joins can help you solve larger table join issues and also help you find indexing problems.

TIP

When hash initialization parameters are set up, the optimizer uses HASH joins in lieu of SORT-MERGE joins. With HASH joins, the first table is used to build a hash table (in memory if available), and the second table in the FROM clause then probes for corresponding hash table matches. The first table in the FROM clause (using the ORDERED hint) is the first table accessed in a HASH join.

A Two-Table INDEXED Join: Equal-Sized Tables (Cost-Based)

To get a better understanding of the driving table and how Oracle processes a query, an example where all conditions are equal in both tables is instructive. Although the queries in this section look strange because I am trying to keep all conditions equal, they are helpful in understanding the way joins work. Consider the following tables (they have been analyzed) that will be used for this example:

```
SMALL1   10000 rows   Index on COL1
SMALL2   10000 rows   Index on COL1
```

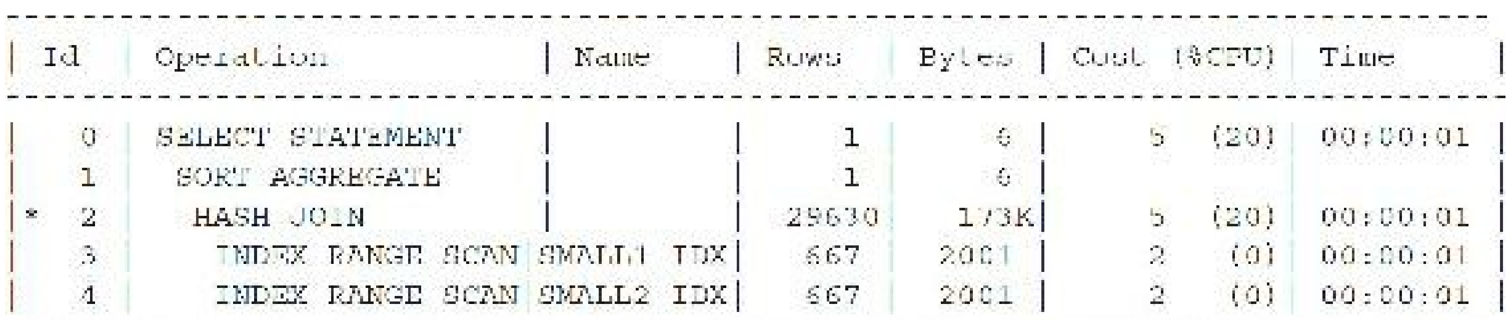
NOTE
This section of examples is important as you learn how the cost-based optimizer works using indexes. Although the query in this section wouldn't normally be written, it shows how the driving table works with a two-table join, all conditions being equal. In other words, it is only for instructional purposes.

Example 1

Both tables have an index on the COL1 column, as in this example:

```
select  small1.col1, small2.col1
from    small1, small2
where   small1.col1 = small2.col1
and     small1.col1 = 77
and     small2.col1 = 77;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL1 index is the query's driving statement (since the SMALL1 table is the first table listed in the FROM clause). The SMALL1 index is accessed first and used to build a hash table. Oracle accesses the SMALL1 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL2 index and probes the hash table for matches to SMALL2. Also note, switching the order of the predicates in the two AND clauses does *not* change anything.



```
-----------------------------------------------------------------------------------
| Id | Operation             | Name       | Rows  | Bytes | Cost (%CPU)| Time     |
-----------------------------------------------------------------------------------
|   0 | SELECT STATEMENT     |            |     1 |     6 |     5  (20)| 00:00:01 |
|   1 |  SORT AGGREGATE      |            |     1 |     6 |            |          |
|*  2 |   HASH JOIN          |            | 29630 |  173K |     5  (20)| 00:00:01 |
|   3 |    INDEX RANGE SCAN  | SMALL1_IDX |   667 |  2001 |     2   (0)| 00:00:01 |
|   4 |    INDEX RANGE SCAN  | SMALL2_IDX |   667 |  2001 |     2   (0)| 00:00:01 |
```

Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up) The SMALL1 index (since the SMALL1 table is the first table listed in the FROM clause) is the query's driving statement. Oracle retrieves the records from the index on SMALL1 and then takes each record and checks for matches in the SMALL2 index. A NESTED LOOPS join is faster when the source rows from the SMALL1 table are a small set and there is a reasonably selective index on the SMALL2 joining column (brief EXPLAIN PLAN listed here).

```
SELECT STATEMENT
   NESTED LOOPS (Cost=2 Card=3 Bytes=90) (small1 result checks small2 matches)
      INDEX (RANGE SCAN) OF 'SMALL1_IDX'  (This is first/gets first row to check)
       INDEX (RANGE SCAN) OF 'SMALL2 IDX'  (This is second/checks for matches)
```

Now change the order of the tables in the FROM clause:

```
select   small1.col1, small2.col1
from     small2, small1
where    small1.col1 = small2.col1
and      small1.col1 = 77
and      small2.col1 = 77;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL2 index (since the SMALL2 table is the first table listed in the FROM clause) is the query's driving statement. The SMALL2 index is accessed first and used to build a hash table. Oracle accesses the SMALL2 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL1 index and probes the hash table for matches to SMALL1. Also note, switching the order of the predicates in the two AND clauses does *not* change anything.

```
--------------------------------------------------------------------------------
| Id   | Operation            | Name        | Rows    | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0  | SELECT STATEMENT     |             |       1 |     6 |      5  (20)| 00:00:01 |
|   1  |  SORT AGGREGATE      |             |       1 |     6 |             |          |
|*  2  |   HASH JOIN          |             |   29630 |  173K|      5  (20)| 00:00:01 |
|   3  |     INDEX RANGE SCAN |SMALL2 IDX|     667 |  2001 |      2   (0)| 00:00:01 |
|   4  |     INDEX RANGE SCAN |SMALL1 IDX|     667 |  2001 |      2   (0)| 00:00:01 |
```

Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up) The SMALL2 index (since the SMALL2 table is the first table in the FROM clause) is the query's driving statement. Oracle retrieves the records from the index on SMALL2 and then takes each record and checks for matches in the SMALL1 index. A NESTED LOOPS join is faster when the source rows from the SMALL2 table are a small set and there is a reasonably selective index on the SMALL1 joining column (brief EXPLAIN PLAN listed here).

```
SELECT STATEMENT
   NESTED LOOPS (Cost 2 Card 3 Bytes 90)   (small2 result checks small1 matches)
      INDEX (RANGE SCAN) OF 'SMALL2_IDX'   (This is first/gets first row to check)
      INDEX (RANGE SCAN) OF 'SMALL1 IDX'   (This is second/checks for matches)
```

Example 1 Outcomes

All conditions being equal, the index from the first table is accessed first (the *first* table in the FROM clause) in cost-based optimization and is the driving table. The index is used on the join condition for the second table. In Example 1, Oracle uses a HASH join to join the queries, but a NESTED LOOPS join or SORT-MERGE join is also possible, depending on other factors in the table and index.

Example 2

Both tables have an index on the COL1 column, and I use the ORDERED hint, as shown here:

```
select   /*+ ORDERED */ small1.col1, small2.col1
from     small1, small2
where    small1.col1 = small2.col1
and      small1.col1 = 77
and      small2.col1 = 77;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL1 index (since the SMALL1 table is the first table listed in the FROM clause) is the query's driving statement. The SMALL1 index is accessed first and used to build a hash table. Oracle accesses the SMALL1 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL2 index and probes the hash table for matches to SMALL2. Also note, switching the order of the predicates in the two AND clauses does *not* change anything.

```
--------------------------------------------------------------------------------
| Id  | Operation              | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT       |             |     1 |     6 |     5  (20)| 00:00:01 |
|   1 |  SORT AGGREGATE        |             |     1 |     6 |            |          |
|*  2 |   HASH JOIN            |             | 29630 |  173K|     5  (20)| 00:00:01 |
|   3 |    INDEX RANGE SCAN    | SMALL1 IDX  |   667 |  2001 |     2   (0)| 00:00:01 |
|   4 |    INDEX RANGE SCAN    | SMALL2 IDX  |   667 |  2001 |     2   (0)| 00:00:01 |
```

Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up) The SMALL1 index (since the SMALL1 table is the first table listed in the FROM clause) is the query's driving statement. Oracle retrieves the records from the index on SMALL1 and then takes each record and checks for matches in the SMALL2 index. A NESTED LOOPS join is faster when the source rows from the SMALL1 table are a small set and there is a reasonably selective index on the SMALL2 joining column (brief EXPLAIN PLAN listed next).

```
SELECT STATEMENT
   NESTED LOOPS (Cost 2 Card 3 Bytes 90) (small1 result checks small2 matches)
       INDEX (RANGE SCAN) OF 'SMALL1_IDX'  (This is first/gets first row to check)
       INDEX (RANGE SCAN) OF 'SMALL2 IDX'  (This is second/checks for matches)
```

Now change the order of the tables in the FROM clause:

```
select   /*+ ORDERED */ small1.col1, small2.col1
from     small2, small1
where    small1.col1 = small2.col1
and      small1.col1 = 77
and      small2.col1 = 77;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL2 index (since the SMALL2 table is the first table listed in the FROM clause) is the query's driving statement. The SMALL2 index is accessed first and used to build a hash table. Oracle accesses the SMALL2 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL1 index and probes the hash table for matches to SMALL1. Also note, switching the order of the predicates in the two AND clauses does *not* change anything.

```
--------------------------------------------------------------------------------
| Id  | Operation               | Name       | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT        |            |     1 |     6 |     5  (20)| 00:00:01 |
|   1 |  SORT AGGREGATE         |            |     1 |     6 |            |          |
|*  2 |   HASH JOIN             |            | 29630 |  173K|     5  (20)| 00:00:01 |
|   3 |    INDEX RANGE SCAN|SMALL2 IDX|   667 |  2001 |     2   (0)| 00:00:01 |
|   4 |    INDEX RANGE SCAN|SMALL1 IDX|   667 |  2001 |     2   (0)| 00:00:01 |
```

Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up) The SMALL2 index (since the SMALL2 table is the first table in the FROM clause) is the query's driving statement. Oracle retrieves the records from the index on SMALL2 and then takes each record and checks for matches in the SMALL1 index. A NESTED LOOPS join is faster when the source rows from the SMALL2 table are a small set and there is a reasonably selective index on the SMALL1 joining column (brief EXPLAIN PLAN listed here).

```
SELECT STATEMENT
   NESTED LOOPS (Cost=2 Card=3 Bytes=90)   (small2 result checks small1 matches)
      INDEX (RANGE SCAN) OF 'SMALL2_IDX'   (This is first/gets first row to check)
      INDEX (RANGE SCAN) OF 'SMALL1 IDX'   (This is second/checks for matches)
```

Example 2 Outcomes

All conditions being equal, the index from the first table is accessed first (the *first* table listed in the FROM clause) in cost-based optimization using a HASH or NESTED LOOPS join and is the driving statement with or without the ORDERED hint. Only the ORDERED hint guarantees the order in which all the tables are accessed. The index is used on the join condition for the second table.

TIP

Using cost-based optimization and a NESTED LOOPS join as the means of joining, the first table in the FROM clause is the driving table (all other conditions being equal), but only the ORDERED hint guarantees this. In NESTED LOOPS joins, choosing a driving table that is the smaller result set (not always the smaller table) makes fewer loops through the other result set (from the nondriving table) and usually results in the best performance.

Forcing a Specific Join Method

When choosing an execution plan for a query involving joins, the Oracle optimizer considers all possible join methods and table orders. The optimizer does its best to evaluate the merits of each option and to choose the optimal execution plan, but sometimes the optimizer does not choose the best solution because of poor indexing strategies.

In these situations, you can use the USE_NL, USE_MERGE, and USE_HASH hints to request a specific join method, and you can use the ORDERED hint to request a specific join order for all tables (or use LEADING to use the first table in the FROM clause as the driving table and leave the order of the remaining tables for Oracle to figure out). The optimizer does its best to observe the wishes of these hints, but if you ask for something impossible (such as a SORT-MERGE join on an antijoin), the optimizer ignores the hint.

When tuning SQL that uses joins, you should run benchmark comparisons between different join methods and table execution order. For example, if a report joins two tables that form a master-detail relationship and the proper primary-key and foreign-key indexes are in place, the optimizer will probably choose to use a NESTED LOOPS join. However, if you know that this particular report joins all of the master records to all of the detail records, you might think it's faster to use a SORT-MERGE join or HASH join instead. Run a benchmark to ensure that you have the best solution.

In the following three listings, the first listing shows an example query and its TKPROF output, the second listing shows the same query with a USE_MERGE hint, and the third listing shows it with a USE_HASH hint. In this example, the indexes were built so that a full table scan must be executed on the PURCHASE_ORDER_LINES table. (Using an index would have been the better choice but not as instructive.) You can see that in this situation the HASH join reduced CPU time by almost 40 percent and logical I/Os by about 98 percent. The goal is not to demonstrate how to tune this type of query, but how to use different types of joining.

Forcing a NESTED LOOPS Join

The PURCHASE_ORDER_LINES table is the driving table. Each record (one at a time) is taken from the PURCHASE_ORDER_LINES table, and for each one, you loop through for matches in the PURCHASE_ORDERS table. This is slow because the driving table list is large. (PURCHASE_ORDER_LINES has a large number of rows.)

```
select      /*+ USE_NL (a b) */
              b.business_unit,b.po_number,b.vendor_type,a.line_number,
              a.line_amount,a.line_status,a.description
from        purchase_order_lines a, purchase_orders b
where       b.business_unit = a.business_unit
and         b.po_number = a.po_number
order by    b.business unit,b.po number,a.line number;


Rows    Execution Plan
0       SELECT STATEMENT   GOAL: CHOOSE
73369    SORT (ORDER BY)
73369     NESTED LOOPS
73726      TABLE ACCESS  GOAL: ANALYZED (FULL) OF 'PURCHASE_ORDER_LINES'
73369      TABLE ACCESS  GOAL: ANALYZED (BY ROWID) OF 'PURCHASE_ORDERS'
73726        INDEX  GOAL: ANALYZED (UNIQUE SCAN) OF 'PURCHASE_ORDERS_PK'
(UNIQUE)
```

Forcing a SORT-MERGE Join

For the SORT-MERGE case, Oracle sorts both tables and then merges the result. This method is still not an efficient way to perform the query.

```
Select      /*+ USE_MERGE (a b) */
              a.business unit,a.po number,a.vendor type,b.line number,
              b.line_amount,b.line_status,b.description
from        purchase_orders a,purchase_order_lines b
where       b.business_unit = a.business_unit
and         b.po_number = a.po_number
order by    a.business unit,a.po number,b.line number;

Rows      Execution Plan
0        SELECT STATEMENT  GOAL: CHOOSE
73369     SORT (ORDER BY)
73369     MERGE JOIN
686         SORT (JOIN)
686           TABLE ACCESS  GOAL: ANALYZED (FULL) OF 'PURCHASE_ORDERS'
73726       SORT (JOIN)
73726         TABLE ACCESS  GOAL: ANALYZED (FULL) OF 'PURCHASE_ORDER_LINES'
```

Forcing a HASH join

The HASH join has proven to be the most efficient because it puts the PURCHASE_ORDERS table into a hash table and then scans to retrieve the corresponding records from PURCHASE_ORDER_LINES. If you cannot get the correct access order, you can use the SWAP_JOIN_INPUTS hint as well.

```
select      /*+ USE_HASH (a b) */
              a.business_unit,a.po_number,a.vendor_type,b.line_number,
              b.line_amount,b.line_status,b.description
from        purchase_orders a,purchase_order_lines b
where       b.business_unit = a.business_unit
and         b.po_number = a.po_number
order by    a.business_unit,a.po_number,b.line_number;

Rows      Execution Plan
0         SELECT STATEMENT  GOAL: CHOOSE
73369      SORT (ORDER BY)
137807       HASH JOIN
686            TABLE ACCESS  GOAL: ANALYZED (FULL) OF 'PURCHASE_ORDERS'
73726          TABLE ACCESS  GOAL: ANALYZED (FULL) OF  'PURCHASE_ORDER_LINES'
```

Oracle chose to do a NESTED LOOPS join in 10*g* and a HASH join in 11*g*. In 12*c*, it does a HASH join. NESTED LOOPS is not the most efficient way of joining in this case, but if you don't set the memory parameters appropriately, Oracle might choose NESTED LOOPS over a HASH Join. For this query, by using the USE_HASH hint, you can cut CPU time by almost 40 percent and logical I/Os by about 98 percent. Although the CPU reduction is impressive, the reduction in logical I/Os (memory reads) is saving SGA memory for other users. Sometimes when you are retrieving a large amount of data, access using a full table scan is the most efficient method. In 11*g*, Oracle uses the HASH join method frequently, provided the initialization parameters related to it are set appropriately.

TIP
To change the method that Oracle uses to join multiple tables, use the USE_MERGE, USE_NL, and USE_HASH hints. Multiple tables may need to be specified for the hint to work, and the driving order is usually from first to last in the FROM clause.

Eliminating Join Records (Candidate Rows) in Multitable Joins

Suppose you have a list of 1000 residents of your town along with each resident's street address, and you are asked to prepare an *alphabetized* list of residents who have the newspaper delivered to their home. (Only 50 get the newspaper.) You could first alphabetize the list of 1000 names (all residents in the town) and then look up each street address in the list of 50 residents who get the newspaper. (Sort the 1000 and then find the 50.) A faster method would be to look up each street address of those who get the newspaper first, and then get the names of the residents at that street and do the alphabetization last. (Find the 50 who get the newspaper from the list of 1000 and then sort the 50 matches.) Either way, you need to look at the 1000 street addresses. However, these lookups will eliminate many names from the list, and the sorting will be faster when you have a list of only 50 to sort.

You can apply the same concept when writing SQL table joins together. The Oracle optimizer is pretty smart about choosing the most efficient order in which to perform tasks, but how a query is written can constrain the options available to the optimizer.

The query in this next listing leaves the optimizer no choice but to read all of Acme's invoice lines (the large table/the intersection table), when, in fact, only the unpaid invoices (the small table) are of interest:

```
select    v.vendor_num, i.invoice_num, sum (l.amount)
from      vendors v, invoices i, invoice_lines l
where     v.vendor_name = 'ACME'
and       l.vendor_num = v.vendor_num
and       i.vendor_num = l.vendor_num
and       i.invoice_num = l.invoice_num
and       i.paid = 'N'
group by  v.vendor_num, i.invoice_num
order by  i.invoice_num;
```

You could rewrite this query, as shown here:

```
select    v.vendor_num, i.invoice_num, sum (l.amount)
from      vendors v, invoices i, invoice_lines l
where     v.vendor_name = 'ACME'
and       i.vendor_num = v.vendor_num
and       i.paid = 'N'
and       l.vendor_num = i.vendor_num
and       l.invoice_num = i.invoice_num
group by  v.vendor_num, i.invoice_num
order by  i.invoice_num;
```

In the rewritten query in this listing, the optimizer eliminates all of the paid invoices (the new intersection table) before joining to the INVOICE_LINES table. If most of the invoices in the database have already been paid, then the rewritten query is significantly faster. (The schema design in this example is dubious and is used only for illustrative purposes.)

TIP

In a three-table join, the driving table is the intersection table or the table that has a join condition to each of the other two tables in the join. Try to use the most limiting table as the driving table (or intersection table) so your result set from the join of the first two tables is small *when you join it to the third table.*

A Two-Table Join Between a Large and Small Table

Consider the following tables that will be used for this example:

```
PRODUCT  70 thousand rows  Index on PRODUCT_ID
PRODUCT LINES  4 million rows  Index on PRODUCT ID
```

This section uses only cost-based optimization. This section of examples is important because it looks at a situation often encountered. It involves a two-table join between a small (business small) table and a large table. The subsequent conditions (beyond the join itself) are on the column that you are joining. At times, the index on this column in the subsequent condition is suppressed. Unfortunately, this situation leads to seven possible situations, based on various conditions. This section covers three of the main situations, and the results are summarized at the end.

Example 1

Neither table can use an index (they are suppressed), and there are no other conditions, as shown in this example:

```
select  product.name, product lines.qty
from    product, product_lines
where   product.product id || ''  = product lines.product id || '';
```

EXPLAIN PLAN Output

```
SELECT STATEMENT
  HASH JOIN
    TABLE ACCESS FULL OF 'PRODUCT'
    TABLE ACCESS FULL OF 'PRODUCT_LINES'
```

The order of the tables in the FROM clause can be reversed, as shown here:

```
select  product.name, product lines.qty
from    product_lines, product
where   product.product id || ''  = product lines.product id || '';
```

EXPLAIN PLAN Output

```
SELECT STATEMENT
  HASH JOIN
    TABLE ACCESS FULL OF 'PRODUCT'
    TABLE ACCESS FULL OF 'PRODUCT_LINES'
```

Example 1 Outcome

All conditions being equal, the *first* table in the FROM clause in cost-based optimization is the driving table (first accessed). Because these tables are different sizes, however, Oracle chooses the *smaller table to be the driving table* regardless of the order in the FROM clause. The PRODUCT table is used to build a hash table on the join key (PRODUCT_ID), and then the PRODUCT_LINES table is scanned, probing the hash table for join key matches.

TIP
Using cost-based optimization, when a large table and a small table are joined, the smaller table is the driving table (accessed first), and the smaller table is used to build a hash table in memory on the join key. The larger table is scanned and then probes the hash table for matches to the join key. Also note that if there is not enough memory for the hash, the operation can become extremely slow because the hash table may be split into multiple partitions that could be paged to disk. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table, and it will be the one used to build the hash table.

Example 2

A subsequent clause allows the large table to use the PRODUCT_ID index:

```
select   product.name, product_lines.qty
from     product, product_lines
where    product.product_id = product_lines.product_id
and      product lines.product id = 4488;
```

EXPLAIN PLAN Output

```
SELECT STATEMENT
  MERGE JOIN
    TABLE ACCESS BY INDEX ROWID PRODUCT
      INDEX RANGE SCAN PRODUCT_ID1
     BUFFER SORT
      TABLE ACCESS BY INDEX ROWID PRODUCT_LINES
        INDEX RANGE SCAN PRODUCT1
```

The order of the tables in the FROM clause can be reversed, as shown here:

```
select   product.name, product_lines.qty
from     product_lines, product
where    product.product_id = product_lines.product_id
and      product lines.product id = 4488;
```

EXPLAIN PLAN Output

```
SELECT STATEMENT
  MERGE JOIN
    TABLE ACCESS BY INDEX ROWID PRODUCT
      INDEX RANGE SCAN PRODUCT_ID1
    BUFFER SORT
      TABLE ACCESS BY INDEX ROWID PRODUCT_LINES
        INDEX RANGE SCAN PRODUCT1
```

Example 2 Outcomes

When a subsequent condition on PRODUCT_ID on the large table exists, the larger table is always the driving table regardless of the order in the FROM clause. The order of the tables in the FROM clause does not alter the order in which Oracle performs this join unless an ORDERED hint is used. In Example 2, a SORT-MERGE join is executed. For this example, a HASH join is also possible.

TIP
Using cost-based optimization, when a large and small table are joined, the larger table is the driving table if an index can be used on the large table. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table.

Example 3

A subsequent clause, shown in the following listing, allows the small table to use the PRODUCT_ID index. The large table still drives the query after getting this condition (on PRODUCT_ID) passed to it by the join. Oracle is smart enough to figure out that PRODUCT_ID exists in both tables and it is more efficient to limit the PRODUCT_LINES table. In the upcoming section "Three-Table Joins: Not as Much Fun," Oracle's excellent internal processing to improve queries will become more evident.

```
select  product.name, product_lines.qty
from    product, product_lines
where   product.product_id = product_lines.product_id
and     product.product id = 4488;
```

EXPLAIN PLAN Output

```
SELECT STATEMENT
  MERGE JOIN
    TABLE ACCESS BY INDEX ROWID PRODUCT
      INDEX RANGE SCAN PRODUCT_ID1
     BUFFER SORT
      TABLE ACCESS BY INDEX ROWID PRODUCT_LINES
        INDEX RANGE SCAN PRODUCT1
```

The order of the tables in the FROM clause can be reversed, as shown here:

```
select  product.name, product_lines.qty
from    product_lines, product
where   product.product_id = product_lines.product_id
and     product.product id = 4488;
```

EXPLAIN PLAN Output

```
SELECT STATEMENT
  MERGE JOIN
    TABLE ACCESS BY INDEX ROWID PRODUCT

  INDEX RANGE SCAN PRODUCT_ID1
 BUFFER SORT
TABLE ACCESS BY INDEX ROWID PRODUCT_LINES
  INDEX RANGE SCAN PRODUCT1
```

Example 3 Outcomes

When a subsequent condition on PRODUCT_ID on the small table exists, the larger table gets this condition passed to it via the join and is *still* the driving table. The order of the tables in the FROM clause does not alter the procedure unless an ORDERED hint is used. For this example, a HASH join is also possible.

Summary

The examples in this section demonstrate the value of some of the optimizer's behavior. The optimizer almost always chooses how to drive a query correctly, but sometimes it must be corrected for a given query. It chooses the right path in most situations.

Three-Table Joins: Not as Much Fun

In a three-table join, Oracle joins two of the tables and joins the result with the third table.

When the query in the following listing is executed, the EMP, DEPT, and ORDERS tables are joined together, as illustrated in Figure 9-5.

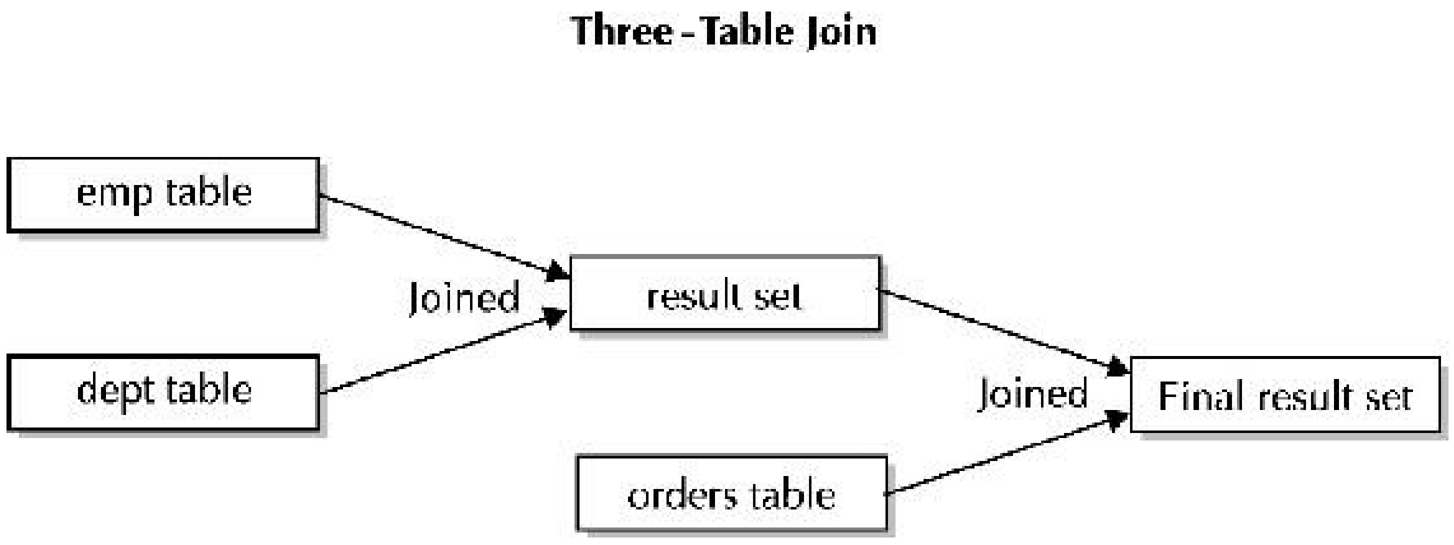


FIGURE 9-5. *A three-table join*

```
select  /*+ ORDERED */ ENAME, DEPT.DEPTNO, ITEMNO
from    EMP, DEPT, ORDERS
where   emp.deptno = dept.deptno
and     emp.empno = orders.empno;
```

Which table is the driving table in a query? People often give different answers, depending on the query that accesses the PLAN_TABLE. This query would drive with the EMP table accessed first, the DEPT table accessed second, and the ORDERS table accessed third (there are always exceptions to the rule).

This next listing shows a query that has only one possible way to be accessed (the subqueries must be accessed first) and a query to the PLAN_TABLE that will be used for the remainder of this chapter. This listing is provided to ensure that you understand how to read the output effectively.

```
explain plan for
 select     cust_last_name, cust_first_name
 from       customers
 where      customer_id =
   (select  customer_id
    from     order_lines
    where    quantity = 1
    and      product_id =
     (select  p.product_id
      from     product_information p
      where    p.product_id = 807
      and      product_description = 'test'));
```

The following listing is a quick and simple EXPLAIN PLAN query (given the PLAN_TABLE is empty). Throughout this chapter, I show many of these, but I also show the output using AUTOTRACE (`SET AUTOTRACE ON`) and TIMING (`SET TIMING ON`).

```
select    lpad(' ',2*level)||operation oper, options, object_name
from      plan_table
connect   by prior id = parent_id
start     with id = 1
order by  id;
```

EXPLAIN PLAN Output

Next, you can see abbreviated EXPLAIN PLAN output. (Additional EXPLAIN PLAN information can be found in Chapter 6.)

```
OPER                       OPTIONS                      OBJECT_NAME
------------------     --------------------         --------------
TABLE ACCESS               BY INDEX ROWID               CUSTOMERS
  INDEX                    RANGE SCAN                   CUSTOMERS_IDX1
    TABLE ACCESS           BY INDEX ROWID               ORDER_LINES
      INDEX                RANGE SCAN                   ORDER_LINES_IDX1
        TABLE ACCESS       BY INDEX ROWID               PRODUCT_INFORMATION
          INDEX            RANGE SCAN                   PRODUCT_INFORMATION_IDX1
```

The order of access is PRODUCT_INFORMATION, ORDER_LINES, and CUSTOMERS. The innermost subquery (to the PRODUCT_INFORMATION table) must execute first so it can return the PRODUCT_ID to be used in the ORDER_LINES table (accessed second), which returns the

CUSTOMER_ID that the CUSTOMERS table (accessed third) needs.

TIP
To ensure that you are reading your EXPLAIN PLAN correctly, run a query in which you are sure of the driving table (with nested subqueries).

One exception to the previous subquery is shown here:

```
explain plan for
select     cust_last_name, cust_first_name
 from       customers
 where      customer_id =
   (select  customer_id
    from     order_lines o
    where    o.product_id = 807
    and      quantity = 1
    and      o.product_id =
     (select  p.product_id
      from     product_information p
      where    p.product_id = 807
      and      product_description = 'test'));
```

EXPLAIN PLAN Output

```
OPER                    OPTIONS         OBJECT_NAME
----------------        -----------     --------------
  TABLE ACCESS          BY INDEX ROWID  CUSTOMERS
    INDEX               RANGE SCAN      CUSTOMERS_IDX1
      FILTER
        TABLE ACCESS    BY INDEX ROWID  ORDER_LINES
            INDEX         RANGE SCAN      ORDER_LINES_IDX1
        TABLE ACCESS    BY INDEX ROWID  PRODUCT_INFORMATION
          INDEX         RANGE SCAN      PRODUCT_INFORMATION_IDX1
```

The expected order of table access is based on the order in the FROM clause: PRODUCT_INFORMATION, ORDER_LINES, and CUSTOMERS. The actual order of access is ORDER_LINES, PRODUCT_INFORMATION, and CUSTOMERS. The ORDER_LINES query takes the PRODUCT_ID from the subquery to the PRODUCT_INFORMATION table and executes first (Oracle is very efficient).

Bitmap Join Indexes

Oracle changes the boundaries of relational database design and implementation with the addition of new indexing features. The bitmap join index allows you to build a single index across the joined columns of two tables. The ROWIDs from one table are stored along with the matching values from the other table. This feature is an incredible performance gold mine, as was the case of the function-based index, and it is as powerful as the designer, developer, or DBA who implements it. This section focuses on the bitmap join index.

Bitmap Indexes

To fully appreciate where a bitmap join index is helpful, it is important to understand a bitmap index. Bitmap indexes are most helpful in a data warehouse environment because they are generally great (fast) when you are only selecting data. A bitmap index is smaller than a b-tree index because it stores only the ROWID and a series of bits. In a bitmap index, if a bit is set, it means that a row in the corresponding ROWID (also stored) contains a key value. For example, consider the EMP table with two new columns indicating gender and marital status:

EMPNO	GENDER (M/F)	MARRIED (Y/N)
1001	F	Y
1002	F	Y
1003	F	N
1004	M	N
1005	M	Y

The bitmaps stored may be the following (the actual storage depends on the algorithm used internally, which is more complex than this example):

EMPNO=	GENDER=F	MARRIED=Y
1001	1	1
1002	1	1
1003	1	0
1004	0	0
1005	0	1

As you can tell from the preceding example, finding all of the females by searching for the gender bit set to a ‘1’ in the example would be easy. You can similarly find all of those who are married or even quickly find a combination of gender and marital status. Oracle stores ranges of rows for each bitmap as well, which is why bitmaps don’t do well when you update the bitmap-indexed column (as you can lock an entire range of rows).

You should use b-tree indexes when columns are unique or near-unique; you should at least consider bitmap indexes in all other cases. Although you generally would *not* use a b-tree index when retrieving 40 percent of the rows in a table, using a bitmap index generally makes this task faster than doing a full table scan. Using an index in this situation is seemingly in violation of the 80/20 or 95/5 rules, which are generally to use an index when retrieving 5–20 percent or less of the data and to do a full table scan when retrieving more. Bitmap indexes are smaller and work differently than b-tree indexes, however. You can use bitmap indexes even when retrieving a large percentage (20–80 percent) of a table. You can also use bitmaps to retrieve conditions based on NULLs (because NULLs are also indexed), and can be used for not-equal conditions for the same reason. The best way to find out is to test!

Bitmap Index Caveats

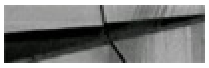
Bitmap indexes do not perform well in a heavy DML (UPDATE, INSERT, DELETE) environment and generally are not used in certain areas of an OLTP environment. There is a heavy cost if you are doing a lot of DML, so be very careful with this. Applying NOT NULL constraints and fixed-length columns allows bitmaps to use less storage, so a good designer is once again worth his or her weight in gold. Use the INDEX_COMBINE hint instead of the INDEX hint or AND_EQUAL hint for bitmap indexes. Like b-tree indexes, bitmap indexes should be rebuilt (ALTER INDEX … REBUILD) if there is a lot of DML activity. Bitmaps are very good for multicolumn read-only indexes that together make a reasonably selective value but separately do not. These columns when indexed together, if often used together in a WHERE clause, are a good choice for a bitmap.

Bitmap Join Index

In a typical business relational database, you are often joining the same two or three tables over and over. The bitmap join index can give you substantial gains when properly applied to many of these circumstances. In a bitmap join index, the ROWIDs from one table are stored along with the indexed column from the joined table. The bitmap join index in Oracle is a lot like building a single index across two tables. You must build a primary key or unique constraint on one of the tables. When you are looking for information from just the columns in the index or a count, then you will be able to access the single join index. Let’s look at a very simple example to learn how to use it. Then I’ll show you how to apply it to multiple columns and multiple tables.

Example 1

Let’s create two sample tables from our friendly EMP and DEPT tables, as shown in this listing:



```
create table emp1
as select * from scott.emp;

create table dept1
as select * from scott.dept;
```

You must then add a unique constraint (or have a primary key) to the DEPT1 table to use this type of index. You can then create the bitmap index on the EMP1 table that includes the columns of both tables.

```
alter table dept1
add constraint dept_constr1 unique (deptno);
Table altered.

create bitmap index empdept_idx
on emp1(dept1.deptno)
from emp1, dept1
where emp1.deptno = dept1.deptno;
Index created.
```

You are now storing the ROWID to the DEPT1 table in the bitmap index that maps to the DEPTNO column in the EMP1 table. To test how well this works, you can perform a simple `count(*)` of the intersection rows between the two tables (you would generally have additional limiting conditions), forcing the use of the bitmap index with an INDEX hint:

```
select /*+ index(emp1 empdept_idx) */ count(*)
from   emp1, dept1
where  emp1.deptno = dept1.deptno;

COUNT(*)
---------------
14

Elapsed: 00:00:00.01

Execution Plan (Explain plan)

---------------------------------------------------------
  0    SELECT STATEMENT
  1  0   SORT (AGGREGATE)
  2  1     BITMAP CONVERSION (COUNT)
  3  2       BITMAP INDEX (FULL SCAN) OF 'EMPDEPT_IDX'
```

You can see from the preceding EXPLAIN PLAN output that the bitmap index was used; alternatively, you could use `SET AUTOTRACE ON` while in SQL*Plus to get the following output:

```
Execution Plan (Autotrace)
-----------------------------------------------------------
Plan hash value: 1200569923

-----------------------------------------------------------------------------
| Id  | Operation                   | Name         |Rows|Bytes|Cost(%CPU|Time     |
-----------------------------------------------------------------------------
|   0 | SELECT STATEMENT            |              |  1  |   3 |    1   (0)|00:00:01|
|   1 |  SORT AGGREGATE             |              |  1  |   3 |           |        |
|   2 |   BITMAP CONVERSION COUNT   |              | 15  |  45 |    1   (0)|00:00:01|
|   3 |    BITMAP INDEX FULL SCAN   |EMPDEPT_IDX   |     |     |           |        |
-----------------------------------------------------------------------------
```

Although this simplistic example shows how to count an index (instead of the table) and applies some benefits of the bitmap join index, the next section explores better uses of the bitmap join index by manipulating columns outside the join in the index.

Best Uses for the Bitmap Join Index

Example 1 in the previous section shows a basic use of the bitmap join index, focusing on just the joined columns. The next three sections show targeted areas where you may discover better uses for bitmap join indexes.

Bitmap Join Indexes on Columns Other Than the Join

Consider this example where the EMP1 and DEPT1 tables are once again joined on the DEPTNO column. In this example, you want to index the LOC column instead of the join column. This allows you to select the LOCATION column from the DEPT1 table by directly accessing only the index and the EMP1 table. Remember, the join condition must be on the primary key or unique column. The example in the following listing assumes that the unique constraint on DEPT1.DEPTNO from the example in the earlier listing (where I added a unique constraint to the DEPT1 table) exists.

```
Create bitmap index emp_dept_location
on    emp1 (dept1.loc)
from  emp1, dept1
where emp1.deptno = dept1.deptno;
```

The query shown next can now use the bitmap join index appropriately:

```
select emp1.empno, emp1.ename, dept1.loc
from   emp1, dept1
where  emp1.deptno = dept1.deptno;
```

Bitmap Join Indexes on Multiple Columns

Consider an example where you want an index on multiple columns. The syntax is still the same, but now you include multiple columns in the index. The next example assumes that the unique constraint on DEPT1.DEPTNO from the example in the earlier listing (where I added a unique constraint to the DEPT1 table) exists.

```
create bitmap index emp_dept_location_deptname
on     emp1 (dept1.loc, dept1.dname)
from   emp1, dept1
where  emp1.deptno = dept1.deptno;
```

The query in the following listing is able to use the bitmap join index appropriately:

```
select emp1.empno, emp1.ename, dept1.loc, dept1.dname
from   emp1, dept1
where  emp1.deptno = dept1.deptno;
```

Bitmap Join Indexes on Multiple Tables

As you become more familiar with using the bitmap join index, you will be able to solve complex business problems that involve multiple tables. The following example shows how to apply the bitmap join index to multiple tables. The syntax is still the same, but it has now been expanded to include multiple columns in the index and multiple tables being joined for the index. The example shown next assumes that the unique constraint on DEPT1.DEPTNO from the example in the earlier listing (where I added a unique constraint to the DEPT1 table) exists and, additionally, that it exists on SALES1.EMPNO (creation not shown).

```
Create bitmap index emp_dept_location_ms
on     emp1 (dept1.loc, sales1.marital_status)
from   emp1, dept1, sales1
where  emp1.deptno = dept1.deptno
and    emp1.empno = sales1.empno;
```

The query in this next listing is now able to use the bitmap join index appropriately:

```
select emp1.empno, emp1.ename, dept1.loc, sales1.marital status
from   emp1, dept1, sales1
where  emp1.deptno = dept1.deptno
and    emp1.empno = sales1.empno;
```

Bitmap Join Index Caveats

Because the result of the join is stored, only one table can be updated concurrently by different transactions, and parallel DML is supported only on the fact table. Parallel DML on the dimension table marks the index as unusable. No table can appear twice in the join, and you can't create a bitmap join index on an index-organized table (IOT) or a temporary table.

Another Nice Use for the Bitmap Join Index

A nice tuning trick when you are counting rows is to try to count the index instead of the table. Consider the following large-table example used for counting. These tables each contain roughly 2 million rows, so that you can see the possible impact on a larger scale. The new tables, EMP5 and EMP6, each have 2 million rows with EMPNO indexes on them.

To add the constraint and run a join without the bitmap index:

```
alter table emp5
add constraint emp5 constr unique (empno);

select count(*)
from emp5, emp6
where emp5.empno-emp6.empno;

COUNT(*)

------------------
2005007
Elapsed: 00:01:07.18

Execution Plan
----------------------------------------------------------
   0     SELECT STATEMENT
   1   0    SORT (AGGREGATE)
   2   1      NESTED LOOPS
   3   2        TABLE ACCESS (FULL) OF 'EMP6'
   4   2        INDEX (RANGE SCAN) OF 'EMP5I_EMPNO' (NON UNIQUE)

Statistics
----------------------------------------------------------
6026820  consistent gets
7760  physical reads
```

There is an index on the EMP5 table, but there is no correlation or index back to the EMP6 table because the index on EMP6 contains only EMPNO as the second part of a concatenated index. The result is a relatively slow query.

If you make EMPNO the only part or the leading part of the concatenated index, you solve this problem. Use the new bitmap join index, as shown here:

```
create bitmap index emp5_j6
on emp6(emp5.empno)
from emp5,emp6
where emp5.empno=emp6.empno;

Index created.

Elapsed: 00:02:29.91

select /*+ index(emp6 emp5_j6) */ count(*)
from emp5, emp6
where emp5.empno=emp6.empno;

COUNT(*)
------------------
2005007

Elapsed: 00:00:00.87

Execution Plan
----------------------------------------------------------
0   SELECT STATEMENT
1   0   SORT (AGGREGATE)
2   1   BITMAP CONVERSION (COUNT)
3   2   BITMAP INDEX (FULL SCAN) OF 'EMP5_J6'

Statistics
----------------------------------------------------------
970  consistent gets
967  physical reads
```

Performing a count of the bitmap join index makes this very fast. I chose this example for a reason. The real problem with the original slow query was not that it took a minute to execute, but that it performed over 6 million memory block reads and over 7000 disk block reads. You may not receive any wait events, but you have a poorly written query that will cause problems when you have volumes of users on the system. Take a step up to expert level by finding queries with large memory and disk reads and start doing proactive tuning now so you don't get to wait states and need to tune things reactively. Using a bitmap join index is one way to improve performance.

Third-Party Product Tuning

Sometimes, you are at the mercy of a third-party product. Although you cannot modify the code, you can often modify the use of indexes. The following three examples are from a third-party financial product.

Example 1

This query took 22 minutes to run. By providing a hint (using SQL Plan Management) to use a more efficient index, I reduced the query execution time to 15 seconds.

This next listing shows the query before the hint was added:

```
update PS_COMBO_DATA_TBL
set    EFFDT_FROM = TO_DATE ('1990-01-01', 'YYYY-MM-DD'),
       EFFDT_TO = TO_DATE ('2099-01-01', 'YYYY-MM-DD')
where  SETID = 'RRD'
and    PROCESS_GROUP = 'GROUP1'
and    COMBINATION = 'ACCT/NOLOC'
and    VALID_CODE = 'V'
and    EFFDT_OPEN = 'Y'
and    EXISTS
 (select  'X'
  from     PS_JRNL_LN
  where    BUSINESS_UNIT = '00003'
  and      PROCESS_INSTANCE = 0000085176
  and      JRNL_LINE_STATUS = '3'
  and      ACCOUNT = PS_COMBO_DATA_TBL.ACCOUNT
  and      PRODUCT = PS_COMBO_DATA_TBL.PRODUCT );
```

Now, here's the query after the index hint was added:

```
update   PS_COMBO_DATA_TBL
set      EFFDT_FROM = TO_DATE ('1990-01-01', 'YYYY-MM-DD'),
         EFFDT_TO = TO_DATE ('2099-01-01', 'YYYY-MM-DD')
where    SETID = 'RRD'
and      PROCESS_GROUP = 'GROUP1'
and      COMBINATION = 'ACCT/NOLOC'
and      VALID_CODE = 'V'
and      EFFDT_OPEN = 'Y'
and      EXISTS
 (select     /*+ INDEX(PS_JRNL_LN PSGJRNL_LN) */ 'X'
  from       PS_JRNL_LN
  where      BUSINESS_UNIT = '00003'
  and        PROCESS_INSTANCE = 0000085176
  and        JRNL_LINE_STATUS = '3'
  and        ACCOUNT = PS_COMBO_DATA_TBL.ACCOUNT
  and        PRODUCT = PS_COMBO_DATA_TBL.PRODUCT );
```

Example 2

The query in the next listing was taking 33 minutes to run. By creating a concatenated index on the PS_GROUP_CONTROL table (columns: DEPOSIT_BU, DEPOSIT_ID, PAYMENT_SEQ_NUM), I reduced the query execution time to 30 seconds, as shown here:

```
select     C.BUSINESS_UNIT, C.CUST_ID, C.ITEM,
           C.ENTRY_TYPE, C.ENTRY_REASON, C.ENTRY_AMT,
           C.ENTRY_CURRENCY, C.ENTRY_AMT_BASE,
           C.CURRENCY_CD, C.POSTED_FLAG, D.PAYMENT_SEQ_NUM
from       PS_PENDING_ITEM C,
           PS_GROUP_CONTROL D
where      D.DEPOSIT_BU = :1
and        D.DEPOSIT_ID = :2
and        D.PAYMENT_SEQ_NUM = :3
and        D.GROUP_BU = C.GROUP_BU
and        D.GROUP_ID = C.GROUP_ID
order by   D.PAYMENT_SEQ_NUM;
```

Here is the EXPLAIN PLAN before the index was added:

```
Execution Plan
   SELECT STATEMENT
     SORT ORDER BY
       NESTED LOOPS
        ANALYZED TABLE ACCESS FULL PS_GROUP_CONTROL
         ANALYZED TABLE ACCESS BY ROWID PS PENDING ITEM
          ANALYZED INDEX RANGE SCAN PS PENDING ITEM
```

And here's the EXPLAIN PLAN after the index was added:

```
Execution Plan
   SELECT STATEMENT
     SORT ORDER BY
       NESTED LOOPS
        ANALYZED TABLE ACCESS BY ROWID PS GROUP CONTROL
           INDEX RANGE SCAN PSAGROUP_CONTROL
         ANALYZED TABLE ACCESS BY ROWID PS PENDING ITEM
          ANALYZED INDEX RANGE SCAN PS PENDING ITEM
```

Example 3

The query shown next was taking 20 minutes to run and was reduced to 30 seconds. To achieve this, I created a concatenated unique index on the PS_CUST_OPTION table (columns: CUST_ID, EFFDT) instead of the current index, which is only on CUST_ID. This forces Oracle to use a concatenated unique index rather than a single-column index, as shown here:

```
INSERT INTO PS_PP_CUST_TMP  (PROCESS_INSTANCE,
 DEPOSIT_BU, DEPOSIT_ID, PAYMENT_SEQ_NUM, CUST_ID,
 PAYMENT_AMT, PAYMENT_DT, PP_METHOD, SETID,
 SUBCUST_QUAL1, SUBCUST_QUAL2, PP_HOLD, PP_MET_SW,
 PAYMENT_CURRENCY)
select   DISTINCT P.PROCESS_INSTANCE, P.DEPOSIT_BU,
         P.DEPOSIT_ID, P.PAYMENT_SEQ_NUM, C.CUST_ID,
         P.PAYMENT_AMT, P.PAYMENT_DT, O.PP_METHOD,
         O.SETID, C.SUBCUST_QUAL1, C.SUBCUST_QUAL2,
         O.PP_HOLD, 'N', P.PAYMENT_CURRENCY
from     PS_CUST_OPTION O, PS_CUSTOMER C, PS_ITEM I,
         PS_SET_CNTRL_REC S, PS_PAYMENT_ID_ITEM X,
         PS_PP_PAYMENT_TMP P
where    P.PROCESS_INSTANCE = 85298
and      S.SETCNTRLVALUE = I.BUSINESS_UNIT
and      I.CUST_ID = C.CUST_ID
and      I.ITEM_STATUS = 'O'
and      (X.REF_VALUE = I.DOCUMENT
or       SUBSTR (X.REF_VALUE, 3, 7)
         = SUBSTR (I.DOCUMENT, 4, 7))
and      S.RECNAME = 'CUSTOMER'
and      S.SETID = C.SETID

and      O.SETID = C.REMIT_FROM_SETID
and      O.CUST_ID = C.REMIT_FROM_CUST_ID
and      O.EFFDT =
      (select  MAX (X.EFFDT)
      from  PS_CUST_OPTION X
      where  X.SETID = O.SETID
      and  X.CUST_ID = O.CUST_ID
      and  X.EFF_STATUS = 'A'
      and  X.EFFDT <= P.PAYMENT_DT)
and      O.PP_METHOD <> ' '
and      P.DEPOSIT_BU = X.DEPOSIT_BU
and      P.DEPOSIT_ID = X.DEPOSIT_ID
and      P.PAYMENT_SEQ_NUM = X.PAYMENT_SEQ_NUM
and      X.REF_QUALIFIER_CODE = 'D';
```

Here's the EXPLAIN PLAN before the index was added:

```
Execution Plan
   INSERT STATEMENT
     SORT UNIQUE
       NESTED LOOPS
         NESTED LOOPS
           NESTED LOOPS
             NESTED LOOPS
               NESTED LOOPS
                ANALYZED TABLE ACCESS BY ROWID PS_PP_PAYMENT_TMP
                 ANALYZED INDEX RANGE SCAN PSAPP_PAYMENT_TMP
                ANALYZED INDEX RANGE SCAN PSAPAYMENT_ID_ITEM
                 ANALYZED INDEX RANGE SCAN PSDSET_CNTRL_REC
             ANALYZED INDEX RANGE SCAN PSEITEM
            ANALYZED TABLE ACCESS BY ROWID PS_CUSTOMER
             ANALYZED INDEX UNIQUE SCAN PS_CUSTOMER
          ANALYZED TABLE ACCESS BY ROWID PS_CUST_OPTION
           ANALYZED INDEX RANGE SCAN PSACUST_OPTION
        SORT AGGREGATE
         ANALYZED TABLE ACCESS BY ROWID PS_CUST_OPTION
           ANALYZED INDEX RANGE SCAN PSACUST_OPTION
```

Here's the EXPLAIN PLAN after the index was added:

```
Execution Plan
   INSERT STATEMENT
     SORT UNIQUE
       NESTED LOOPS
         NESTED LOOPS
           NESTED LOOPS
             NESTED LOOPS
               NESTED LOOPS
                   ANALYZED TABLE ACCESS BY ROWID PS_PP_PAYMENT_TMP
                     ANALYZED INDEX RANGE SCAN PSAPP_PAYMENT_TMP
                   ANALYZED INDEX RANGE SCAN PSAPAYMENT_ID_ITEM

     ANALYZED INDEX RANGE SCAN PSDSET_CNTRL_REC
   ANALYZED INDEX RANGE SCAN PSEITEM
 ANALYZED TABLE ACCESS BY ROWID PS_CUSTOMER
   ANALYZED INDEX UNIQUE SCAN PS_CUSTOMER
 ANALYZED TABLE ACCESS BY ROWID PS_CUST_OPTION
   ANALYZED INDEX RANGE SCAN PS_CUST_OPTION
SORT AGGREGATE
  ANALYZED TABLE ACCESS BY ROWID PS_CUST_OPTION
    ANALYZED INDEX RANGE SCAN PS_CUST_OPTION
```

TIP

You may not be able to modify actual code for some third-party products, but you can often add, force, or suppress indexes (using SQL Plan Management) to improve performance.

Tuning Distributed Queries

When improperly written, distributed queries can sometimes be disastrous and lead to poor performance. In particular, a NESTED LOOPS join between two row sources on separate nodes of a distributed database can be very slow because Oracle moves all the data to the local machine (depending on how the query is written). The following listing shows a simple distributed query and its execution plan. This query is slow because, for each row retrieved from the CUSTOMERS table, a separate query is dispatched to the remote node to retrieve records from the BOOKINGS table. This results in many small network packets moving between the two database nodes, and the network latency and overhead degrade performance.

```
select    customer_id, customer_name, class_code
from      customers cust
where     exists
(select    1
from       bookings@book bkg
where      bkg.customer_id = cust.customer_id
and        bkg.status = 'OPEN' )
order by   customer_name;
```

The following is the TKPROF output (note that TKPROF still works in 11*g* and is located in $ORACLE_HOME/bin):

```
Call      count    cpu      elapsed    disk    query    current    rows
Parse     1        0.00     0.01       0       0        0          0
Execute   1        0.00     0.00       0       0        0          0
Fetch     156      0.41     11.85      0       476      2          155
total     158      0.41     11.86      0       476      2          155

Rows   Execution Plan
0      SELECT STATEMENT  GOAL: CHOOSE
155      SORT (ORDER BY)
467        FILTER
```

```
467        TABLE ACCESS  GOAL: ANALYZED (FULL) OF 'CUSTOMERS'
0            REMOTE [BOOK.WORLD]
               SELECT "CUSTOMER_ID","STATUS" FROM "BOOKINGS" BKG WHERE
                 "STATUS"='open' AND "CUSTOMER_ID"=:1
```

The query in the preceding listing can be rewritten in a form that causes less network traffic. In the next listing, one query is sent to the remote node to determine all customers with open bookings. The output is the same, but performance is greatly improved. Both versions of the query use roughly the same CPU time and logical I/Os on the local node, but the elapsed time is about 97 percent better here. This gain is attributable to reduced network overhead.

```
select    customer_id, customer_name, class_code
from      customers
where     customer_id in
(select   customer_id
from      bookings@book
where     status = 'OPEN' )
order by  customer_name;
```

Here is the TKPROF output:

```
Call      count     cpu      elapsed     disk     query     current     rows
Parse     1         0.00     0.01        0        0         0           0
Execute   1         0.00     0.00        0        0         0           0
Fetch     156       0.07     0.27        0        467       0           155
total     158       0.07     0.28        0        467       0           155

Rows  Execution Plan
0     SELECT STATEMENT  GOAL: CHOOSE
155     SORT (ORDER BY)
155      NESTED LOOPS
156       VIEW
1000       SORT (UNIQUE)
1000        REMOTE [BOOK.WORLD]
              SELECT "CUSTOMER_ID","STATUS" FROM "BOOKINGS" BOOKINGS WHERE
                "STATUS"='open'
155         TABLE ACCESS  GOAL: ANALYZED (BY ROWID) OF 'CUSTOMERS'
156         INDEX  GOAL: ANALYZED (UNIQUE SCAN) OF 'SYS C002139'
                  (UNIQUE)
```

When distributed queries cannot be avoided, use IN clauses, set operators such as UNION and MINUS, and use everything else you can to reduce the network traffic between nodes of the database. Views that limit the records in a table can also improve performance by reducing what is sent from the remote client to the local client.

TIP
When distributed queries cannot be avoided, use IN clauses, set operators such as UNION and MINUS, and use everything else you can to reduce the network traffic between database nodes. Queries written in a manner that causes looping between distributed nodes (distributed databases) can be extremely slow.

When You Have Everything Tuned

If you have successfully tuned all of *your* queries, then you can start working on those that go to the data dictionary views. Is it possible to get tuning tips or techniques from looking at data dictionary queries and how they are structured? The answer is yes! You can see them in the SQL_TRACE output. The next example shows that even Oracle's own views have some highly complex joining schemes (note that this process has one less step than 10*g* required, and it still takes a fraction of a second and only 37 memory reads):

```
select  *
from    dba_ind_columns
where   table_name = 'PRODUCT_LINES';
```

The execution plan output is as follows:

```
| Id  | Operation                      | Name      |
--------------------------------------------------------
|   0 | SELECT STATEMENT               |           |
|   1 |  NESTED LOOPS OUTER            |           |
|   2 |  TABLE ACCESS BY INDEX ROWID   | COL$      |
|*  3 |  INDEX UNIQUE SCAN             | I_COL3    |
|*  4 |  TABLE ACCESS CLUSTER          | ATTRCOL$  |
|   5 |  NESTED LOOPS                  |           |
|   6 |  NESTED LOOPS                  |           |
|   7 |  NESTED LOOPS OUTER            |           |
|   8 |  NESTED LOOPS                  |           |
|   9 |  NESTED LOOPS                  |           |
|  10 |  NESTED LOOPS                  |           |
|  11 |  NESTED LOOPS                  |           |
|* 12 |  INDEX SKIP SCAN               | I_OBJ2    |
|  13 |  TABLE ACCESS CLUSTER          | ICOL$     |
|* 14 |  INDEX UNIQUE SCAN             | I_OBJ#    |
|  15 |  TABLE ACCESS BY INDEX ROWID   | OBJ$      |
|* 16 |  INDEX RANGE SCAN              | I_OBJ1    |
|* 17 |  TABLE ACCESS BY INDEX ROWID   | IND$      |
|* 18 |  INDEX UNIQUE SCAN             | I_IND1    |
|* 19 |  TABLE ACCESS CLUSTER          | COL$      |
|* 20 |  TABLE ACCESS CLUSTER          | ATTRCOL$  |
|  21 |  TABLE ACCESS CLUSTER          | USER$     |
|* 22 |  INDEX UNIQUE SCAN             | I_USER#   |
|  23 |  TABLE ACCESS CLUSTER          | USER$     |
|* 24 |  INDEX UNIQUE SCAN             | I_USER#   |
```

Miscellaneous Tuning Snippets

The issues covered in this section will help the advanced DBA. I'll discuss external tables, consider the "Snapshot Too Old" issue along with how to set the event to dump every wait, and explore what's really going on by performing block dumps.

External Tables

External tables allow you to access data that is not inside the database. Relational databases took off in the 1980s because of the ability to access data through relational tables. This was the first move away from mainframes and legacy systems that stored information in flat files or some facsimile of that. Oracle 11*g* continues the next paradigm in relational database technology. External tables extend the relational model beyond the database. Now you have a means by which to access all of the legacy data. You have a way to access all of that information dumped into flat files (perhaps, via third-party products).

One of the most costly parts of the extract, transform, load (ETL) process used for data warehousing and business intelligence is loading data into temporary tables so it can be used with other tables already in the database. Although external tables were introduced primarily to assist in the ETL process, Pandora's box cannot be closed. I have seen a plethora of uses for external tables, and I believe it's just the beginning. If Java and XML were minor aspects integrated into the relational model, the use of external tables brings the entire machine into the database and forever changes the rules of engagement.

This simple example shows you exactly how to use external tables. First, you need a flat file of data to access for the examples. You do this by simply spooling some data from our familiar friend, the EMP table:

```
set head off
set verify off
set feedback off
set pages 0
spool  emp4.dat

select empno||','||ename ||','|| job||','||deptno||','
from   scott.emp;

spool off
set head on
set verify on
set feedback on
set pages 26
```

The following is partial output of the `emp4.dat` file:

```
7369,SMITH,CLERK,20,
7499,ALLEN,SALESMAN,30,
7521,WARD,SALESMAN,30,
7566,JONES,MANAGER,20,
7654,MARTIN,SALESMAN,30,
```

Then you need to create a directory from within SQL*Plus so Oracle knows where to find your external tables:

```
SQL> create directory rich_new as '/u01/home/oracle/rich';

Directory created.
```

You then create the actual table definition that will reference the flat file that resides externally. Note that even if you successfully create the table, access to the external table may not necessarily result in a successful query. If the data is not stored in a way that matches the column definition of your table, you will get an error when you select the actual data. An example of the CREATE TABLE command is shown here:

```
create table emp_external4
(empno char(4), ename char(10), job char(9), deptno char(2))
organization external
 (type oracle_loader
  default directory rich_new
  access parameters
   (records delimited by newline
  fields terminated by ','
   (empno , ename, job, deptno ))
 location ('emp4.dat'))
reject limit unlimited;

SQL> desc emp_external4
Name                                       Null? Type
------------------------------------------ -------- -------------
EMPNO                                               CHAR(4)
ENAME                                               CHAR(10)
JOB                                                 CHAR(9)
DEPTNO                                              CHAR(2)

select  *
from    emp_external4;

EMPNO     ENAME            JOB            DEPTNO
--------  --------------   ------------   --------------
7369      SMITH            CLERK          20
7499      ALLEN            SALESMAN       30
7521      WARD             SALESMAN       30
...
```

There is currently no support for DML (INSERT, UPDATE, DELETE) commands, but you can always do this outside the database because the data is in a flat file. By using shell scripting, as shown next, you can certainly replicate those commands. Although you can’t create an index currently, external tables are pleasantly and surprisingly fast.

```
SQL> insert into emp_external4 ...;
            *
ERROR at line 1:
ORA-30657: operation not supported on external organized table

SQL> create index emp ei on emp external4(deptno);
                       *
ERROR at line 1:
ORA-30657: operation not supported on external organized table
```

To count records, you can either use the Unix command or do it within the database. Either way, you have a means to work with data in flat files that are not within the database. This next listing is the `wc` (word count) command with the `-l` option, which indicates to count the lines. This is a simple Unix command for counting records in a flat file. I created a file with 200,020 rows for the next more intensive test.

```
$ wc -l emp4.dat
  200020  200020 4400400 emp4.dat
$ ls -l emp4.dat
-rwxr-xr-x  1 oracle  oinstall 4400400 Aug  9 06:31 emp4.dat
```

You can also count the records in the flat file using SQL, since you've now built an external table. The command shown next takes less than one second to return its result:

```
select count(*)
from  emp_external4;

  COUNT(*)
----------
    200020
Elapsed: 00:00:00.63
```

Once you know you can count records in less than one second, you press on to look for specific information. Can you count selective pieces of data that fast? Yes. The code in the next listing looks for specific employee numbers (EMPNO) from the flat file, which is now referenced via an external table. The result is returned once again in less than one second.

```
select  count(*)
from    emp_external4
where   empno=7900;

  COUNT(*)
----------
        20
Elapsed: 00:00:00.82
```

Once you know you can scan through 200,000 records in less than one second (on a single-processor machine in my case), you want to see how fast you can scan through millions of records. The example shown next builds a second table and joins it with the first so you can test scanning through 4 million rows. The result is less than 3 seconds to scan through this massive amount of data using only modest hardware.

```
create table emp_external5
(empno char(4), ename char(10), job char(9), deptno  char(2))
organization external
    ...
location ('emp5.dat'));
```

Now you join the two 200,000-row tables to create a join that merges the 20 rows in the first result set with the 20 rows of the second table, as shown next. This results in a join accessing 4 million rows with a result set of 400 rows. The result is an answer in less than 3 seconds.

```
select a.empno, b.job, a.job
from   emp_external4 a, emp_external5 b
where  a.empno = b.empno
and    a.empno = 7900
and    b.empno = 7900;

400 rows selected.
Elapsed: 00:00:02.46
```

Here is the execution plan for the previous join:

```
Execution Plan
-----------------------------------------------------------
   0     SELECT STATEMENT
   1   0   SORT AGGREGATE
   2   1     HASH JOIN
   3   2       EXTERNAL TABLE ACCESS (FULL) OF 'EMP EXTERNAL5'
   4   3       EXTERNAL TABLE ACCESS (FULL) OF 'EMP EXTERNAL4'
```

You can also use hints with external tables, and you can join external tables with regular tables. You can parallelize the operation, and you can even insert the data from the external table directly into the database at any time. The possibilities are endless. External tables are not simply a serious advantage of using Oracle; they are one of the greatest benefits to relational technology in the past decade. They give you the window into the data that is *not* in your database. They allow you to access those legacy systems that have data stored in a multitude of flat files. They provide you the path to consolidate those legacy systems by moving step-by-step into the future.

Consider the quick use for an external table to read the alert file shown in the following listing. The original script for this was written by Dave Moore and passed to me by Howard Horowitz. The following is an alteration of those scripts:

```
SQL> Create directory alert1 as 'c:\app\user\diag\rdbms\orcl\orcl\trace';
Directory created.
SQL> Create table alert_log (text varchar2(200))
Organization EXTERNAL
(Type oracle_loader
Default directory alert1
Access parameters
(Records delimited by newline
Badfile 'rich1.bad'
Logfile 'rich1.log')
Location ('alert_ora.log'))
Reject limit unlimited;
Table created.

select *
from   alert_log
where  rownum < 25;

TEXT
--------------------------------------------------------------------------------
Sun Mar 06 16:45:43 2011
Starting ORACLE instance (normal)
...
Oracle Database 11g Enterprise Edition Release 11.2.0.1.0 - 64bit Production
With the Partitioning, OLAP, Data Mining and Real Application Testing options.
Using parameter settings in client-side pfile
 C:\APP\USER\CFGTOOLLOGS\DBCA\ORCL\INITORCLTEMP.ORA on machine USER-PC
System parameters with non-default values:
  processes                = 150
  memory_target            = 6560M
(partial listing only of selected data)
```

CAUTION

External tables are one of the best Oracle inventions in many versions. Your innovative mind will drive you to new heights using external tables. But be careful: data residing outside the database is not subject to the same Oracle backups and security as data inside the database.

Snapshot Too Old: Developer Coding Issue

Oracle holds undo information in case you need to roll back a transaction and also to keep a read-consistent version of data. Long-running queries may need the read-consistent versions of the data in UNDO segments because they may not be at the same System Change Number (SCN) as the ones currently in memory. (They may have been changed since the start of the query.) If the UNDO segment holding the original data is overwritten, the user receives the dreaded Snapshot Too Old error. With advances in Oracle 11*g*, this error is, indeed, not rare (using automatic undo management), but there is another, more frequent occurrence of the error in the later versions of Oracle.

In their infinite wisdom, developers find wonderful ways to update information that they are querying within the same piece of code causing this problem. They are the ones both querying and updating and causing the Snapshot Too Old error to occur. One flawed developer method is known as the *Fetch Across Commit*. In this method, the developer first selects a large number of rows from a table into a cursor and then fetches the rows to use for an update to the table, committing after a select number (say, every 1000 records) based on a counter. What happens is that the cursor needs a read-consistent image of the table, yet the developer is committing 1000 records within the same code to the table. The result is a Snapshot Too Old error.

TIP
In addition to the more typical reasons, when developers modify the data as it is being selected, fetching across commits, the Snapshot Too Old error can occur. To fix this problem, close and reopen the cursor causing the issue.

Set Event to Dump Every Wait

In Chapter 14, you will learn about two excellent tuning tools that Oracle offers: Statspack and AWR. These are great tools for showing everything in a single report for you to analyze. But what if you have a burning issue and you directly need to dump exactly what the system is doing so you can see every wait on the system? If the compilation of all waits in the V$ views is not enough to solve problems and you need to see the waits in real time, the answer is the very dangerous "Set Event 10046 at the system level." You can also do this at the session level (see Chapter 13 for additional settings beyond this section).

This event dumps every single wait that occurs so you can search through and see exactly what's causing the problem. You should use this strategy *only* as a last resort, and you should rarely use it.

You need a lot of disk space to use it when you have a lot of waits.

When you're ready to dump the problem, here's how to turn it on:

```
Alter system set events '10046 trace name context forever, level 12';

System altered.
```

NOTE

You are also often required to increase the max size of dump files to get all the info you need within the single trace file.

The following listing shows what you'll get (in your DIAGNOSTIC_DEST):

```
Trace file c:\app\user\diag\rdbms\orcl\orcl\trace\orcl_ora_1776.trc
Oracle Database 11g Enterprise Edition Release 11.2.0.1.0 - 64bit Production
With the Partitioning, OLAP, Data Mining and Real Application
----------------------
PARSING IN CURSOR #9 len=61 dep=0 uid=84 oct=3 lid=84 tim=95022706805 hv=2099451087
ad='2f1b1a128' sqlid='8y7yrdiyk656g'
select count(*)
from small2 a, small1 b
where a.empno=b.empno
END OF STMT
PARSE #9:c=0,e=1414,p=0,cr=0,cu=0,mis=1,r=0,dep=0,og=1,plh=1041396182,tim=95022706804
EXEC #9:c=0,e=28,p=0,cr=0,cu=0,mis=0,r=0,dep=0,og=1,plh=1041396182,tim=95022706929
WAIT #9: nam='SQL*Net message to client' ela= 3 driver id=1111838976 #bytes=1 p3=0
obj#=76920 tim=95022706981
... (PARTIAL LISTING - SELECTED LINES ONLY)
```

Although this output shows some irrelevant waits that come up when you quickly turn this on and off, when you have a real problem, the waits will be clear. You are looking for a section with something like the following, which shows a latch free issue. (See Chapter 14 for steps on how to resolve this issue.) When you don't know what you're waiting for, this gives you a slightly more "at the street" level understanding of exactly what's going on than the V$ views do:

```
WAIT #2: nam='latch free' ela= 0 p1=-2147423252 p2=105 p3=0
WAIT #2: nam='latch free' ela= 0 p1=-2147423252 p2=105 p3=1
WAIT #2: nam='latch free' ela= 0 p1=-1088472332 p2=106 p3=0
WAIT #2: nam='latch free' ela= 0 p1=-2147423252 p2=105 p3=0
WAIT #2: nam='latch free' ela= 0 p1=-2147423252 p2=105 p3=1
WAIT #2: nam='latch free' ela= 1 p1=-2147423252 p2=105 p3=2
WAIT #2: nam='latch free' ela= 0 p1=-2147423252 p2=105 p3=0

WAIT #2: nam='latch free' ela= 1 p1=-2147423252 p2=105 p3=1
WAIT #2: nam='latch free' ela= 0 p1=-2147423252 p2=105 p3=0
WAIT #2: nam='latch free' ela= 0 p1=-2147423252 p2=105 p3=1
```

When you have a nice dump of the problem, here's how you turn it off:

```
Alter system set events '10046 trace name context off';

System altered.
```

CAUTION
Using the event 10046 at the system level can give a real-time dump of waits. Be careful because you can use a lot of space very quickly on a very busy system. Only an expert who has the help of Oracle Support should use this method.

14 Hours to 30 Seconds with the EXISTS Operator

Although the Oracle optimizer is very good at ensuring a query is efficient, you can change a multitable join into a query with a subquery using the EXISTS operator. You can only do this if the table to put into the subquery doesn't have anything being selected from it in the SELECT statement. In this example, the goal is to pull one row back to use for test data in a test system:

```
--query with table join
explain plan for
SELECT MEMBER_NO
   , CONTRACT
   , DEP
   , SBSB_CK
   , SBSB_ID
   , GRGR_ID
   , MEME_BIRTH_DT
   , x.MEME_CK
   , MEME_REL
   , MEME_SFX
   , MEME_LAST_NAME
   , MEME_FIRST_NAME
   , to_timestamp('06/01/2006','mm/dd/yyyy')
   , 'PHASE 3'
   , CREATE_WHO
   , CREATE_DT
   , UPDATE_WHO
   , UPDATE_DT FROM PROD_PH.XREF_MEME x
         , PROD.CMC_MEPE_PRCS_ELIG
WHERE x.meme_ck = e.meme_ck
  and rownum = 1;

--Star query plan with B-TREE indexes!
```

```
-----------------------------------------------------------------------------
| Id | Operation              |  Name             | Rows   | Bytes | Cost   |
-----------------------------------------------------------------------------
|  0 | SELECT STATEMENT       |                   |  1272G|  123T  |  274M  |
|  1 |  MERGE JOIN CARTESIAN  |                   |  1272G|  123T  |  274M  |
|  2 |   TABLE ACCESS FULL    | XREF_MEME         |  638K |  65M   |  757   |
|  3 |   BUFFER SORT          |                   |  1991K|        |  274M  |
|  4 |    INDEX FAST FULL SCAN| CMCX_MEPE_SECOND  |  1991K|        |  429   |
-------------------------------------------------------------------------------

-- exists subquery example
SELECT MEMBER_NO
   , CONTRACT
   , DEP
   , SBSB_CK
   , SBSB_ID
   , GRGR_ID
   , MEME_BIRTH_DT
   , x.MEME_CK
   , MEME_REL
   , MEME_SFX
   , MEME_LAST_NAME
   , MEME_FIRST_NAME
   , to_timestamp('06/01/2006>,'mm/dd/yyyy')
   , 'PHASE 3'
   , CREATE_WHO
   , CREATE_DT
   , UPDATE_WHO
   , UPDATE_DT
 FROM PROD_PH.XREF_MEME x
WHERE exists(
         select 0
           from prod.cmc_mepe_prcs_elig e
         where e.meme_ck = x.meme_ck
     )
  and rownum = 1;

---------------------------------------------------------------------------------
| Id | Operation             |  Name              | Rows    | Bytes |TempSpc| Cost |
---------------------------------------------------------------------------------
|  0 | SELECT STATEMENT      |                    |  1      |  112  |       | 5067 |
|* 1 |  COUNT STOPKEY        |                    |         |       |       |      |
|* 2 |   HASH JOIN SEMI      |                    |  635K   |  67M  |  72M  | 5067 |
|  3 |   TABLE ACCESS FULL   | XREF_MEME          |  638K   |  65M  |       |  757 |
|  4 |   INDEX FAST FULL SCAN| CMCX_MEPE_CLUSTER  |  1991K  |  9726K|       |  464 |
```

You can see from this example that using EXISTS instead of joining the tables can be very beneficial. Thanks to Mark Riedel of TUSC for sending, as he puts it, “the TUSC patented EXISTS statement.” We first discovered this around 1990.

Tuning at the Block Level (Advanced)

Although block tuning is covered briefly in Chapter 14, here I cover it in a bit more depth. An internal table called the *buffer hash table* (X$BH) holds block headers. There is a hash chain to which blocks are linked that are protected by a *CBC latch* (*cache buffers chains latch*). This hash chain links to the actual address located in memory (the memory set up with DB_CACHE_SIZE, which is the cache used for data). For a given block in Oracle, only one version of a block is CURRENT, and no more than six other CR versions of the block (as of 11*g*) exist. Thus, only seven versions of a given block (maximum) are in memory at a time (forming a hash chain of six), although different blocks can be hashed to the same chain (depending on the hashing algorithm). When you perform a DML transaction —INSERT, UPDATE, or DELETE—you always need the CURRENT version of a block. In some versions of Oracle 8, you had to set _DB_BLOCK_HASH_BUCKETS to a prime number to keep the dba blocks evenly balanced in the hash buckets (more information on this in Chapter 14) and to avoid a long hash chain arising from the way the hash was calculated. If you didn't set this to a prime number, you could get a very long hash chain (as many blocks were hashed to the same chain), and then get major CBC latch waits (CBC latches are used in 10*g*, 11*g* and 12*c*, although not under all conditions). The hashing algorithm changed and will not need to be prime in 12*c* (so don't change it).

Also note that Oracle has something called *in-memory undo (IMU)*, which can give you some hard-to-understand results when you are viewing information at the block level. If you are familiar with IMU, which was new as of 10*g*, you will find that blocks don't show up as dirty when you query X$BH and they have been dirtied. This is because updates are made *inside the actual block*, as opposed to in the UNDO block, before images are taken. I discovered that this happens only for certain retention settings, though. There is a parameter, _IN_MEMORY_UNDO=TRUE, in the initialization file that is set to FALSE for some TPC benchmarks. Other parameters include _IMU_POOLS and _DB_WRITER_FLUSH_IMU. If you access the block trying to update a different row in the block, the IMU is flushed to the UNDO block, and the block shows as dirty (in my tests anyway, although I was told this depends on what the UNDO retention is set to). IMU writes the UNDO and REDO to memory instead of to disk (which is what the _IMU_POOLS parameter is for). IMU transactions always have room reserved in the current log file for writing out their REDO. They also acquire an *interested transaction list (ITL)* in the block header (discussed in the next section) and reserve space in the UNDO segment. Several sections of IMU statistics are displayed in the AWR Report or the Statspack Report.

When you are querying a block for the first time, you always use the CURRENT version. If the block is being used, you will build a *clone* of the block called a *CONSISTENT READ (CR)* version by applying any UNDO needed to the CURRENT version of the block to get it to a point in time that makes it useful to you (perhaps you need a version of the block before the DML was performed and not committed by another user). This complex and Oracle-patented process may include reading the ITL (which is populated when someone does a DML [Data Manipulation Language] on a block), mapping the record to the UNDO HEADER, or directly to the UNDO BLOCK, and then applying the UNDO to get the correct CR version that you need. So let's take a look at how this happens:

- User 1 updates a record in block 777 (User 1 has not committed).
- User 2 queries the same block and sees that the lock byte is set for a row being queried.
- User 2 goes to the ITL portion of the block and gets the transaction ID (XID).

- The XID maps to the UNDO block, which holds the information before the update was performed.
- A clone of the block is made (call it *block* 778).
- The UNDO information is applied to the block, rolling it back to where it used to be.
- Block 777 is a CURRENT block.
- Block 778 is a CONSISTENT READ block before the User 1 update occurred.
- If another user wants to do a query before the commit, that user can also read the CR version.

Also note that REDO goes forward; UNDO goes back. Yes, the UNDO (ROLLBACK) information is applied to the block, but this has the effect of undoing the most recent changes to the block, including setting the SCN for the block to a past time, not a future time. This is why they are called ROLLBACK segments.

Note *especially* the fact that the block is not *rolled back* to what it was, but it is *rolled forward* to what it used to be. While the result is the same, how Oracle performs this operation is *critical* to understanding how Oracle works. Oracle blocks are always moving forward in time (this is why the REDO works—it's always applying things forward sequentially). There are also links to all blocks for the least recently used (LRU) and least recently used-write (LRU-W) to help make buffer replacement and writing much faster. This information is also maintained in the buffer headers.

If nothing has been advanced enough for you so far, this section is worth the price of the book and should keep you busy for the next decade tuning your system to perfection (if you'd like). Oracle often has perplexing new features: either I can't seem to get them working or there's simply a bug in the program that I am unaware of. How do you find out if a problem is yours or Oracle's? Dump the blocks one at a time.

Consider the intense example in the listing that follows. Find the table/index block information that you want to dump, as shown here:

```
SELECT FILE_ID, BLOCK_ID, BLOCKS FROM DBA_EXTENTS
WHERE SEGMENT_NAME = 'EMP'
AND OWNER = 'SCOTT';

   FILE_ID        BLOCK_ID       BLOCKS
----------  -------------  -----------
         1           50465            3
```

Dump the table/index block information, as demonstrated here:

```
ALTER SYSTEM DUMP DATAFILE 5 BLOCK 50465;
ALTER SYSTEM DUMP DATAFILE 5 BLOCK 50466;
ALTER SYSTEM DUMP DATAFILE 5 BLOCK 50467;

-- You could also issue the following command to dump the range of blocks:

ALTER SYSTEM DUMP DATAFILE 5 BLOCK MIN 50465 BLOCK MAX 50467;
```

The ALTER SYSTEM command selects and then dumps the data blocks for the EMP table owned by SCOTT to a trace file for the current user session in the DIAGNOSTIC_DEST directory, much like TKPROF. The information that is dumped is very cryptic, but it can be helpful for tuning purposes.

The information in the listing that follows compares portions of the block dumps of two different bitmap join indexes. One is on the DEPTNO column, where the tables are also being joined by DEPTNO. The other is on the LOCATION column, where the table is being joined by DEPTNO. By comparing index information, you can see that the LOCATION column was included in the stored part of the index, even though the query was going back to the table to retrieve the LOCATION column in the query. The problem was an Oracle bug that you would discover only by performing this dump (partially shown in this next listing; only the first record is displayed for each).

```
DUMP OF BITMAP JOIN INDEX ON location JOINING deptno ON EMP1/DEPT1
row#0[3912] flag: -----, lock: 0
col 0; len 7; (7): 43 48 49 43 41 47 4f
col 1; len 6; (6): 00 40 f3 31 00 00
col 2; len 6; (6): 00 40 f3 31 00 0f
col 3; len 3; (3): c9 36 0a
...
----- end of leaf block dump -----End dump data blocks tsn: 0 file#:
DUMP OF BITMAP JOIN INDEX ON deptno JOINING deptno ON EMP1/dept1 TABLE ***
row#0[3917] flag: -----, lock: 0
col 0; len 2; (2): c1 0b
col 1; len 6; (6): 00 40 f3 31 00 00
col 2; len 6; (6): 00 40 f3 31 00 0f
col 3; len 3; (3): c9 40 21
...
----- end of leaf block dump -----End dump data blocks tsn: 0 file#:
```

The best use for dumping blocks is to see how Oracle really works (unless data encryption is enabled, making it unhelpful). Get ready for a long night if you plan to use this tip; I spent a weekend playing with this the first time I used it.

TIP

Dumping data blocks can be a valuable tool to understand how Oracle works and to investigate *problem-tuning areas. Only a tuning expert should use block dumps, and even an expert should use the help of Oracle Support. Oracle does not publish the structure of block dumps, so they can change at any time.*

Now let's look at an example to show you how to interpret some of the output that you get from a block dump as well as some other helpful queries that you can do when you do the deep dive into block dumps.

This query will give you the block number for *every* record of a table:

```
select rowid,empno,
       dbms_rowid.rowid_relative_fno(rowid) fileno,
       dbms_rowid.rowid_block_number(rowid) blockno,
       dbms_rowid.rowid_row_number(rowid)  rowno, rownum table_rownum,
       rpad(to_char(dbms_rowid.rowid_block_number(rowid), 'FM0xxxxxxx') || '.' ||
              to_char(dbms_rowid.rowid_row_number  (rowid), 'FM0xxx'    ) || '.' ||
              to_char(dbms_rowid.rowid_relative_fno(rowid), 'FM0xxx'    ), 18) myrowid
from   emp1;

ROWID                   EMPNO     FILENO    BLOCKNO      ROWNO    TABLE_ROWNUM
------------------ ---------- ---------- ---------- ---------- ------------
MYROWID
------------------
AAAMfcAABAAANOKAAA       7369          5      56586          0            1
0000dd0a.0000.0001
AAAMfcAABAAANOKAAB       7499          5      56586          1            2
0000dd0a.0001.0001
AAAMfcAABAAANOKAAC       7521          5      56586          2            3
0000dd0a.0002.0001
(partial listing)
```

Most of the information found in block dumps can be found in the data dictionary or can be accessed using a built-in package such as DBMS_SPACE. In certain scenarios, however, knowing how to read a block dump might benefit you; for instance, it may help you determine exactly why a transaction is blocked. You will probably use other tools prior to dumping a block, `utllockt.sql`, for instance, or Enterprise Manager, but if you want to see exactly what is holding a lock on a row in a block, and how many rows are blocked, the block dump output can be quite useful. You may also want to look at row chaining, look at the space utilization in the block for each row, or simply look at the block because a block is corrupted and you want to take a closer look at it. Sometimes, looking at what is stored in a corrupted block can help you figure out where the corruption originated—for example, text that comes from a third-party tool or a block for which large chunks were changed to all zeros (disk repair utilities).

Key Sections of a Block Dump

Sections to note within the block dump include the block ITL, the flag section, and the block data section. Each section is discussed in the text that follows.

The Block ITL Section in a Block Dump

One of the key sections of a block dump is the *interested transaction list (ITL)*. The ITL section shown next appears in the early part of the dump. This one shows *two* ITL slots (two is the *minimum* number of ITL slots for both tables and indexes—if you don't believe what you read, you can dump it yourself to make sure). The XID is the transaction ID. The UBA is the Undo Block Address. I'll discuss the Flag in a moment. The Lock shows the number of records locked (four records are locked in the first ITL slot because I deleted four rows for this example), and the SCN/FSC is either the SCN for committed information (Flag is a C) or FSC (Free Space Credit), which is the amount of bytes that will be recovered within the block if the transaction is committed. This number is a hexadecimal number. For this example, it is 9d, which is 157 bytes recovered if the transaction to delete four records is committed; the transaction could also be rolled back.

```
Itl           Xid                  Uba         Flag  Lck        Scn/Fsc
0x01   0x0004.010.00000fba  0x0080003d.08b5.10  ----    4  fsc 0x009d.00000000
0x02   0x0004.016.00000fae  0x008000cc.08af.34  C---    0  scn 0x0000.003deb5b
```

Here is another block dump example of an ITL section where three updates were being done on the EMP1 table, DEPTNO column: one user updating all records with DEPTNO=10 (6 records), one user updating all records with DEPTNO=20 (4 records), and a third user updating all records with DEPTNO=30 (5 records).

```
Itl           Xid                  Uba         Flag  Lck        Scn/Fsc
0x01   0x0002.010.00000b7c  0x00c536cc.03c8.2a  ----    6  fsc 0x0000.00000000
0x02   0x0004.007.00000b0d  0x00c00ccb.0407.28  ----    4  fsc 0x0000.00000000
0x03   0x0006.019.00000bf9  0x00c012ce.0420.3b  ----    5  fsc 0x0000.00000000
```

The Flag Section

The flag section is a bit complex. It tells you what state the transaction is in (CBUT):

----	The transaction is active, or it is committed pending block cleanout.
C---	The transaction has been committed and the row locks have been cleaned out.
-B--	The Undo Block Address contains undo for this block.
--U-	The transaction is committed (the SCN is the upper bound), but block cleanout has not occurred (a fast commit).
---T	This transaction was still active when the SCN for block cleanout was recorded.
C-U-	The block was cleaned by delayed block cleanout, and the undo segment information has been overwritten. The SCN will show the lowest SCN that could be re-created by the undo segment.

The Block Dump Data Section

The next block dump shows the data section. This is the first part (the header section) of the block dump data section.

```
tab 0, row 13, @0x1b0b
tl: 39 fb: --H-FL-- lb: 0x0  cc: 8
```

Following is the description of this header information:

```
tab - this data is for table 0
row 13 = 14th Row (0-13 total rows)
Offset: 1b0b (in Hex) - Offset from header
tl: Total bytes of row plus the header = 39
fb: --H-FL-- = flag byte; ( -KCHDFLPN)
H = Head of row piece, F = First data piece, L=Last piece
D = Deleted; P= First column continues from previous piece (chaining) ; N=
Last column continues in next piece; K = Cluster Key; C = Cluster table member
lb: Lock byte is 1+ if this row is locked - 0 (unlocked)
cc: Column count = 8
```

The data part of the block dump data section starts with the line `col0`, as is shown in the block dump that follows:

```
col  0: [ 3]  c2 50 23
col  1: [ 6]  4d 49 4c 4c 45 52
col  2: [ 5]  43 4c 45 52 4b
col  3: [ 3]  c2 4e 53
col  4: [ 7]  77 b6 01 17 01 01 01
col  5: [ 2]  c2 0e
col  6: *NULL*
col  7: [ 2]  c1 0b...
```

The following example shows how to interpret the output from the block dump data section for the first column (`col0`), which is the EMPNO column:

```
col  0: [ 3]  c2 50 23

Hex to Decimal:   Col0 = EMPNO = 7934
50 (Hex) = 80 (Decimal) - 1 = 79
23 (Hex) = 35 (Decimal) - 1 = 34
c2: Number in the thousands (c2 is exponent)
```

The following example shows how to interpret the dump output from the block dump data section for the second column (`col1`), which is ENAME:

```
col  1: [ 6]  4d 49 4c 4c 45 52

Hex to Character:     Col1 = ENAME = MILLER
4d (Hex) = M (Character) [= 77 (decimal)]
49 (Hex) = I (Character)
4c (Hex) = L (Character)
4c (Hex) = L (Character)
45 (Hex) = E (Character)
52 (Hex) = R (Character)
```

Also note that the hex values correspond to the character mapping tables (which depend on the National Language Support [NLS] settings for your database). For example, if you search "ASCII code character" on Google, you can view a table of hex/decimal ASCII codes, in which 4d/77 corresponds to *M*.

This example from the dump output from the block dump data shows the HIREDATE column, which is a DATE field:

```
col  4: [ 7]  77 b6 01 17 01 01 01

Hex to Decimal: Col4 = HIREDATE = 23-JAN-82
77 (Hex) - 119 (Decimal) - 100 - 19 <century>
B6 (Hex) = 182 (Decimal) - 100 = 82 <year>
01(Hex) = 1 (Decimal) <month>
17 (Hex) = 23 (Decimal) <day>
01 01 01 (Hex) = This is the Hour, Minute, Second
(The Default time is 00:00:00)
```

You may want to select the hex data from the table. The following example uses `SELECT dump()` and gets the ENAME from the hex:

```
select   dump(ename,16), ename
from   emp1
where   dump(ename,16) like '%4d,49,4c,4c,45,52';
DUMP(ENAME,16)                                       ENAME
--------------------------------------------------   --------------
Typ=1 Len=6: 4d,49,4c,4c,45,52                       MILLER
```

Let's query a new block (56650) from EMP1 and watch the EMP1 buffer header change (so far it's clean—the dirty bit is N—and consists of only one copy [or record], and it's the current version, with state=1):

```
select lrba_seq, state, dbarfil, dbablk, tch, flag, hscn_bas,cr_scn_bas,
       decode(bitand(flag,1), 0, 'N', 'Y') dirty,  /* Dirty bit */
       decode(bitand(flag,16), 0, 'N', 'Y') temp, /* temporary bit */
       decode(bitand(flag,1536),0,'N','Y') ping, /* ping (to shared or null) bit */
       decode(bitand(flag,16384), 0, 'N', 'Y') stale,  /* stale bit */
       decode(bitand(flag,65536), 0, 'N', 'Y') direct,  /* direct access bit */
       decode(bitand(flag,1048576), 0, 'N', 'Y') new  /* new bit */
from  x$bh
where dbablk = 56650
order by dbablk;

LRBA_SEQ         STATE    DBARFIL     DBABLK       TCH         FLAG        HSCN_BAS
------------------------------------------------------------------------------------
CR_SCN_BAS D T P S D N
---------- - - - - - -
         0           1          1      56650         0      35659776     4294967295
          0 N N N N N N
```

Watch the EMP1 buffer header when you delete a row:

```
delete from emp1
where comm = 0;

1 row deleted.
```

Let's query the block (56650) and watch the EMP1 buffer header. There are now two copies (or records): one copy is the current version (state=1), and one is a clone (CR, state=3).

```
select lrba_seq, state, dbarfil, dbablk, tch, flag, hscn_bas,cr_scn_bas,
       decode(bitand(flag,1), 0, 'N', 'Y') dirty,  /* Dirty bit */
       decode(bitand(flag,16), 0, 'N', 'Y') temp,  /* temporary bit */
       decode(bitand(flag,1536),0,'N','Y') ping, /* ping (to shared or null) bit */
       decode(bitand(flag,16384), 0, 'N', 'Y') stale,  /* stale bit */
       decode(bitand(flag,65536), 0, 'N', 'Y') direct,  /* direct access bit */
       decode(bitand(flag,1048576), 0, 'N', 'Y') new  /* new bit */
from   x$bh
where dbablk = 56650
order by dbablk;

  LRBA_SEQ      STATE    DBARFIL     DBABLK        TCH       FLAG   HSCN_BAS
---------- ---------- ---------- ---------- ---------- ---------- ----------
CR_SCN_BAS D T P S D N
---------- - - - - - -
         0          1          1      56650          1       8200 4294967295
         0 N N N N N N
         0          3          1      56650          2     524288          0
   4347881 N N N N N N
```

Note that V$TRANSACTION now has the record (created when transactions have UNDO):

```
SELECT t.addr, t.xidusn USN, t.xidslot SLOT, t.xidsqn SQN, t.status,
               t.used_ublk UBLK, t.used_urec UREC, t.log_io LOG,
               t.phy_io PHY, t.cr_get, t.cr_change CR_CHA
FROM   v$transaction t, v$session s
WHERE  t.addr = s.taddr;

ADDR              USN       SLOT        SQN  STATUS           UBLK
-------- ---------- ---------- ---------- ---------------- ----------
      UREC        LOG        PHY     CR_GET   CR_CHA
---------- ---------- ---------- ---------- ----------
69E50E5C            5         42        652 ACTIVE                  1
         1          3          0          3        0
```

The column names in the output have these meanings:

- USN is the Undo Segment Number (ROLLBACK segment ID).
- SLOT is the slot number in the ROLLBACK segment’s transaction table.
- SQN is the sequence number for the transaction.
- USN+SLOT+SQN are the three values that uniquely identify a transaction XID.
- UBLK is the block for the last UNDO entry (it tells you how many UNDO blocks there are).
- UREC is the record number of the block (it shows how many table and index entries the transaction has inserted, updated, or deleted).

If you are doing an INSERT or DELETE, then you will see that UREC is set to (*number of indexes* *for this table*) + (*how many rows you insert/delete)*. If you UPDATE a column, then UREC will be set to (*number of indexes that his column belongs to*) * 2 + (*number of updated rows)*. If the column belongs to no index, then the UREC is set to the number of rows that were updated. If UBLK and UREC decrease each time you query, then the transaction is rolling back. When UREC reaches zero, the rollback is finished.

If you dump the block at this time, you see the locked record in the first row of the ITL section:

```
Itl           Xid                  Uba                 Flag  Lck        Scn/Fsc
0x01   0x0005.02a.0000028c  0x008000a1.02b6.01  ----    1  fsc 0x0023.00000000
0x02   0x0004.016.00000fae  0x008000cc.08af.34  C---    0  scn 0x0000.003deb5b
```

Now let's do an INSERT in four other sessions to get XSBH up to six versions of the block. There are now six copies: one copy is the current version (state=1) and five are clones (CR, state=3).

```
LRBA_SEQ          STATE     DBARFIL      DBABLK          TCH         FLAG     HSCN_BAS
---------- ---------- ---------- ---------- ---------- ---------- ----------
CR_SCN_BAS D T P S D N
---------- - - - - - -
         0            3          1       56650          1       524416           0
4350120 N N N N N N

         0            3          1       56650          1       524416           0
4350105 N N N N N N
       365            1          1       56650          7     33562633     4350121
         0 Y N N N N N
         0            3          1       56650          1       524416           0
4350103 N N N N N N
         0            3          1       56650          1       524416           0
4350089 N N N N N N
         0            3          1       56650          1       524288           0
4350087 N N N N N N
```

NOTE
The Least Redo Block Address (LRBA) is set only for the current block, and the current block is the one with the DIRTY flag set to Y.

Can you get more than six versions of a block? Probably, but this is unsupported. In the following listing, I've selected the maximum-allowed CR buffers per data block address (dba):

```
select a.ksppinm, b.ksppstvl, b.ksppstdf, a.ksppdesc
from   x$ksppi a, x$ksppcv b
where  a.indx = b.indx
and    substr(ksppinm,1,1) = '_'
and    ksppinm like '%&1%'
order  by ksppinm;

KSPPINM                   KSPPSTVL  KSPPSTDF KSPPDESC
------------------------- --------- -------- ----------------------------------------
 _db_block_max_cr_dba         6     TRUE     Maximum Allowed Number of CR buffers per dba
```

Now consider an example in 11*g* where I am updating/selecting multiple times in a block to get the maximum number of CR versions of a block:

```
select lrba_seq, state, dbarfil, dbablk, tch, flag, hscn_bas,cr_scn_bas,
       decode(bitand(flag,1), 0, 'N', 'Y') dirty,  /* Dirty bit */
       decode(bitand(flag,16), 0, 'N', 'Y') temp, /* temporary bit */
       decode(bitand(flag,1536),0,'N','Y') ping, /* ping (to shared or null) bit */
       decode(bitand(flag,16384), 0, 'N', 'Y') stale,  /* stale bit */
       decode(bitand(flag,65536), 0, 'N', 'Y') direct,  /* direct access bit */
       decode(bitand(flag,1048576), 0, 'N', 'Y') new  /* new bit */
from  x$bh
where dbablk = 56650
order by dbablk;

LRBA_SEQ        STATE    DBARFIL    DBABLK        TCH       FLAG   HSCN_BAS
---------- ---------- ---------- ---------- ---------- ---------- ----------
CR_SCN_BAS D T P S D N
---------- - - - - - -
         0          3         10    1410707          1     524288          0
  23105852 N N N N N N
         0          3         10    1410707          1     524288          0
  23105815 N N N N N N

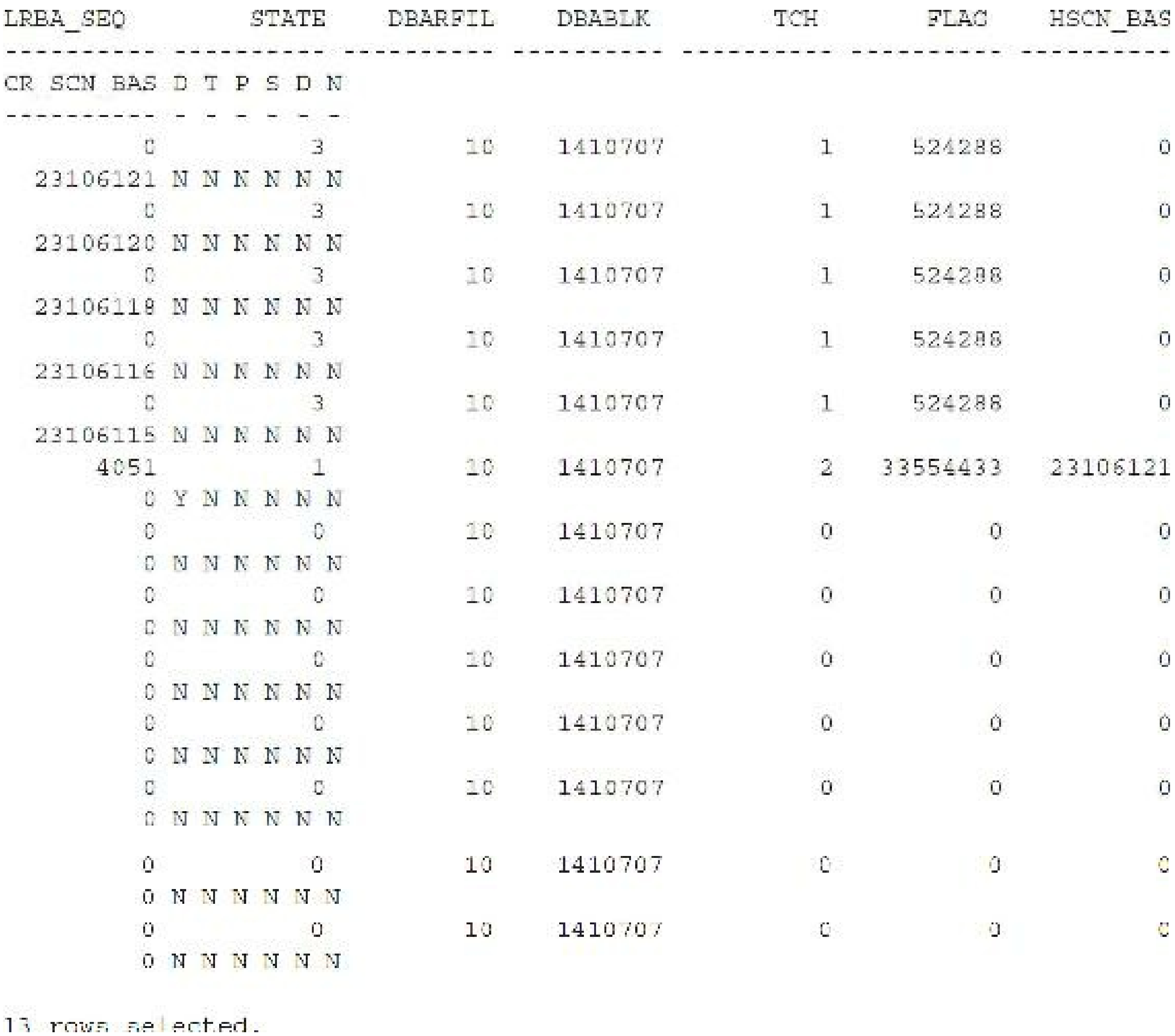
         0          3         10    1410707          1     524288          0
  23105727 N N N N N N
         0          3         10    1410707          1     524288          0
  23105710 N N N N N N
         0          3         10    1410707          1     524288          0
  23105677 N N N N N N
         0          3         10    1410707          1     524288          0
  23105674 N N N N N N
      4051          1         10    1410707          4   35651593   23105710
         0 Y N N N N N

7 rows selected.
```

Now I am going to run the 11*g* command to flush the buffer cache:

```
SQL> alter system flush buffer_cache;
System Altered.
```

Now I'll rerun all of my SELECTs/UPDATEs to refill the cache to see the result. The result is that I get five CR versions and one CURRENT version of the block, but the original seven buffered blocks that I had are now reset to mostly zeros. Oracle has populated all new records in X$BH and zeroed out the original ones after the buffer cache flush (5 CR and 1 CURRENT + 7 other zeroed out).



```
LRBA_SEQ        STATE    DBARFIL     DBABLK        TCH       FLAG   HSCN_BAS
---------- ---------- ---------- ---------- ---------- ---------- ----------
CR_SCN_BAS D T P S D N
---------- - - - - - -
         0          3         10    1410707          1     524288          0
  23106121 N N N N N N
         0          3         10    1410707          1     524288          0
  23106120 N N N N N N
         0          3         10    1410707          1     524288          0
  23106118 N N N N N N
         0          3         10    1410707          1     524288          0
  23106116 N N N N N N
         0          3         10    1410707          1     524288          0
  23106115 N N N N N N
      4051          1         10    1410707          2   33554433   23106121
         0 Y N N N N N
         0          0         10    1410707          0          0          0
         0 N N N N N N
         0          0         10    1410707          0          0          0
         0 N N N N N N
         0          0         10    1410707          0          0          0
         0 N N N N N N
         0          0         10    1410707          0          0          0
         0 N N N N N N
         0          0         10    1410707          0          0          0
         0 N N N N N N

         0          0         10    1410707          0          0          0
         0 N N N N N N
         0          0         10    1410707          0          0          0
         0 N N N N N N

13 rows selected.
```

This listing still has room for one more active CR block. The listing gives a good feeling for how Oracle handles the buffer cache flush. Testing things at the block level can help you to understand new functionality but shouldn't be used every day. Block tuning should be primarily used in a test system for often-run code that needs detailed attention.

A deeper dive into block tuning is beyond the scope of this book. However, some of the queries

I've presented in this section will allow you to investigate what is going on at the block level in the very rare case that you need to see it. The best reason to perform block dumps is to see what's going on inside of Oracle. In the next section, you get a brief look at the block level of bitmap indexes and a few other types.

A Brief Look at an Index Block Dump

Now let's take a quick look at some index block dumps. First let's look at a bitmap index. Each of the indexed rows consists of five lines:

row#0:	Row identification.
col 0:	Indexed value (length in hex).
col 1:	ROWID for the first occurrence of the indexed value.
col 2:	ROWID for the last occurrence of the indexed value.
col 3:	Actual bitmap which will have 1 where value occurred in range between first and last rowid, otherwise 0 in swap byte notification, first byte usually cx where x in (8,…,f). When all slots for cf filled, new segment starts.

Consider the following bitmap index block dump:

```
row#0[8010] flag: ---D-, lock: 2
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 07
col 3; len 1; (1):  00

row#1[7989] flag: ---D-, lock: 2
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 07
col 3; len 2; (2):  c8 03
row#2[7968] flag: -----, lock: 2
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 07
col 3; len 2; (2):  c8 07
```

If you insert 64 rows (0–63) and then take a block dump (note the 3f in col 2),

```
row#0[8008] flag: -----, lock: 0
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 3f
col 3; len 9; (9):  cf ff ff ff ff ff ff ff ff
```

then you insert one more row (0–64), you get the following (note the 40 in col 2):

```
row#0[8007] flag: -----, lock: 0
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 40
col 3; len 10; (10):  cf ff ff ff ff ff ff ff ff 00
```

An index value exists in a block with `ROWID=02 40 2d 60 00 40 (40(hex) => 64 (decimal))`. The previous end ROWID was `3f (3*16+15 = 63)`. When the index is updated, you must have enough space to accommodate growth; if you don't, a split occurs. Not just that, a lock is placed on the entry in the leaf index—but this entry can span over multiple blocks. As a side effect, for the duration of a lock, no other transaction can update the blocks in the affected block range. Bitmap indexes are used for a column with just a few different values, so on bigger tables each bitmap likely covers quite a few blocks. A lock placed on those blocks can have disastrous effects on other transactions, which is why bitmap indexes are almost always used for query-only data or mostly static data.

Now let's see how the block dump of a reverse key index looks. Note that a reverse key index will be marked with the value NORMAL/REV in `dba_indexes (index_type)`. You can see in the following example that the hex values in col 1 are reversed.

Regular index entry:

```
col 0; len 2; (2):  c1 02
col 1; len 7; (7):  78 69 0c 19 03 27 10
col 2; len 6; (6):  02 40 2e 70 00 00
```

Reverse key:

```
col 0; len 2; (2):  02 c1
col 1; len 7; (7):  10 27 03 19 0c 69 78
col 2; len 6; (6):  02 40 2e 70 00 00
```

Finally, let's take a quick look at how a regular index (ascending) differs from a descending index when you do an index block dump.

A regular index:

```
col 0; len 1; (1):  61
col 0; len 2; (2):  61 61
col 0; len 3; (3):  61 61 61
col 0; len 4; (4):  61 61 61 61
col 0; len 5; (5):  61 61 61 61 61
col 0; len 6; (6):  61 61 61 61 61 61
col 0; len 7; (7):  61 61 61 61 61 61 61
col 0; len 8; (8):  61 61 61 61 61 61 61 61
col 0; len 9; (9):  61 61 61 61 61 61 61 61 61
col 0; len 10; (10):  61 61 61 61 61 61 61 61 61 61
```

A descending index:

```
col 0; len 10; (10):  9e 9e 9e 9e 9e 9e 9e 9e 9e ff
col 0; len 9; (9):      9e 9e 9e 9e 9e 9e 9e 9e ff
col 0; len 8; (8):      9e 9e 9e 9e 9e 9e 9e ff
col 0; len 7; (7):      9e 9e 9e 9e 9e 9e ff
col 0; len 6; (6):      9e 9e 9e 9e 9e ff
col 0; len 5; (5):      9e 9e 9e 9e ff
col 0; len 4; (4):      9e 9e 9e ff
col 0; len 3; (3):      9e 9e ff
col 0; len 2; (2):      9e ff
```

You can see from all of these examples that the block dump can give you insight into new features as well as details about internal data structures and indexes in Oracle. Use the block dump sparingly and generally on a test system, however.

Tuning Using Simple Mathematical Techniques

This section discusses some simple but effective mathematical techniques you can use to significantly improve the performance of some Oracle SQL–based systems. These techniques can leverage the effectiveness of Oracle performance diagnostic tools and uncover hidden performance problems that can be overlooked by other methods. Using these techniques also helps you make performance predictions at higher loads.

NOTE
Joe A. Holmes provided the material for this section. I am extremely grateful for his contribution because I believe it ties all the chapters of this book together.

The methodology called *Simple Mathematical Techniques* involves isolating and testing the SQL process in question under ideal conditions, graphing the results of rows processed versus time, deriving equations using simple methods (without regression), predicting performance, and interpreting and applying performance patterns directly to tuning SQL code.

Traditional Mathematical Analysis

First of all, do not be intimidated by this section. You *will* be able to understand this, and the information provided will help you predict response times for your queries as the tables grow.

Traditional mathematical methods are very useful for analyzing performance. These may include graphing performance metrics on an *x-y* coordinate axis to obtain a picture of what a process is really doing and applying Least Squares Regression or Polynomial Interpolation to derive equations for predicting performance at higher loads. Computer science academics and specialists use these techniques extensively for performance analysis, which is laden with problems. First, textbook notation and explanations are often very complex and difficult to understand. Most math textbooks I have encountered that treat approximation and interpolation, for example, are steeped in theory rather than providing clear and practical examples.

Second, little or no information is available on how to apply this kind of analysis directly to tuning SQL code. This is probably because SQL analysis requires more specific interpretations to be useful rather than something broader or more general.

Seven-Step Methodology

The following are seven steps in the methodology. Note that deriving performance equations and interpreting patterns are discussed in more detail in the sections that follow.

1. Isolate the SQL code in question.

   The SQL code in question is isolated from surrounding system code and placed in a SQL*Plus or PL/SQL script that can be run independently to duplicate the production process.

2. Run tests under ideal conditions.

   In this context, "ideal" is defined as one SQL process running on a dedicated machine with hardware-processing power fixed and executed under high-volume data.

3. Graph performance observations on an *x-y* coordinate axis.

   From tests, the number of rows processed (*x*) versus time (*y*) for each SQL statement within a process is graphed on an *x-y* coordinate axis. This is referred to as a *row-time metric*. Ideally, the optimizer is, for the most part, more mechanical and less random, creating a more clearly defined and predictable trendline. The basic line shape can provide clues to the cause of underlying performance problems.

4. Use simple equation determination.

   Once points are plotted on a graph, you assume that what appears straight is a linear function and what appears curved upward is a quadratic function. (Other shapes may appear, but they are beyond the scope of this section.) From these observations, you can use either a simple two-point linear or three-point quadratic method to determine the equations. You can perform both methods easily by hand or with a basic calculator. You can also use spreadsheets like Microsoft Excel with graphing and trendline (regression) capabilities. Each separate SQL statement is graphed and analyzed individually.

5. Predict performance.

   You can use derived equations to predict performance at much higher loads than are practical to test. Because the accuracy of the predictions may decrease as the predicted load increases, it is suggested that you make only ballpark predictions.

   It may be advantageous to calculate two performance lines: the first as a lower bound if the performance line is truly linear, and the second as an upper bound if the performance line might turn out to be a quadratic curve. The predicated value would, therefore, lie somewhere in between. Later, you may want to try a test to see how close your prediction was to the actual time. Also be aware that it is not as important whether a slow-running process is predicted to take 20 or 24 hours, but rather, whether it can be improved to, say, 1 hour.

6. Interpret performance patterns and experiment.

   The shape of the performance lines and the nature of the equations can provide clues about the cause of underlying performance problems and support (or sometimes contradict) the interpretations of diagnostic tools. You can conduct experiments on SQL code based on pattern clues and the correction applied to production code. You can graph tests of an improved process again and compare the results with the original process.

7. Keep a record of results to build expertise.

   To build up your expertise at using both these mathematical methods and your interpretation of Oracle diagnostic tools, keep a record of before and after performance graphs, the true cause of performance problems, and the effective solutions you found. Graphs provide hard evidence of performance problems that you can present in a clear visual form to management and end users.

Deriving Performance Equations

The following sections discuss two simple methods for equation determination based on simplified versions of Newton's Divided Difference Interpolating Polynomial. You can use these methods if you assume that what appears as a straight line is linear and what appears as upward sloping is quadratic.

Simple Linear Equation Determination

The following is a simple two-point method for determining a linear best-performance line equation:

$y = a_0 + a_1x$ (This is the final equation to use for linear queries.)

y = the number of rows in the table

x = the time to process the query

a_1 = the slope of the line (Calculate this with two query tests.)

a_0 = the y-intercept of the line (Calculate this with two query tests.)

Figure 9-6 shows points from an ideal test that appears linear. You visually select two points (x_1, y_1) and (x_2, y_2) that define a straight line of minimum slope, where slope: $a_1 = (y_2 - y_1)/(x_2 - x_1)$:

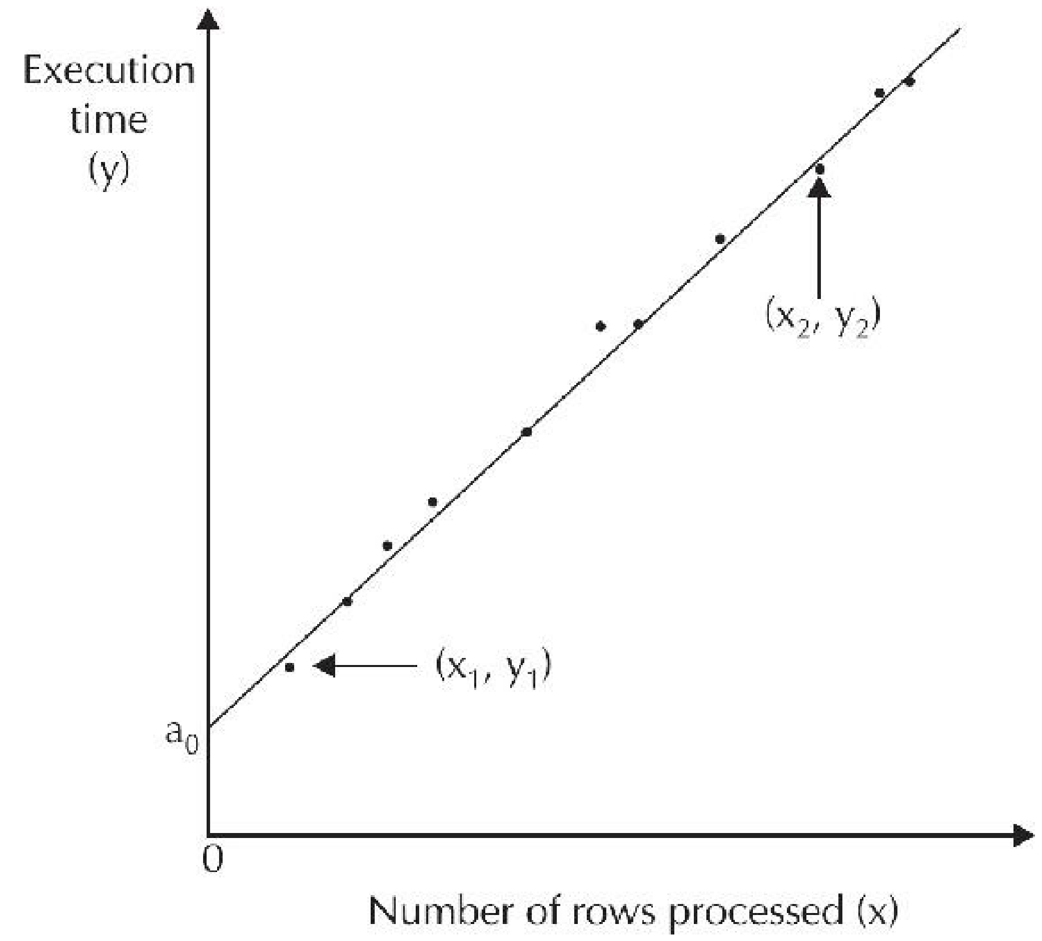


FIGURE 9-6. *Linear best-performance line*

y-intercept: $a_0 = y_1 - a_1 x_1$

A Simple Example These equations look great, but let's look at a real-life query (using a basic query to the EMP table). You must time the query on the basis of two different table sizes to get an equation for the line.

```
select ename, deptno
from   emp
where  deptno = 10;
```

For a very small system, consider the response for two tests:

1. When 1000 records were in the EMP table, this query took 2 seconds.
2. When 2000 records were in the EMP table, this query took 3 seconds.

Therefore, you know that

$y_1 = 2$ (seconds)

$x_1 = 1000$ (records)

$y_2 = 3$ (seconds)

$x_2 = 2000$ (records)

- **Step 1** Find the slope of the line.

  $a_1 = (y_2 - y_1)/(x_2 - x_1)$

  $a_1 = (3 - 2)/(2000 - 1000)$

  $a_1 = 0.001$ (The slope of the line is 0.001.)

- **Step 2** Get the *y*-intercept.

  $a_0 = y_1 - a_1 x_1$

  $a_0 = 2 - (0.001)(1000)$

  $a_0 = 2 - 1$

  $a_0 = 1$ (The *y*-intercept is 1.)

- **Step 3** Now you can calculate response for any size EMP table.

You now have everything you need for this query, so you can figure out how long this query will take as the number of rows in the EMP table increases.

What will the response time be for 3000 rows?

$y = a_0 + a_1 x$ (The response time is *y*, and *x* is the number of rows in the table.)

$y = 1 + (0.001)(3000)$

$y = 1 + 3$

$y = 4$ seconds (The response time for this query in a 3000-row EMP table will be 4 seconds.)

What will the response time be for 100,000 rows?

$y = a_0 + a_1 x$

$y = 1 + (0.001)(100{,}000)$

$y = 101$ seconds (The response time for a 100,000-row EMP table will be 1 minute and 41 seconds.)

Simple Quadratic Equation Determination

Unfortunately, many queries don't behave linearly. Consequently, the preceding section doesn't always help you. But never fear—a simple method for curved lines is next. Once again, do not be intimidated by this section. You *will* be able to understand this, and with this information, you will be able to predict query scaling (predict any response time for an increased number of rows). The following is a simple three-point method for determining a quadratic best-performance equation. This is the equation you will use:

$y = a_0 + a_1 x + a_2 x^2$ (This is the final equation to use for nonlinear queries.)

y = response time for a query

x = number of rows

a_0, a_1, a_2 = constants derived from the curve the query creates

Figure 9-7 shows points from an ideal test.

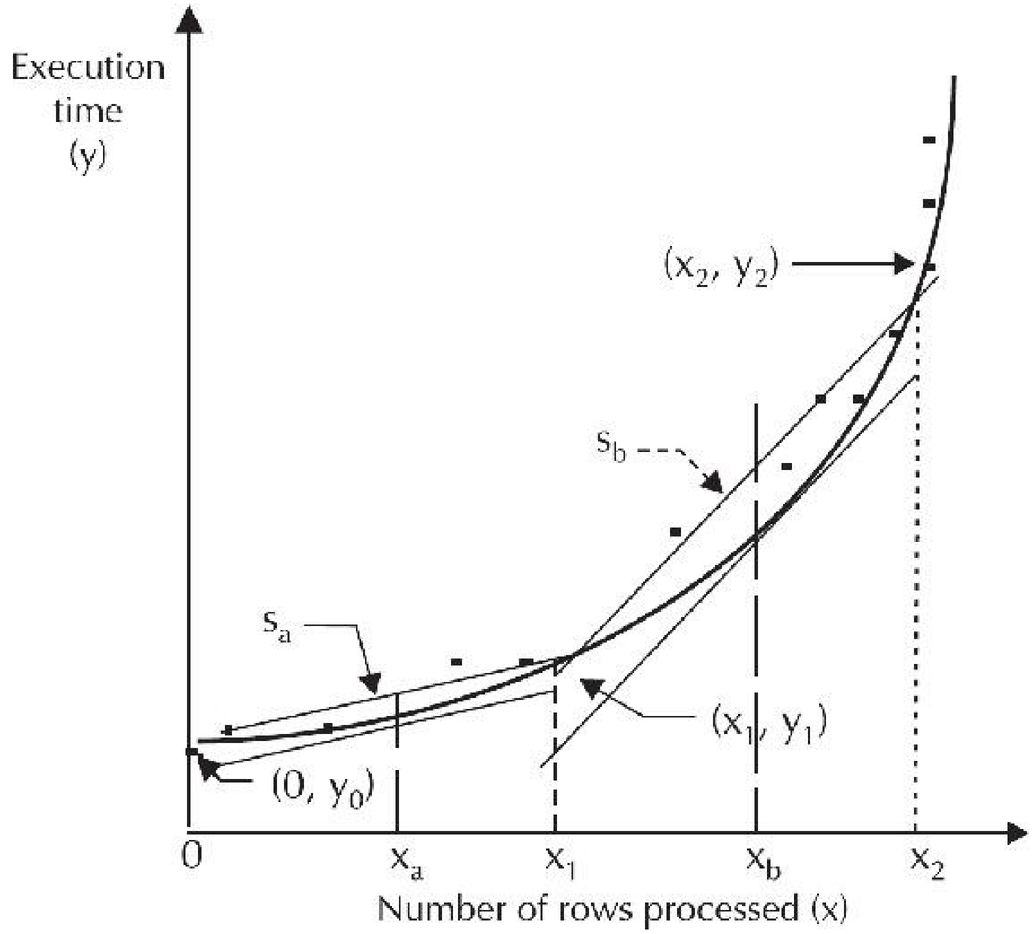


FIGURE 9-7. *Quadratic best-performance curve*

You visually select three points, $(0, y_0)$, (x_1, y_1), and (x_2, y_2), that appear to be of minimum slope on a quadratic-like curve. The midpoint between 0 and x_1 is x_a, and the midpoint between x_1 and x_2 is x_b, such that

$x_a = (x_1 + 0)/2$ and $x_b = (x_2 + x_1)/2$

When joined, $(0, y_0)$ and (x_1, y_1) form a *secant* (a straight line that connects two points on a curve) with slope S_a, and (x_1, y_1) and (x_2, y_2) form a secant with slope S_b. The x midpoints (x_a, y_a) and (x_b, y_b) lie on the desired curve with tangents having slopes S_a and S_b, respectively. From the derivative of a quadratic equation, which gives the slope of the curve at the midpoints, you have

$S_a = (y_1 - y_0)/(x_1 - 0) = a_1 + 2a_2x_a$

S_a = slope of the lower part of the curve

$S_b = (y_2 - y_1)/(x_2 - x_1) = a_1 + 2a_2x_b$

S_b = slope of the upper part of the curve

Using Gauss elimination, you solve for the a_i coefficients, such that

$a_2 = (S_b - S_a)/[2(x_b - x_a)] = (S_b - S_a)/x_2$
$a_1 = S_a - 2a_2x_a = S_a - a_2x_{1-}$
$a_0 = y_0$

You'll have to use these three equations to get a_0, a_1, and a_2, and then you can use the final equation. These will be the constants in the equation that will give you the response time of a query as you vary the number of rows in the table.

NOTE
This method will not work in all cases. If any a_i coefficients are negative, the equation may dip below the X axis and something else must be used. Often, the origin or $a_0 = y_0 = 0$ works best with this method.

A Simple Example All of these equations look great, but let's look at a real-life query. You must time the query using two different table sizes to get an equation for the line. The ORDERS table has an index on ORDNO, but it is suppressed by the NVL function (causing the nonlinear response time). The real solution to this problem is to eliminate NULLs in the ORDERS table and remove the NVL function from the query. However, this example is for instructional purposes to generate a quadratic equation.

```
select   ordno, total
from     orders
where    nvl(ordno,0) = 7777;
```

For your system, consider the response of this query for two tests:

- When there were 100 records in the ORDERS table, this query took 5 seconds.

- When there were 2000 records in the ORDERS table, this query took 1000 seconds.

You want to know how long this query will take when you have 10,000 rows in the ORDERS table. Therefore, you know that

$y_1 = 5$ (seconds)

$x_1 = 100$ (records)

$y_2 = 1000$ (seconds)

$x_2 = 2000$ (records)

$y_0 = 1$ (second – estimate); this is the y-intercept

You could calculate y_0 by using two points near the lower part of the curve (near 100 rows using the linear equations from the preceding section), but because the lower part of the curve is small (5 seconds for 100 rows), you can guesstimate this to be 1 second. (You should calculate it.)

- **Step 1** Calculate S_a and S_b.

  $S_a = (y_1 - y_0)/(x_1 - 0)$

  $S_a = (5 - 1)/(100 - 0)$

  $S_a = 0.04$ (The slope of the lower part of the curve is almost horizontal.)

  $S_b = (y_2 - y_1)/(x_2 - x_1)$

  $S_b = (1000 - 5)/(2000 - 100)$

  $S_b = 0.52$ (The slope of the upper part of the curve is much higher than the lower part.)

- **Step 2** Calculate a_0, a_1, and a_2.

  $a_2 = (S_b - S_a)/x_2$

  $a_2 = (0.52 - 0.04)/2000$

  $a_2 = 0.00024$

  $a_1 = S_a - a_2x_1$

  $a_1 = 0.04 - (0.00024)(100)$

  $a_1 = 0.016$

  $a_0 = y_0$

  $a_0 = 1$ (The y-intercept is 1.)

- **Step 3** Create the equation to use as the table grows.

$y = a_0 + a_1x + a_2x_2$

$y = 1 + (0.016)x + (0.00024)x^2$ (This is your equation to calculate future responses.)

- **Step 4** Calculate the *expected* response for 10,000 rows.

  $y = 1 + (0.016)x + (0.00024)x^2$

  $y = 1 + (0.016)(10{,}000) + (0.00024)(10{,}000^2)$

  $y = 24{,}161$ (The query will take 24,161 seconds, or just under seven hours; you have a problem.)

You'll have to fix the NVL problem soon so the users don't have to wait seven hours. But in reality, you have calculated only a couple of points, and this should be extended out further to get a better future estimate of performance.

TIP
Spreadsheets like Microsoft Excel are very useful tools for graphing performance metrics and automatically deriving trendline equations. For example, to create a graph using Excel, list the observed (x,y) data in cells. Highlight the cells, and select Chart Wizard | XY (Scatter) | Chart Sub-type. Select a Line subtype and click Next | Next | Finish to create the graph. To derive a trendline equation, click the graph line once, and select Chart | Add Trendline. On the Type tab, select Linear, Polynomial Order = 2 (for quadratic) or other model type. To show the trendline equation, on the Options tab, select Display Equation On Chart. Then click OK to complete the graph. The solution equation can be programmed back into the spreadsheet (depending on your spreadsheet version) and used to predict values at higher volumes.

Pattern Interpretation

Graphical performance patterns provide clues to underlying SQL problems and solutions, as seen in Figure 9-8. The ultimate goal in using these methods is to convert a steep linear or quadratic best-performance line to one that is both shallow and linear by optimizing the SQL process. This may involve experiments with indexes, temporary tables, optimizer hint commands, or other Oracle SQL performance tuning methods.

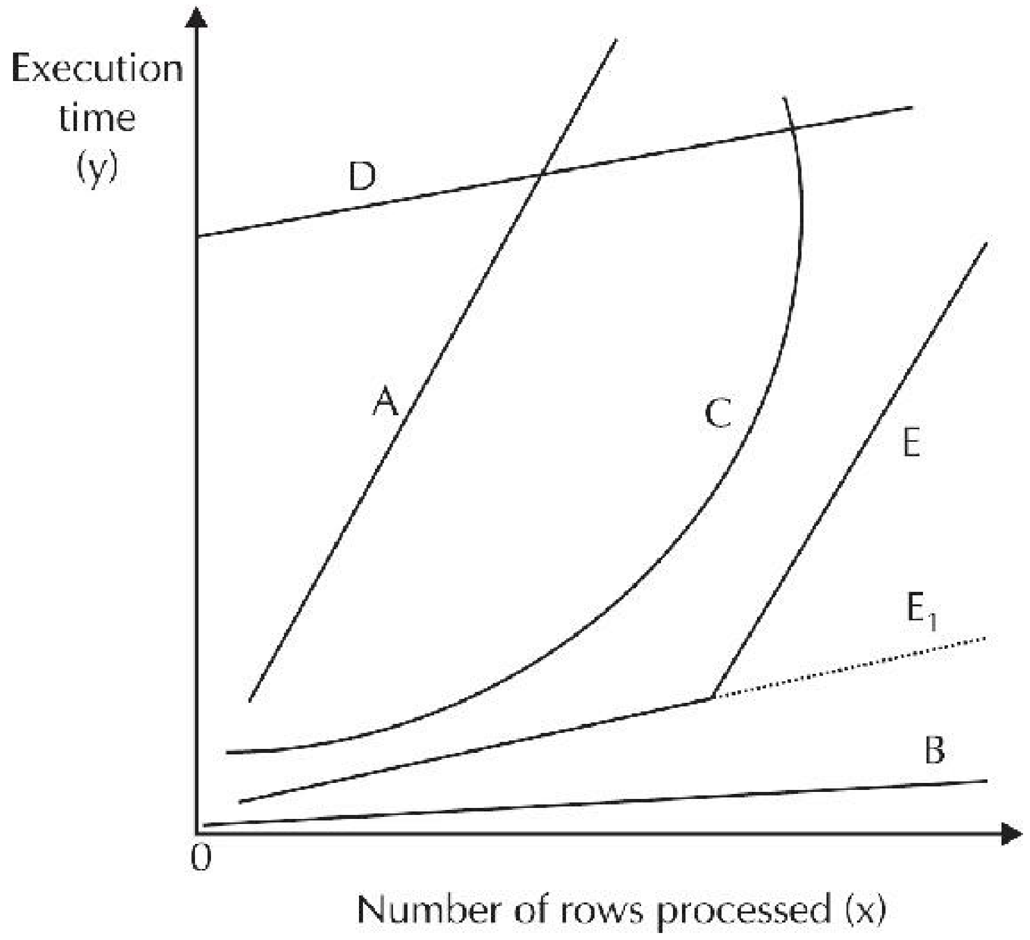


FIGURE 9-8. *Examples of performance patterns*

With pattern interpretation, performing your own application-specific SQL experiments to develop expertise at using these methods is important. Table 9-2 shows more specific interpretations—based on my personal experience—that provide a general idea of how you can apply what you observe directly to tuning SQL code. Assuming the scale is correct, pattern interpretation often provides a more accurate picture of what is actually happening to a process and may support or even contradict what a diagnostic tool tells you.

Pattern in Figure 9-8	Possible Problem	Possible Solution
A	Missing index on a query SELECTing values.	Create an index. Fix a suppressed index.
A	Over-indexed table suffering during DML statements.	Drop some of the indexes or index fewer columns (or smaller columns) for the current indexes.
B	No problem.	Don't touch it!
C	Missing index on a query SELECTing values.	Create an index. Fix a suppressed index.
C	Over-indexed table suffering during an INSERT.	Drop some of the indexes or index fewer columns (or smaller columns) for the current indexes.
D	Doing a full table scan or using the ALL_ROWS hint when you shouldn't be.	Try to do an indexed search. Try using the FIRST_ROWS hint to force the use of indexes.
E	The query was fine until some other limitation (such as disk I/O or memory) was encountered.	Find out which ceiling you hit caused this problem. Increasing the SGA may solve the problem, but this could be many things.
E_1	If the limitation in line *E* is corrected, processing should continue along a straight line.	Further tuning may improve the process to line *B*.

TABLE 9-2. *Graphical Representations of Various Tuning Situations*

General Linear and Quadratic Interpretations

A shallow linear performance line usually indicates a relatively efficient process compared to something much steeper or curved. The slope a_1 indicates the rate y increases for a given x. Scale is important because a shallow line on one scale can look steep on another, and vice versa. A large a_0 coefficient always indicates an inefficient process.

An upward-sloping (concave) quadratic curve almost always indicates a problem with the process because as more rows are added, the time to process each additional row increases. Coefficient a_2 affects the bowing of the curve. If it is very small, the equation may be more linear. However, even a very slight bowing may be an indicator of something more insidious under much higher volumes.

In rare cases, a quadratic curve might appear downward sloping (convex), indicating a process where as more rows are added, the time to process each additional one decreases (i.e., economies of scale). This is desirable and may occur at a threshold, where a full table scan is more efficient than using an index.

Indexing

Missing indexes commonly cause poor SQL performance. In Figure 9-8, line *A* or *C* could result from a missing index, depending on code complexity and data volume. Proper indexing improves performance to line *B*. Over-indexing can be as bad as missing indexes. Line *A* or *C* could be a process that is forced to use an index, whereas a full table scan would improve the process to *B*. Inserting into an indexed table is always slower than into an index-free table. Line *A* or *C* could be from an INSERT into a heavily indexed table versus line *B* with no indexing.

Indexing Example This listing illustrates what can happen with indexing analysis. Suppose you have two tables, TABLE_A and TABLE_B, and there is a one-to-many relationship between them based on KEY_FIELD. There does not have to be a join between the two tables.

```
TABLE_A
KEY_FIELD  NUMBER
TOTAL      NUMBER

TABLE_B
KEY_FIELD  NUMBER
AMOUNT     NUMBER
```

You want to perform the following update within a KEY_FIELD:

```
table a.total = table a.total + sum(table b.amount)
```

The SQL statement shown next will do this. Note that the EXISTS subquery must be used to prevent the NULLing out of any TABLE_A.TOTAL fields, where TABLE_A.KEY_FIELD does not match TOTAL_B.KEY_FIELD.

```
update  table_a ta  set ta.total =
(select   ta.total + sum(tb.amount)
from      table_b tb
where     tb.key_field = ta.key_field
group by  ta.total)
where  exists
(select   null
from      table_b tb2
where     tb2.key_field = ta.key_field);
```

If there is a unique index on the TABLE_A.KEY_FIELD and a nonunique index on

TABLE_B.KEY_FIELD, then the performance will be similar to line *B* in Figure 9-8. However, if there is no index on TABLE_B.KEY_FIELD or the cost-based optimizer decides to shut it off, a line will be generated similar to *A* or *C*. The reason is that the EXISTS subquery heavily depends on indexing.

I have seen cases where the number of rows in TABLE_A was small (< 2000), but the cost-based optimizer shut off the index on TABLE_B and reported a small EXPLAIN PLAN cost. This was regardless of the number of rows in TABLE_B (which was up to 800,000 rows). Actual tests showed a steep performance line that contradicted the EXPLAIN PLAN cost. This is an example of uncovering a problem that may have been overlooked by a diagnostic tool.

When the optimizer (cost-based) finds a query to retrieve less than 5–6 percent (based on the average distribution) of the data in a table, the optimizer generally drives the query with an index if one exists. Figure 9-9 shows how Oracle has evolved through the past years prior to Oracle9*i*. In Oracle 10*g*, the optimizer is very good at analyzing not only the number of rows, but also the distribution of data, and also knows if the query has been run previously. The first time a query is executed is different from the second time even if this was weeks ago. While the response time still depends on the percentage of blocks (better than looking at the percentage of rows) retrieved by the query, what kind of disks, cache for the disks, cache for the operating system, and previous queries change the upper part of the graph greatly (where you retrieve most of the table). Everything starts depending more on your hardware and access patterns. In 11*g*, this continues to improve, and in Exadata, you have a whole new paradigm with even greater efficiencies. I have left the following graph in Figure 9-9 in this version of the book to show where Oracle has been in the past (Chapter 8 shows a graph of where we are currently with 11*g*).

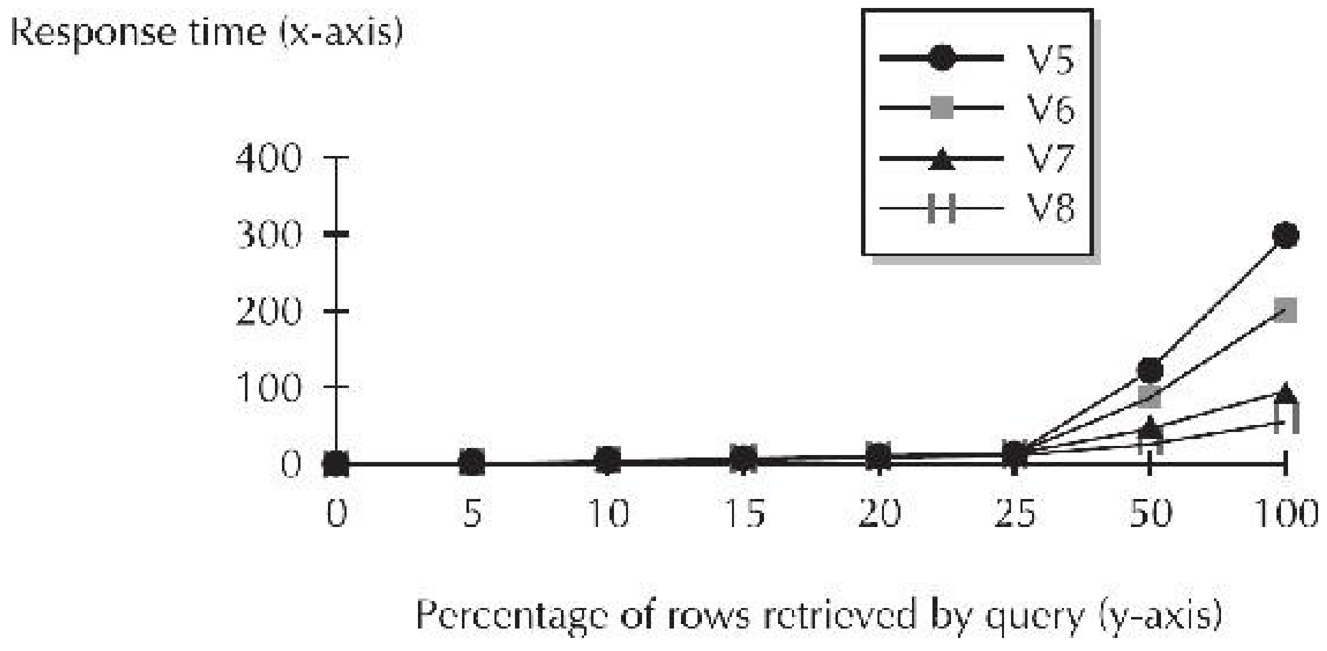


FIGURE 9-9. *Optimum percentage of rows for index for older versions of Oracle*

Optimizer Execution Plan

You can graph performance patterns to leverage available diagnostic tools. For example, you analyzed a slow and complex SQL statement that used views and ran high-volume data under the

Oracle cost-based optimizer. Results showed a very high performance line identical to *D* in Figure 9-8. The Oracle EXPLAIN PLAN also showed an inefficient execution plan. Once an effective optimizer hint command was found (i.e., FIRST_ROWS) and added directly to the SQL statements that defined the views, performance improved dramatically to line *B*.

Multiple Table Joins

Complex *multiple-table join* statements often run poorly regardless of the conventional tuning used and may be similar to lines *A* or *C* in Figure 9-8. From past experience, rather than trying to tune only the statement with conventional techniques, a more effective solution is to decompose it into a series of simple SQL statements using temporary tables. The final result would be the same, but at much faster speed, represented by a composite line at *B*.

Jackknifing

Jackknifing is a pattern where a performance line starts off shallow but then veers steeply upward at a certain threshold point, similar to *E* in Figure 9-8. Two linear equations may define the behavior; its cause could be anything from disk I/O or memory limitations to a switch in the optimizer execution plan due to changing data volumes. Possible solutions are to increase the system's limitations, run fresh optimizer statistics, or break the statement into selection ranges. Proper tuning might either straighten out the line to E_1 or improve it further to line *B*.

Riding the Quadratic Curve

Often, a poorly performing SQL process is designed and tested on low-volume data, but in production under higher volumes, its true and degrading quadratic nature is revealed, as shown by curve *A* in Figure 9-10. In this example, a process was created and tested up to x_1. Performance was believed to be close to line *B*, but once in production and when the volume was increased to x_3, the line really turned out to be curve *A*.

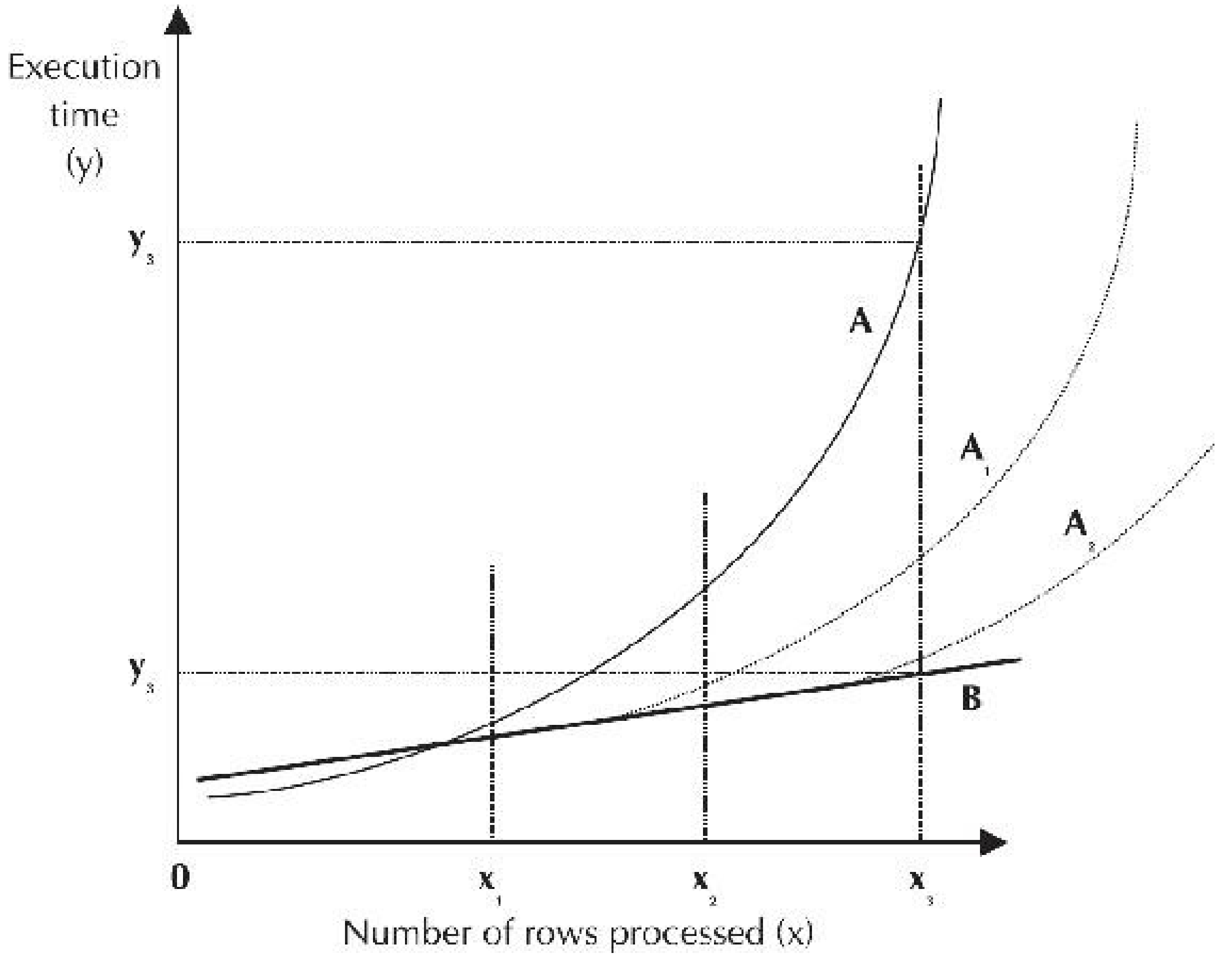


FIGURE 9-10. *Example of riding the quadratic curve*

If you cannot find a proper tuning solution, you can still improve a quadratic process of unknown cause by breaking the original statement into lower-volume selection ranges and riding the shallow part of the quadratic curve. Suppose in Figure 9-10, you break the process into three selection ranges: from [0 to x_0] that rides the lower part of curve A, from [x_1 to x_2] that rides the lower part of curve A_1, and from [x_2 to x_3] that rides the lower part of curve A_2. The overall result is something closer to line *B* from [0 to x_3] with y_2' taking a lot less time than the original y_2. Although this technique may not be the best solution, it could still solve the problem.

Instead of running everything all at once, breaking up the process using a SQL loop and commit mechanism can sometimes buy better overall performance for processes like UPDATEs and DELETEs that use ROLLBACK segments.

Volatility Effects

Running under ideal conditions and graphing the results makes it much easier to analyze the effects of outside traffic and its resulting volatility. For example, line *A* in Figure 9-11 is from an inefficient linear process run under ideal conditions. Suppose a controlled amount of traffic from another process is then run at the same time. It could be a large query, insert, update, or backup, etc. This second test moves line *A* by 100 percent to A_1. In other words, the process with added traffic on the system is twice as slow.

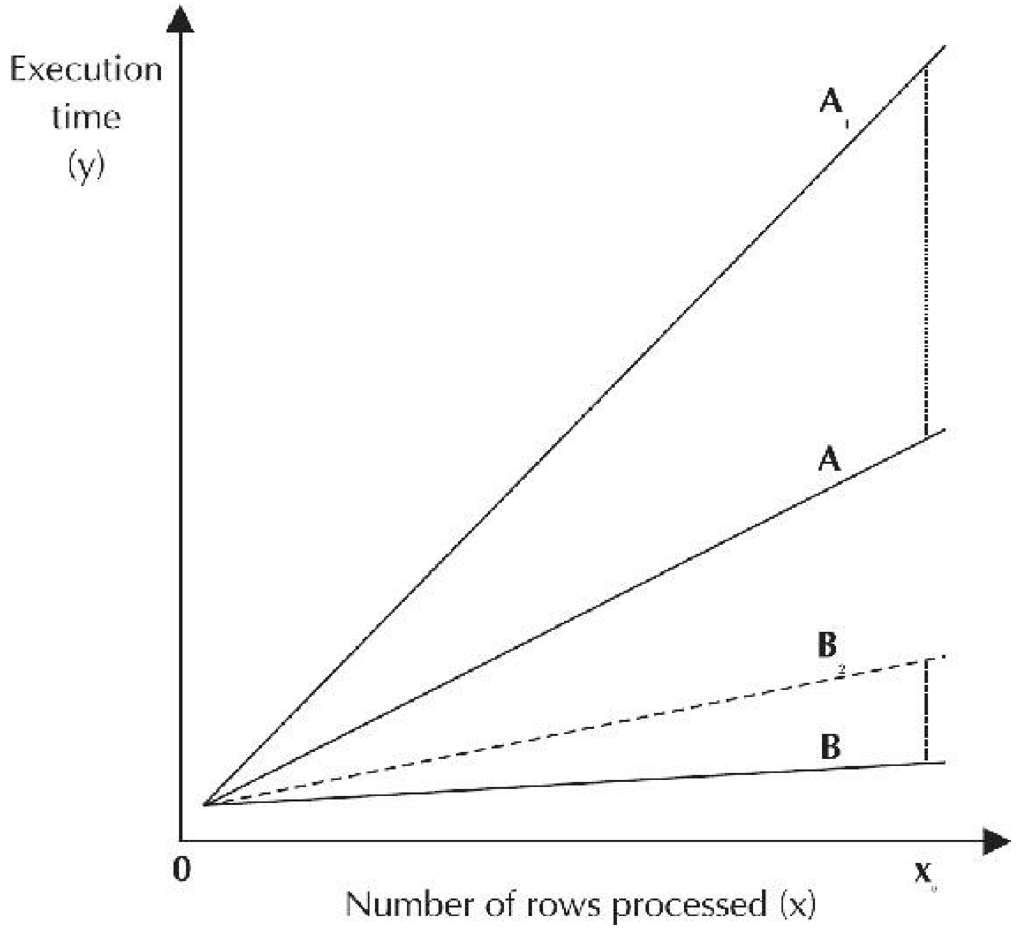


FIGURE 9-11. *Example of volatility effects*

Now suppose you optimize the original process. Under an ideal test of the new process, the best performance line shifts down to *B*. If you were to predict what would happen if you applied the same controlled traffic to the new process, you might predict a 100 percent shift to B_2.

However, since the slopes between *A* and *B* differ (with *A* being much steeper than *B*), the 100 percent time increase from *B* to B_2 would be much less than from *A* to A_1. In fact, an actual traffic test on line *B* might prove to be much less than even the predicted 100 percent due to the overall efficiency of the line *B* process. In general, more efficient SQL processes are less susceptible to added traffic effects than less efficient processes.

Mathematical Techniques Conclusions

Simple Mathematical Techniques is an effective Oracle SQL performance analysis and tuning methodology that involves running tests under ideal conditions, graphing performance observations, and using simple linear and quadratic equation determination for predicting performance at higher loads. It also includes the interpretation of performance patterns that can be applied directly to tuning SQL code. You can build your own tuning tools using these methods.

The methodology acts as a catalyst by combining the use of some traditional mathematical analysis with Oracle diagnostic tools to aid in their interpretation and to leverage their effectiveness. It can also help you identify hidden problems that may be overlooked by other diagnostic methods by providing a broad picture of performance. The technique can also help you overcome performance-tuning barriers such as inexperience with Oracle, lack of hard evidence, or difficulties with diagnostic tool interpretation that may prevent effective performance tuning. You can also analyze volatility effects from outside traffic. Graphs provide a visual picture of performance for presentation to management and end users. And you can use spreadsheets such as Microsoft Excel with these techniques for quick and easy performance analysis.

TIP
If you want an Oracle symphony as great as one of Beethoven's, you must learn and know how to apply mathematical techniques to your tuning efforts. You don't have to learn everything that you learned in college calculus; merely apply the simple equations in this chapter to tie everything in this book together. Thank you, Joe Holmes, for doing the math for us!

Tips Review

- Using cost-based optimization, the first table in the FROM clause is the driving table when the ORDERED hint is used. This overrides the optimizer from choosing the driving table. If a SORT-MERGE join is used, then the order of the tables has no impact because neither will drive the query (although the first listed table is accessed first for the operation and is the driving table). Knowing which table is generally the driving table when using an ORDERED hint in small joins can help you solve larger table join issues and also help you find indexing problems.
- When hash initialization parameters are set up, the optimizer uses HASH joins in lieu of SORT-MERGE joins. With HASH joins, the first table is used to build a hash table (in memory if available), and the second table in the FROM clause then probes for corresponding hash table matches. The first table in the FROM clause (using the ORDERED hint) is the first table accessed in a HASH join.
- Using cost-based optimization and a NESTED LOOPS join as the means of joining, the first table in the FROM clause is the driving table (all other conditions being equal), but only the ORDERED hint guarantees this. In NESTED LOOPS joins, choosing a driving table that is the smaller result set (not always the smaller table) makes fewer loops through the other result set (from the nondriving table) and usually results in the best performance.
- To change the method that Oracle uses to join multiple tables, use the USE_MERGE, USE_NL, and USE_HASH hints. Multiple tables may need to be specified for the hint to work, and the driving order is usually from first to last in the FROM clause.
- In a three-table join, the driving table is the intersection table or the table that has a join condition to each of the other two tables in the join. Try to use the most limiting table as the driving table (or intersection table) so your result set from the join of the first two tables is small when you join it to the third table. Also, ensure that all join conditions on all tables are indexed!

- Using cost-based optimization, when a large table and a small table are joined, the smaller table is the driving table (accessed first), and the smaller table is used to build a hash table in memory on the join key. The larger table is scanned and then probes the hash table for matches to the join key. Also note that if there is not enough memory for the hash, the operation can become extremely slow because the hash table may be split into multiple partitions that could be paged to disk. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table, and it will be the one used to build the hash table.
- Using cost-based optimization, when a large and small table are joined, the larger table is the driving table if an index can be used on the large table. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table.
- To ensure that you are reading your EXPLAIN PLAN correctly, run a query for which you are sure of the driving table (with nested subqueries).
- You may not be able to modify actual code for some third-party products, but you can often add, force, or suppress indexes (using SQL Plan Management) to improve performance.
- When distributed queries cannot be avoided, use IN clauses, set operators such as UNION and MINUS, and use everything else you can to reduce the network traffic between database nodes. Queries written in a manner that causes looping between distributed nodes (distributed databases) can be extremely slow.
- In addition to the more typical reasons, when developers modify the data as it is being selected, fetching across commits, the Snapshot Too Old error can occur. To fix this problem, close and reopen the cursor causing the issue.
- Dumping data blocks can be a valuable tool to understand how Oracle works and to investigate problem-tuning areas. Only a tuning expert should use block dumps, and even an expert should use the help of Oracle Support. Oracle does not publish the structure of block dumps, so they can change at any time.
- If you want an Oracle symphony as great as one of Beethoven's, you must learn and know how to apply mathematical techniques to your tuning efforts. You don't have to learn everything that you learned in college calculus; merely apply the simple equations in this chapter to tie everything in this book together.
- If you've read and understood this entire chapter, you're probably among the top-tuning professionals and you will see the heights and joys that I've seen with tuning Oracle.

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CHAPTER 10

Using PL/SQL to Enhance Performance (Developer and DBA)

As with each release before it, Oracle Database 12*c* continues to elevate PL/SQL performance and functionality to new levels. This chapter focuses on helpful tips that are new with 12*c* (up to 12*c*R2) as well as tips that continue to be useful from older versions. Once you have great queries to monitor your system, you need to automate them. PL/SQL gives you the capability to do so while also providing some great packages and procedures that you can use for tuning. The PL/SQL engine processes all PL/SQL requests and passes the statements on to Oracle for execution. When PL/SQL is passed to Oracle, it is placed in Oracle's System Global Area (SGA), more particularly in the shared pool. In Oracle, PL/SQL source code can be stored in the database in the form of procedures, functions, packages, and triggers. Once these objects are stored in the database in compiled format, they can be executed from any Oracle tool by any user who has been granted EXECUTE privilege on that object. Upon execution, the p-code (executable code) is loaded into the shared pool and executed by Oracle. A PL/SQL object remains in the shared pool until the object is aged out with a Least Recently Used (LRU) algorithm. If any process calls the object, it does not have to be reloaded into the SGA shared pool as long as it has not been aged out. Therefore, Oracle looks in the shared pool (which is very efficient) for the object prior to going to disk (which is not as efficient) to load the object. How well the SQL within the PL/SQL is tuned is probably the biggest factor driving performance, yet I will cover other tuning considerations in this chapter. The last portion of this chapter is dedicated to understanding and being able to locate the PL/SQL. Here are the tips covered in this chapter:

- Leverage the PL/SQL Function Result Cache to improve performance (improved in 12*c*)
- Define PL/SQL subprograms in a SQL statement (new in 12*c*)
- Reference sequences directly in PL/SQL expressions
- Identity Columns (new in 12*c*)
- Max size increase for VARCHAR2, NVARCHAR2, and RAW data types (new in 12*c*)
- Binding PL/SQL-only data types to SQL statements using DBMS_SQL (new in 12*c*)
- Use named parameters in SQL function calls
- Simplify loops with the CONTINUE statement
- Leverage compile-time warnings to catch programming mistakes

- Increase performance with native compilation (improved in 12*c*)
- Maximize performance with the optimizing compiler (improved in 12*c*)
- Use DBMS_APPLICATION_INFO for real-time monitoring
- Use a custom replacement of DBMS_APPLICATION_INFO for real-time monitoring in a RAC environment
- Log timing information in a database table
- Reduce PL/SQL program unit iterations and iteration time
- Use ROWID for iterative processing
- Standardize on data types, IF statement order, and PLS_INTEGER
- Reduce the calls to SYSDATE
- Reduce the use of the MOD function
- Improve shared pool use by pinning objects
- Identify the PL/SQL that needs to be pinned
- Use and modify DBMS_SHARED_POOL.SIZES
- Get detailed object information from DBA_OBJECT_SIZE
- Find invalid objects
- Find disabled triggers
- Use PL/SQL associative arrays for fast reference table lookups
- Find and tune the SQL when objects are used
- Consider the time component when working with Oracle's DATE data type
- Use PL/SQL to tune PL/SQL
- Understand the implications of PL/SQL location
- Specify a rollback segment for a large cursor
- Use temporary database tables for increased performance
- Integrate a user-tracking mechanism to pinpoint execution location
- Limit the use of dynamic SQL
- Use pipelined table functions to build complex result sets
- Suppress debugging commands with conditional compilation
- Take advantage of the samples just for the beginners (beginners start here)

Leverage the PL/SQL Function Result Cache to Improve

Performance (Improved in 12*c*)

Perhaps the best developer feature in Oracle Database 12*c* is the improved PL/SQL Function Result Cache. This feature provides a quick way to build a cache of function results that will be used automatically when a subsequent call to a function is made with the same parameter values. It essentially eliminates the hand-coded caches that you've had to build in the past using PL\SQL array structures. More importantly, the new Function Result Cache works at the instance level, not the session level as is the case with hand-coded mechanisms.

Let's start the example with these tables:

```
Table Name  Rows        Column        Type      Length
----------- ----------- ------------- --------- ------
countries            65 country_id    number
                        country_name  varchar2      50
cities            1,111 city_id       number
                        country_id    number
                        city_name     varchar2      50
residents     1,000,000 resident_id   number
                        first_name    varchar2      50
                        last_name     varchar2      50
                        salary        number
                        city id       number

Table Name  Constraint Name  Type Column        Related Constraint
----------- ---------------- ---- ------------- ------------------
countries   countries_pk     PK   country_id
countries   countries_uk1    UK   country_name
cities      cities_pk        PK   city_id
cities      cities_uk1       UK   country_id
                                  city_name
cities      cities_fk1       FK   country_id    countries_pk
residents   residents_pk     PK   resident_id
residents   residents fk1    FK   city id       cities pk
```

There are a total of 398,124 USA residents with these totals in some key cities:

```
City Name      Count
------------- -----
Anchorage       907
Baltimore       865
Chicago         869
Dallas          924
New York City   890
```

Next, you create a function that returns the average salary for a specified country:

```
CREATE OR REPLACE FUNCTION get_avg_sal (p_country_c in varchar2) return number is
 v_avg_n number;
BEGIN
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id      = t.city_id
     and t.country_id   = c.country_id
     and c.country_name = p_country_c;
  return v_avg_n;
END get_avg_sal;
```

The baseline performance is obtained by executing the function several times to compute the average salary of residents in the USA:

```
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515368.02

Execution Times
---------------
0.421 seconds
0.359 seconds
0.358 seconds
0.359 seconds
0.374 seconds
```

The initial execution, which incurs the overhead of parsing the statement, is ignored to yield an average execution time of 0.3625 seconds. Not a bad showing overall considering the RESIDENTS table contains 1 million records. However, let's see how this seemingly fast performance can compound into poor performance when the function is utilized within a complex query. The task is to determine the number of Chicago residents who earn more than the average salary. Here are the results:

```
select count(*)
  from residents r,
       cities    c,
       countries cr
 where r.city_id        = c.city_id
   and c.country_id     = cr.country_id
   and cr.country_name = 'USA'
   and c.city_name      = 'Chicago'
   and r.salary         > get_avg_sal(cr.country_name);

  COUNT(*)
----------
       434

Executed in 309.318 seconds
```

Clearly, the problem here is that the GET_AVG_SAL function is being executed 869 times, once for each resident who lives in Chicago. Realizing that the GET_AVG_SAL function can only return 65 different values (one for each country), one might be inclined to build a caching mechanism into the function call. You can implement a cache in a matter of seconds by simply adding the RESULT_CACHE keyword to the function definition:

```
CREATE OR REPLACE FUNCTION get_avg_sal(p_country_c in varchar2) return number
result_cache is
 v_avg_n number;
BEGIN
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id       = t.city_id
     and t.country_id    = c.country_id
     and c.country_name = p_country_c;
  return v_avg_n;
END get_avg_sal;
```

With the Result Cache enabled, the average execution time of the function has dropped to 0.0155 seconds, as shown here:

```
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515368.02
```

```
Execution Times
---------------
1.373 seconds
0.015 seconds
0.016 seconds
0.016 seconds
0.015 seconds
```

The complex Chicago query now completes in a blazing 0.749 seconds!

Let's take a closer look at what is happening within the function. First, the function is modified slightly to generate console output every time it executes:

```
CREATE OR REPLACE FUNCTION get_avg_sal(p_country_n in varchar2) return number result_cache is
 v_avg_n number;
BEGIN
  dbms_output.put_line('Executing Function Body');
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id         = t.city_id
     and t.country_id      = c.country_id
     and c.country_name = p_country_n;
  return v_avg_n;
END get_avg_sal;
```

Now let's run the complex Chicago query:

```
select count(*)
  from residents r,
       cities    c,
       countries cr
 where r.city_id         = c.city_id
   and c.country_id      = cr.country_id
   and cr.country_name = 'USA'
   and c.city_name       = 'Chicago'
   and r.salary          > get_avg_sal(cr.country_name);

  COUNT(*)
----------
       434

Executing Function Body

Executed in 1.591 seconds
```

The single "Executing Function Body" indicates that the function body was only executed a single time. When you re-execute the query,

```
/
  COUNT(*)
----------
       434

Executed in 0.749 seconds
```

the “Executing Function Body” text does not appear because the results are coming from the Result Cache. As an added benefit, the Result Cache is automatically leveraged by any session of the instance. In comparison, a manually coded cache would be session-specific (each session would maintain its own copy of the cache array and values). To test this, start a new SQL session and run the complex Chicago query:

```
select count(*)
  from residents r,
       cities    c,
       countries cr
 where r.city_id        = c.city_id
   and c.country_id     = cr.country_id
   and cr.country_name = 'USA'
   and c.city_name      = 'Chicago'
   and r.salary         > get_avg_sal(cr.country_name);

  COUNT(*)
----------
       434

Executed in 0.811 seconds
```

Clearly, the new database session is utilizing the cache that was populated in the original session for the `get_avg_sal('USA')` function call. If you alter the query to report on Dublin, Ireland, you will see that the function must be executed again to fill the cache with data for Ireland:

```
select count(*)
  from residents r,
       cities    c,
       countries cr
 where r.city_id        = c.city_id
   and c.country_id     = cr.country_id
   and cr.country_name = 'Ireland'
   and c.city_name      = 'Dublin'
   and r.salary         > get_avg_sal(cr.country_name);

  COUNT(*)
----------
       431

Executing Function Body

Executed in 1.872 seconds
```

If you are wondering what happens to the cache when the underlying table data is changed, let's take a look using a few SQL commands (run in a relaunched database):

```
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515368.02
```

```
Executing Function Body

Executed in 2.278 seconds

update residents r
   set r.salary = r.salary + 100;

1000000 rows updated

Executed in 32.152 seconds

commit;

Commit complete

Executed in 0 seconds

select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515368.02

Executed in 0.015 seconds
```

Clearly the cache is not aware of the underlying data manipulations and the result being returned is now incorrect. Oracle provides a utility package, DBMS_RESULT_CACHE, that you can leverage to force an immediate purging of the cache, as shown next. Purging, of course, allows the cache to be repopulated with the proper values, taking into account the sweeping salary change that was made. Note that EXECUTE privileges for the DBMS_RESULT_CACHE package are not provided by default.

```
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515368.02

Executed in 0.016 seconds

exec dbms_result_cache.flush;
PL/SQL procedure successfully completed

Executed in 0.031 seconds

select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515468.02

Executing Function Body

Executed in 1.186 seconds
```

The appropriate long-term solution is to alter the function definition to identify underlying dependencies that the cache needs to take into account. Do this with the RELIES_ON clause:

```
CREATE OR REPLACE FUNCTION get_avg_sal(p_country_c in varchar2)
return number result_cache relies_on(cities, residents) is
 v_avg_n number;
BEGIN
  dbms_output.put_line('Executing Function Body');
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id      = t.city_id
     and t.country_id   = c.country_id
     and c.country_name = p_country_c;
  return v_avg_n;
END get_avg_sal;
```

The Result Cache now monitors changes to the CITIES and RESIDENTS tables and refreshes itself as needed. The CITIES table is listed as a dependency to track any reorganizations that may occur, such as a new city being added to a country. Let's see how this change impacts the results:

```
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515468.02

Executing Function Body

Executed in 0.92 seconds

select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515468.02

Executed in 0.015 seconds

update residents r
   set r.salary = r.salary + 100;
1000000 rows updated
Executed in 32.277 seconds
commit;
Commit complete
Executed in 0.031 seconds
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515568.02

Executing Function Body

Executed in 1.435 seconds
```

The cache now responds to changes in the underlying tables that the function relies on and refreshes itself as needed.

In addition to the DBMS_RESULT_CACHE package mentioned earlier, Oracle provides several performance views to monitor the Result Cache: V$RESULT_CACHE_STATISTICS, V$RESULT_CACHE_MEMORY, V$RESULT_CACHE_OBJECTS, and V$RESULT_CACHE_DEPENDENCY. From a developer perspective, the most useful of these views are V$RESULT_CACHE_STATISTICS and V$RESULT_CACHE_OBJECTS. The former provides a summary overview of the entire Result Cache, whereas the latter provides details for each object in the Result Cache.

The V$RESULT_CACHE_STATISTICS view always returns ten records providing summary information about the entire Result Cache. Here’s an example of the information returned by V$RESULT_CACHE_STATISTICS:

```
select * from sys.v_$result_cache_statistics;

        ID NAME                                     VALUE
---------- ------------------------------ ----------
         1 Block Size (Bytes)                        1024
         2 Block Count Maximum                       1056
         3 Block Count Current                         32
         4 Result Size Maximum (Blocks)                52
         5 Create Count Success                         2
         6 Create Count Failure                         0
         7 Find Count                                1739
         8 Invalidation Count                           0
         9 Delete Count Invalid                         0
        10 Delete Count Valid                           0

10 rows selected
```

These name-value pairs are defined as follows:

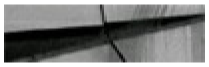
Name	Value
Block Size (Bytes)	Size of each memory block.
Block Count Maximum	Maximum number of memory blocks allowed.
Block Count Current	Number of memory blocks currently allocated.
Result Size Maximum (Blocks)	Maximum number of blocks allowed for a single result.

Create Count Success	Number of cache results successfully created.
Create Count Failure	Number of cache results that failed to create.
Find Count	Number of cached results that were successfully serviced by the cache (so the function body did not need to be executed).
Find Copy Count	Number of cached results that were copies.
Hash Chain Length	As more blocks are hashed to the same hash chain, the length increases. If this becomes too long, scanning the long hash chain could cause performance degradation.
Invalidation Count	Total number of invalidations. An invalidation occurs when the cached results are no longer valid due to a dependency. For example, when the salaries were changed above, the cache becomes invalid and will be refreshed on the next function call.
Delete Count Invalid	Number of invalid cached results deleted.
Delete Count Valid	Number of valid cached results deleted.

The STATUS column of V$RESULT_CACHE_STATISTICS indicates the viability of the data in the cache with values being limited to

- **New** Result is still under construction.
- **Published** Result is available for use.
- **Bypass** Result will be bypassed for use.
- **Expired** Result has exceeded expiration time.
- **Invalid** Result is no longer available for use.

The rows in the V$RESULT_CACHE_OBJECTS view with the value 'Result' for the TYPE column are of most interest as they allow you to review information such as hit rates. The view contains a "Published Result" record (TYPE = 'Result' and STATUS = 'Published') for each unique combination of function name and input parameters that is still valid in the cache. The V$RESULT_CACHE_OBJECTS view also contains "Invalid" records (STATUS = 'Invalid') that result when cache entries are invalidated, such as when a change in a RELIES_UPON object causes the cache to be refreshed. Based on the SQL that has been issued during this discussion, you can expect the view to have two published result records: one for the numerous calls to `get_avg_sal('USA')` and one for the calls to `get_avg_sal('Ireland')`. Here is a portion of the record for the USA call:



```
ID                       6
TYPE                     Result
STATUS                   Published
BUCKET_NO                595
HASH                     1988862551
NAME                     "SCOTT"."GET_AVG_SAL"::8."GET_AVG_SAL"#8440831613f0f5d3 #1

NAMESPACE               PLSQL
CREATION_TIMESTAMP       1/23/2009 9:58:57 AM
CREATOR_UID             5512
DEPEND_COUNT             3
BLOCK_COUNT              1
SCN
COLUMN_COUNT             1
PIN_COUNT                0
SCAN_COUNT               4345
ROW_COUNT                1
ROW_SIZE_MAX             7
ROW_SIZE_MIN             7
ROW_SIZE_AVG             7
BUILD_TIME               146
LRU_NUMBER               0
INVALIDATIONS            NULL
OBJECT_NO                NULL
SPACE_OVERHEAD           274
SPACE_UNUSED             743
```

These columns are identified as follows:

Column Name	Description
ID	Identifier for the cache object (also the ID of the first block)
TYPE	Type of the cache object
STATUS	Status of the object
BUCKET_NO	Internal hash bucket for the object
HASH	Hash value for the object
NAME	Name (for example, SQL prefix or PL/SQL function name)
NAMESPACE	The type of cached result (SQL or PL/SQL)
CREATION_TIMESTAMP	Time when the object was created
CREATOR_UID	The ID of the user that created the result
DEPEND_COUNT	The number of dependencies for each result, or the number of dependents if the TYPE is a dependency
BLOCK_COUNT	Total number of blocks in the cached object
SCN	Either the build SCN for a result or the SCN at which a dependency was invalidated
COLUMN_COUNT	Number of columns in the cached result
PIN_COUNT	Number of active scans on this result
SCAN_COUNT	Total number of scans initiated on the cached result
ROW_COUNT	Total number of rows in the cached result
ROW_SIZE_MAX	Size of the largest row (in bytes)
ROW_SIZE_MIN	Size of the smallest row (in bytes)
ROW_SIZE_AVG	Average size of a row (in bytes)
BUILD_TIME	Amount of time (in hundredths of a second) it took to build the cached result
LRU_NUMBER	LRU list position (the smaller the value, the more recent the usage)
OBJECT_NO	The data dictionary object number for the dependency object
INVALIDATIONS	The number of times the dependency object has invalidated its dependent objects
SPACE_OVERHEAD	Overhead (in bytes) for the result
SPACE_UNUSED	Unused space (in bytes) for the result

In conclusion, the new PL/SQL Function Result Cache makes possible enormous performance gains with a minimum of development effort. It shouldn't be used as a crutch for poorly written/designed functions but as another tool for creating highly efficient routines.

In 12*c*, we also can combine invoker rights (AUTHID CURRENT_USER) with the Function Result Cache (RESULT_CACHE). Our function will look like this now:

```
CREATE OR REPLACE FUNCTION get_avg_sal(p_country_c in varchar2) return number
AUTHID CURRENT_USER
RESULT_CACHE is
 v_avg_n number;
BEGIN
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id      = t.city_id
     and t.country_id   = c.country_id
     and c.country_name = p_country_c;
  return v_avg_n;
END get_avg_sal;
```

With this declaration the Result Cache for an invoker rights function is logically partitioned by the name of the current user. Performance will be improved when executed by the same user invoking this function with exactly the same parameter.

Define PL/SQL Subprograms in a SQL Statement (New in 12*c*)

Release 12*c* presented two new features to increase query performance when a subprogram is called. We can now create a PL/SQL subprogram inline SELECT statement utilizing the WITH clause declaration. This function when created in the WITH clause subquery is only available for the current query and is not stored as an object in the database (similar to an inline view). Since this subprogram in the WITH clause will be called from the SELECT statement, only the function in the declaration can be used.

Let's use the function from the previous example:

```
CREATE OR REPLACE FUNCTION get avg sal(p country c in varchar2)
return number is
   v_avg_n number;
BEGIN
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id      = t.city_id
     and t.country_id   = c.country_id
     and c.country_name = p_country_c;
  return v_avg_n;
END get avg sal;
```

In 12*c*, if we don't want to store this function in the database, and use it just in SELECT statements, we can use the WITH clause:

```
WITH FUNCTION get_avg_sal(p_country_c in varchar2)
return number result_cache relies_on(cities, residents) is
 v_avg_n number;
BEGIN
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id      = t.city_id
     and t.country_id   = c.country_id
     and c.country_name = p_country_c;
  return v_avg_n;
END;
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515568.02
```

No switching from SQL to PL/SQL engines and vice versa, and no stored object with all needed grants, synonyms, and so on! In addition to performance gains for one execution, this new 12*c* feature is very helpful for queries written using read-only accounts. You don't need to create functions' privileges in the specialized reports if no reusability is required. The local WITH clause declaration takes precedence over the stand-alone function with the same name.

A second, related feature new in 12*c* is that a function can be created with the *UDF* pragma to inform the compiler that the function is always called in a SELECT statement. UDF stands for user-defined function. Since version 7, we have been able to create PL/SQL functions, store them in the database, and call them from SQL or PL/SQL. The problem on the performance side is that this requires context switching from SQL and PL/SQL each time. With Oracle 12*c* we can use PRAGMA UDF as a compiler directive indicating that this function is used in the SQL statement.

Let's take our function from the previous example and add this PRAGMA UDF:

```
FUNCTION get_avg_sal(p_country_c in varchar2)
return number result_cache relies_on(cities, residents) is
PRAGMA UDF;
 v_avg_n number;
BEGIN
  select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities    t
   where r.city_id       = t.city_id
     and t.country_id    = c.country_id
     and c.country_name = p_country_c;
  return v_avg_n;
END;
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
         515568.02
```

Let's compare the performance of this new option to just calling the simple stored GET_AVG_SAL function, which we will set as 1× performance. When using the WITH option, performance is 3.7× faster, and with UDF pragma performance is 3.9× faster. As you can see, the performance gain is significant, but you need to remember a few of the drawbacks. A function utilizing the WITH clause is not stored in the database and cannot be reused. A function created with PRAGMA UDF can slow down performance if called directly from another PL/SQL program. So, use PRAGMA UDF in a function only when calling it from a SQL statement.

Reference Sequences Directly in PL/SQL Expressions

You can reference sequences directly in PL/SQL expressions without the archaic "select from dual" construct. The result is more streamlined code that is easier to read and maintain. Oracle also promises improved performance and scalability. Let's start with a PL/SQL block written the "old fashioned" way with a "select from dual" construct being used to pull values from a sequence:

```
drop sequence my_seq;

create sequence my_seq
minvalue 1
start with 1
increment by 1
nocache;

DECLARE
  v_time_start_i integer;
  v_time_end_i   integer;
  v_value_i      integer;
BEGIN
  v_time_start_i := dbms_utility.get_time;
  for i in 1..100000 loop
    select my_seq.nextval
      into v_value_i
      from dual;
  end loop;

  v_time_end_i := dbms_utility.get_time;
  dbms_output.put_line('Execution Time: '||
                          (v_time_end_i - v_time_start_i)/100||
                          ' seconds');
END;
/
```

This block executes in 61.47 seconds (averaged across three executions).

You can streamline the code by referencing the NEXTVAL and CURRVAL pseudocolumns directly within the PL/SQL code, as shown here:

```
drop sequence my_seq;

create sequence my_seq
minvalue 1
start with 1
increment by 1
nocache;

DECLARE
  v_time_start_i integer;
  v_time_end_i   integer;
  v_value_i      integer;
BEGIN
  v_time_start_i := dbms_utility.get_time;
  for i in 1..100000 loop
    v_value_i := my_seq.nextval;
  end loop;

  v_time_end_i := dbms_utility.get_time;
  dbms_output.put_line('Execution Time: '||
                           (v_time_end_i - v_time_start_i)/100||
                           ' seconds');
END;
/
```

The average execution time with this block is 61.90 seconds. While the ability to reference the sequence value directly in PL/SQL has simplified the code, a performance gain has not been realized. In fact, the performance has degraded slightly. To investigate further, the previous tests are repeated with sequences using various cache sizes. The results are summarized here.

Time (in Seconds) to Fetch 100,000 Values from a Sequence

Cache Size	Select from Dual	Inline
None	61.47	61.90
20	6.76	6.72
500	3.94	3.89

So it would appear that the inline construct has a slight performance advantage, particularly when the sequences are defined with a cache. However, the advantage is so slight that I am reluctant to say definitively that the new construct is indeed faster. A second round of testing with the same parameters as before and the performance advantage now tips in favor of the "select from dual" construct.

Time (in Seconds) to Fetch 100,000 Values from a Sequence

Cache Size	Select from Dual	Inline
None	61.36	62.37
20	6.80	6.96
500	3.96	3.99

Identity Columns (New in 12*c*)

You can utilize the ability to define an IDENTITY clause against a table column defined using a numeric type, instead of code that creates and uses a sequence object (the Create Sequence privilege is required to create Identity Columns *since they are in fact sequential values or sequences*). When creating a table (or altering a column) with the 12*c* Identity Column, the following options are available: ALWAYS, BY DEFAULT, and ON NULL. ALWAYS forces the use of the identity. If an INSERT statement references the Identity Column (even to specify a NULL value), an error will be raised.

An example with ALWAYS looks like this:

```
drop table emps PURGE;
CREATE TABLE emps (
    Emp_ID      NUMBER GENERATED ALWAYS AS IDENTITY,
    First_Name    VARCHAR2(55),
    Middle_Name VARCHAR2(30),
    Last_Name      VARCHAR2(100));
SQL> INSERT INTO emps ('JOE', 'A', 'SMITH');
1 row created.
```

But any attempt to pass a value for the EMP_ID will result in an error:

```
SQL> INSERT INTO emps (Emp_ID, LAST_NAME) VALUES (2, 'SMITH');
INSERT INTO emps (Emp_ID, LAST_NAME) VALUES (2, 'SMITH');
*
ERROR at line 1:
ORA-32795: cannot insert into a generated always identity column
 (passing NULL to the GENERATED ALWAYS column will result with the same error).
```

The BY DEFAULT clause allows you to use the identity if the column isn't referenced in the INSERT statement, but if the column is referenced, the specified value will be used in place of the identity.

An example with BY DEFAULT looks like this:

```
drop table emps PURGE;
CREATE TABLE emps (
    Emp_ID       NUMBER GENERATED BY DEFAULT AS IDENTITY,
    First_Name     VARCHAR2(55),
    Middle_Name VARCHAR2(30),
    Last_Name       VARCHAR2(100)
);
SQL> INSERT INTO emps (Emp_ID, LAST_NAME) VALUES (2, 'SMITH');
1 row created.
```

The BY DEFAULT ON NULL clause allows the identity to be used if the Identity Column is referenced but a value of NULL is specified.

An example with BY DEFAULT ON NULL looks like this:

```
drop table emps PURGE;
CREATE TABLE emps (
    Emp_ID       NUMBER GENERATED BY DEFAULT ON NULL AS IDENTITY,
    First_Name     VARCHAR2(55),
    Middle_Name VARCHAR2(30),
    Last_Name       VARCHAR2(100));
SQL> INSERT INTO EMPS (LAST_NAME) VALUES ('SMITH');
1 row created.
SQL> INSERT INTO EMPS (EMP_ID, LAST_NAME) VALUES (99, 'SMITH 99');
1 row created.
SQL> INSERT INTO EMPS (EMP_ID, LAST_NAME) VALUES (NULL, 'SMITH NULL');
1 row created.

SELECT Emp_ID, Last_Name FROM EMPS;
EMP_ID     LAST_NAME
---------- ------------------------------
         1 SMITH
        99 SMITH 99
           2 SMITH NULL
```

A couple of additional notes about Identity Columns:

- Identity Columns are always NOT NULL.
- [DBA|ALL|USER]_TAB_IDENTITY_COLS views show information about Identity Columns.
- The link between the table and the sequence is stored in the SYS.IDNSEQ$ table:

```
SELECT a.name AS table_name,
       b.name AS sequence_name
FROM   sys.idnseq$ c
       JOIN obj$ a ON c.obj# = a.obj#
       JOIN obj$ b ON c.seqobj# = b.obj#;

TABLE_NAME      SEQUENCE_NAME
-------------------- ------------------------------
EMPS                ISEQ$$_92125
```

Performance tests between using sequences and an Identity Column gave comparable results since sequences internally created and utilized the sequence, where an Identity Column allows clear column identity and less code to populate sequential values.

Max Size Increase to 32K for VARCHAR2, NVARCHAR2, and RAW Data Types (New in 12*c*)

Since the introduction of the VARCHAR2 and NVARCHAR2 data types, the maximum size limitation has been 4K (and RAW with 2K). To overcome this limitation, Large Object (LOB) data types needed to be used. With 12*c*, this limitation is removed and data types can be declared up to 32,767 bytes, which is especially useful for search capabilities in SQL statements and indexing for these increased-size columns. Size declaration will direct how the column is stored internally in the database. When declared with up to 4K for VARCHAR2 and NVARCHAR2 (and RAW up to 2K), the data is stored inline. When utilizing new increased sizing up to 32K, the data is stored out-of-line and the column is called an *extended character data type column*.

The database needs to be configured to utilize this new extended character data type. Simply creating a table with the column of this extended type will result in an error:

```
SQL> CREATE TABLE extended_type (test_32k  VARCHAR2(32000));
CREATE TABLE extended_type (test_32k  VARCHAR2(32000))
*
ERROR at line 1:
ORA-00910: specified length too long for its datatype
```

The following steps must be completed first to use this new extended data type:

1. Restart the database in upgrade mode (STARTUP UPGRADE).
2. Issue `ALTER SYSTEM set max_string_size=extended.`
3. Execute the `utl32k.sql` script from rdbms/admin as SYSDBA.
4. Restart the database in normal mode.

Now we can create this table with the extended character data type:

```
SQL> CREATE TABLE extended_type (test_32k  VARCHAR2(32000));
Table created.
```

Allow Binding PL/SQL-Only Data Types to SQL Statements (New in 12*c*)

Oracle 12*c* now supports the binding of PL/SQL-only data types to anonymous blocks, PL/SQL function calls in SQL, the TABLE operator in SQL, and CALL statements like

- BOOLEAN Type
- Record Types
- TABLE Operator
- Collections

Some of the most interesting uses of this feature are in dynamic SQL. Let's take a look at an example with a Boolean type calling function, where annual salary will be increased *or not increased* based on the passed Boolean parameter:

```
CREATE OR REPLACE FUNCTION emp_review (p_emp_id in NUMBER,
                            p_review_date in DATE,
                            p_full_increase in BOOLEAN)
   RETURN VARCHAR2 IS
BEGIN
  IF p_boolean THEN
   UPDATE emp
          SET review_date  = p_review_date,
                             pay  = pay * .3
    WHERE emp_id = p_emp_id;
 RETURN 'INCREASED';
  ELSE
 UPDATE emp
          SET review_date  = p_review_date,
    WHERE emp_id = p_emp_id;
RETURN 'NO INCREASE';
  END IF;
END;
/
SET SERVEROUTPUT ON
DECLARE
  v_sql        VARCHAR2(32000);  -- (note: utilizing increased allowable size)
  v_boolean  BOOLEAN := TRUE;
  v_result   VARCHAR2(30);
  v_date     DATE;
BEGIN
   v_date := SYSDATE;
  v_sql := 'SELECT emp_review (357, v_date, :v_boolean) INTO :l_result FROM dual';

  EXECUTE IMMEDIATE l_sql INTO l_result USING l_boolean;
  DBMS_OUTPUT.put_line('Review result  = ' || l_result);
END;
/
Review_result = INCREASED

PL/SQL procedure successfully completed.
```

Use Named Parameters in SQL Function Calls

When passing formal parameter values to PL/SQL subprograms, Oracle has always permitted position, named, and mixed notations. It is generally an accepted best practice to use the named notation, as it both increases code readability and offers a level of protection against changes to a subprogram's signature. Unfortunately, in prior versions to 11*g* the named notation was not available when PL/SQL functions were called from within a SQL command. This limitation left PL/SQL function calls that were embedded in SQL statements vulnerable to undesired effects if the subroutine signatures were not changed in a very careful manner.

Let's look at an example. First, I create a function that accepts a person's first and last names and formats them into a single string using the format *LastName, FirstName*:

```
CREATE OR REPLACE FUNCTION format_name(p_first_c in varchar2 default null,
                                       p_last_c  in varchar2 default null)
return varchar2 is
BEGIN
  return(p_last_c||', '||p_first_c);
END format_name;
```

I'll now use this function to format a couple of fictitious records from an EMPLOYEES table. I start out by using the positional notation that was mandatory in 11*g*:

```
select t.*,
       format_name(t.first_name, t.last_name) as name
  from emps t
 where emp_id in (1, 7);

    EMP_ID FIRST_NAME  MIDDLE_NAME LAST_NAME   NAME
---------- ----------- ----------- ----------- -------------------------
         1 Richard     John        Irons       Irons, Richard
         7 Julianne    Amy         Perrineau   Perrineau, Julianne

2 rows selected
```

For comparison purposes, I'll employ the same data using a PL/SQL block, as that method has always offered the use of named notation:

```
DECLARE
  cursor v_emps_cur is
    select *
      from emps
     where emp_id in (1, 7);
```

```
BEGIN
  dbms_output.put_line(lpad('EMP ID',       10, ' ')||' '||
                       rpad('FIRST NAME',   11, ' ')||' '||
                       rpad('MIDDLE NAME', 11, ' ')||' '||
                       rpad('LAST NAME',    11, ' ')||' '||
                       rpad('NAME',         25, ' '));

  dbms_output.put_line(lpad('-', 10, '-')||' '||
                       rpad('-', 11, '-')||' '||
                       rpad('-', 11, '-')||' '||
                       rpad('-', 11, '-')||' '||
                       rpad('-', 25, '-'));

  for r in v_emps_cur loop
    dbms_output.put_line(lpad(r.emp_id,       10, ' ')||' '||
                         rpad(r.first_name,   11, ' ')||' '||
                         rpad(r.middle_name, 11, ' ')||' '||
                         rpad(r.last_name,    11, ' ')||' '||
                         format_name(p_first_c => r.first_name,
                                     p_last_c  => r.last_name));
  end loop;
END;
/

    EMP ID FIRST NAME  MIDDLE NAME LAST NAME   NAME
---------- ----------- ----------- ----------- -------------------------
         1 Richard     John        Irons       Irons, Richard
         7 Julianne    Amy         Perrineau   Perrineau, Julianne

PL/SQL procedure successfully completed
```

As expected, the results are identical to what was returned by the SQL statement. Now let's fast-forward to a future enhancement in which the FORMAT_NAME function supports the middle name as well:

```
CREATE OR REPLACE FUNCTION format_name(p_first_c  in varchar2 default null,
                                      p_middle_c in varchar2 default null,
                                      p_last_c   in varchar2 default null)
return varchar2 is
BEGIN
  return(p_last_c||', '||p_first_c||' '||p_middle_c);
END format_name;
```

Note that the developer interjected the new middle name parameter between the existing parameters. Re-executing the SQL and PL/SQL extraction commands from before, you see that the former is returning incorrect results because of the positional notation:

```
    EMP_ID FIRST_NAME  MIDDLE_NAME LAST_NAME   NAME
---------- ----------- ----------- ----------- -------------------------
         1 Richard     John        Irons       , Richard Irons
         7 Julianne    Amy         Perrineau   , Julianne Perrineau

2 rows selected

    EMP_ID FIRST_NAME  MIDDLE_NAME LAST_NAME   NAME
---------- ----------- ----------- ----------- -------------------------
         1 Richard     John        Irons       Irons, Richard
         7 Julianne    Amy         Perrineau   Perrineau, Julianne

PL/SQL procedure successfully completed
```

You can now utilize the named notation with SQL to limit the impact of function signature changes, as shown here:

```
select t.*,
       format_name(p_first_c => t.first_name,
                   p_last_c  => t.last_name) as name
  from emps t
 where emp_id in (1, 7);

    EMP_ID FIRST_NAME  MIDDLE_NAME LAST_NAME   NAME
---------- ----------- ----------- ----------- -------------------------
         1 Richard     John        Irons       Irons, Richard
         7 Julianne    Amy         Perrineau   Perrineau, Julianne

2 rows selected
```

TIP
Named notation continues to be the preferred method for passing parameters to subroutines. You can now extend this best practice approach to SQL statements to yield consistency across the entire code base.

Simplify Loops with the CONTINUE Statement

The CONTINUE statement is used to cycle a loop (and skip the remaining statements) without requiring a branch to the end or raising an exception. The CONTINUE statement has two forms:

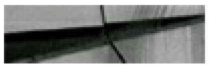
CONTINUE;

CONTINUE WHEN *boolean expression*;

The first form executes unconditionally and the second form executes only when the Boolean expression is TRUE. The CONTINUE statement will not necessarily improve performance but it provides better structured coding techniques and helps to avoid the awkward GOTO statement.

The following example displays only numbers divisible by three from within a loop.

Without CONTINUE statement:

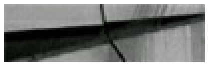


```
BEGIN
  for v_count_i in 1 .. 20 loop
    if mod(v_count_i, 3) != 0 then
      goto skip;
    end if;

    dbms output.put line('Value = ' || v count i);
    <<skip>>
    null;
  end loop;
END;

Results:
Value = 3
Value = 6
Value = 9
Value = 12
Value = 15
Value = 18
```

With CONTINUE statement:



```
BEGIN
  for v_count_i in 1 .. 20 loop
    if mod(v_count_i, 3) != 0 then
      continue;
    end if;
    dbms_output.put_line('Value = ' || v_count_i);
  end loop;
END;

Results:
Value = 3
Value = 6
Value = 9
Value = 12
Value = 15
Value = 18
```

With CONTINUE statement using WHEN clause:

```
BEGIN
  for v_count_i in 1 .. 20 loop
    continue when mod(v_count_i, 3) != 0;
    dbms_output.put_line('Value = ' || v_count_i);
  end loop;
END;

Results:
Value = 3
Value = 6
Value = 9
Value = 12
Value = 15
Value = 18
```

From a performance perspective, none of these three techniques has a distinctive advantage over the other two. Consider the following modified versions of the samples executed over a much larger number of iterations:

```
DECLARE
  v_total_count_i binary_integer := 0;
  v_div3_count_i  binary_integer := 0;
BEGIN
  for v_count_i in 1 .. 10000000 loop
    v_total_count_i := v_total_count_i + 1;
    if mod(v_count_i, 3) != 0 then
      goto skip;
    end if;
    v_div3_count_i := v_div3_count_i + 1;
    <<skip>>
    null;
  end loop;
  dbms_output.put_line('Total Iterations: '||v_total_count_i);
  dbms_output.put_line('  Divisible by 3: '||v_div3_count_i);
END;
/

Total Iterations: 10000000
  Divisible by 3: 3333333
PL/SQL procedure successfully completed
Executed in 10.343 seconds

DECLARE
  v_total_count_i binary_integer := 0;
  v_div3_count_i  binary_integer := 0;
BEGIN
  for v_count_i in 1 .. 10000000 loop
    v_total_count_i := v_total_count_i + 1;
    if mod(v_count_i, 3) != 0 then
      continue;
    end if;
    v_div3_count_i := v_div3_count_i + 1;
  end loop;
  dbms_output.put_line('Total Iterations: '||v_total_count_i);
  dbms_output.put_line('  Divisible by 3: '||v_div3_count_i);
END;
/

Total Iterations: 10000000
  Divisible by 3: 3333333
PL/SQL procedure successfully completed
Executed in 10.358 seconds
```

```
DECLARE
  v_total_count_i binary_integer := 0;
  v_div3_count_i  binary_integer := 0;
BEGIN
  for v_count_i in 1 .. 10000000 loop
    v_total_count_i := v_total_count_i + 1;
    continue when mod(v_count_i, 3) != 0;
    v_div3_count_i := v_div3_count_i + 1;
  end loop;
  dbms_output.put_line('Total Iterations: '||v_total_count_i);
  dbms_output.put_line('  Divisible by 3: '||v_div3_count_i);
END;
/

Total Iterations: 10000000
  Divisible by 3: 3333333
PL/SQL procedure successfully completed
Executed in 10.374 seconds
```

In this particular execution, both uses of the new CONTINUE statement were outpaced by the original GOTO technique; however, the gap was very small and repeated executions show that the lead can easily tip in any direction.

TIP
The new CONTINUE statement creates loop constructs that are more streamlined, but there are no performance gains to be realized at this time.

Leverage Compile-Time Warnings to Catch Programming Mistakes (Improved in 12*c*)

Since 10*g*, the PL/SQL compiler has had the capability to provide compile-time warnings regarding common programming mistakes. These warnings cover an assortment of issues that, if left unattended, may result in performance problems or logic errors. Before moving into the examples, note that the PL/SQL compiler does not issue compile-time warnings by default. This functionality is controlled by the Oracle Server parameter, PLSQL_WARNINGS. This parameter can be set specifically for a desired session by altering the session, as shown here:

```
alter session set plsql_warnings='ENABLE:ALL';
```

To ensure that compilation warnings are given consistently, however, it is recommended that the parameter be configured at the database level (consider setting this *only* for development or test systems, not for production systems).

Consider the following sample procedure in which the developer has created an if-then condition that is unreachable during execution. The PL/SQL compiler issues a warning drawing the developer's attention to the problem.

```
create or replace procedure warning_proc is
BEGIN
  if 1 - 2 then
    dbms_output.put_line('Inside If Statement');
  end if;
  dbms_output.put_line('After If Statement');
END warning_proc;
/

SP2-0804: Procedure created with compilation warnings

SQL> show errors

Errors for PROCEDURE WARNING_PROC:

LINE/COL ERROR
-------- ---------------------------
4/5      PLW-06002: Unreachable code
```

Since 11*g*, Oracle included additional deficiencies that the PL/SQL compiler can detect. Easily the most notable of these is PLW-06009, which detects the inappropriate use of the WHEN OTHERS exception handler. Consider the following example:

```
create or replace procedure warning_proc is
  v_ctr_n number(2);
BEGIN
  for i in 1..100 loop
    v_ctr_n := i;
  end loop;
EXCEPTION
  when OTHERS then
    null;
END warning_proc;
/

SP2-0804: Procedure created with compilation warnings

SQL> show errors

Errors for PROCEDURE WARNING_PROC:

LINE/COL ERROR
-------- -----------------------------------------------------------------
8/8      PLW-06009: procedure "WARNING_PROC" OTHERS handler does not end
         in RAISE or RAISE_APPLICATION_ERROR
```

The developer has made a programming error that will cause the variable `v_ctr_n` to be overflowed on the last iteration of the loop. Normally, this error would not be a major concern because the overflow would trip a runtime exception that could be used to respond to and handle the overflow. However, the developer's inappropriate use of the WHEN OTHERS exception handler effectively suppresses any such runtime exception, so the system reacts as if nothing has gone wrong. Indeed, if the procedure is executed, it seems to complete successfully:

```
SQL> exec warning_proc;
PL/SQL procedure successfully completed.
```

While there are a few legitimate cases in which WHEN OTHERS NULL might be useful, in general, it is an extremely bad programming habit that developers should avoid. Runtime exceptions that should be ignored should be isolated with an exception handler specific to that exception. The WHEN OTHERS handler, when employed, should propagate the exception (or raise a new one) to identify the failure condition to the calling subroutine. Tweaking the previous code in this manner yields the desired runtime results, as shown here:

```
create or replace procedure warning_proc is
  v_ctr_n number(2);
BEGIN
  for i in 1..100 loop
    v_ctr_n := i;
  end loop;
EXCEPTION
  when OTHERS then
    raise;
END warning_proc;
/

SQL> exec warning_proc;
BEGIN warning_proc; END;
*
ERROR at line 1:
ORA-06502: PL/SQL: numeric or value error: number precision too large
ORA-06512: at "TUSC_11G_BOOK.WARNING_PROC", line 9
ORA-06512: at line 1
```

TIP
Experienced and novice developers alike should leverage PL/SQL compile-time warnings to catch obscured programming problems before code deployment.

Increase Performance with Native Compilation

Native compilation is the process by which a stored PL/SQL program is compiled into native code that does not need to be interpreted at runtime. In comparison, code that is not natively compiled is stored in an intermediate form that must be interpreted at runtime.

The ability to compile PL/SQL code natively has been around since Oracle9*i*; however, the implementation has changed significantly starting with 11*g*. In 9*i* and 10*g*, the compiled program units were stored and executed externally as C programs. The compilation required an external C compiler and system configuration by a DBA. Starting with 11*g* and continuing with 12*c*, the database can handle the native compilation on its own and an external compiler is no longer needed. The natively compiled program units are stored within the databases in the system tablespace.

Because the natively compiled code does not need to be interpreted at runtime, the expectation is that it will execute faster. However, the native compilation only applies to the procedural code in a PL/SQL program unit, not any embedded SQL statements. As a result, the performance gains to be realized really depend upon how much procedural code exists in relation to SQL code. At a bare minimum, a natively compiled program unit that is SQL heavy should execute at least as fast as its non-natively compiled counterpart. As the volume of procedural code increases, the faster the natively compiled code should be.

To begin, let's start with four stored procedures utilizing various amounts of procedural and SQL code. The first procedure contains absolutely no SQL, whereas the rest contains increasing amounts of SQL intermixed with the PL/SQL.

```
create or replace function native_comp_1 return number as
  v_avg_n   number := 0;
  v_total_n number := 0;
BEGIN
  for i in 1..10000000 loop
    v_total_n := v_total_n + i;
    v_avg_n   := v_total_n/i;
  end loop;
  return(v_avg_n);
END;

create or replace function native_comp_2 return number as
  cursor c1 is
    select *
      from residents;
BEGIN
  for c1_rec in c1 loop
    null;
  end loop;
  return(null);
END;

create or replace function native_comp_3 return number as
  v_salary_n number := 0;
  cursor c1 is
    select salary
      from residents;
BEGIN
  for c1_rec in c1 loop
    v_salary_n := v_salary_n + c1_rec.salary;
  end loop;
  return(v_salary_n);
END;
```

```
create or replace function native_comp_4 return number as
  type v_csal_table is table of number
                       index by varchar2(50);
  v_csal_array v_csal_table;
  v_idx_c      varchar2(50);
  v_salary_n   number := 0;
  cursor c1 is
    select c.country_name,
           r.salary
      from countries c,
           cities    c2,
           residents r
     where c.country_id = c2.country_id
       and c2.city_id   = r.city_id;
BEGIN
  --Load array with salary totals by country.
  for c1_rec in c1 loop
    v_idx_c := c1_rec.country_name;
    if not v_csal_array.exists(v_idx_c) then
      v_csal_array(v_idx_c) := 0;
    end if;
    v_csal_array(v_idx_c) := v_csal_array(v_idx_c) +
                             c1_rec.salary;
  end loop;
  --Compute the total for countries that begin with "N".
  v_idx_c := v_csal_array.first;
  while (v_idx_c is not null) loop
    if (v_idx_c like 'N%') then
      v_salary_n := v_salary_n + v_csal_array(v_idx_c);
    end if;
    v_idx_c := v_csal_array.next(v_idx_c);
  end loop;
  return(v_salary_n);
END;
```

The default compilation mode (native or interpreted) can be set at the system level via the PLSQL_CODE_TYPE database initialization parameter. Alternatively, the mode can be changed at the session level using one of the following commands:

```
alter session set plsql_code_type=interpreted;
alter session set plsql_code_type=native;
```

The session/system needs to be altered prior to compiling a given program unit. Altering the compilation mode parameter does not impact program units that are already compiled in the database. To ascertain the compilation type from an existing program unit, query the PLSQL_CODE_TYPE column of the USER_PLSQL_OBJECT_SETTINGS dictionary table.

Here are the results when the test procedures are compiled in interpreted mode:

```
Procedure        Code Type   Iterations Fastest     Slowest     Average
---------------- ----------- ---------- ---------- ---------- ----------
native_comp_1    INTERPRETED 20               5.36       6.12     5.4465
native_comp_2    INTERPRETED 20               1.97       2.28      2.138
native_comp_3    INTERPRETED 20               1.17       1.48     1.3555
native_comp_4    INTERPRETED 20               2.81       3.21     2.8895
```

Here are the results when the test procedures are compiled natively:

```
Procedure        Code Type   Iterations Fastest     Slowest     Average
---------------- ----------- ---------- ---------- ---------- ----------
native_comp_1    NATIVE      20               4.79       5.14      4.846
native_comp_2    NATIVE      20               1.88       2.14     2.0515
native_comp_3    NATIVE      20                .98       1.36     1.2065
native_comp_4    NATIVE      20               2.49       2.68      2.582
```

Native compilation provided increased performance across the board, particularly with the program units that contained more procedural logic in relation to SQL commands, as detailed in the table:

Function	Interpreted	Native	% Increase
NATIVE_COMP_1	5.4465	4.846	11.02
NATIVE_COMP_2	2.138	2.0515	4.05
NATIVE_COMP_3	1.3555	1.2065	10.99
NATIVE_COMP_4	2.8895	2.582	10.64

With nothing to lose and everything to gain, setting the database default to native compilation would seem to make sense. Any performance degradation caused by it—and I have yet to come across any—should be handled on a one-off basis, shifting individual program units back to native interpretation as needed.

Maximize Performance with the Optimizing Compiler

With each release of the database, Oracle tweaks the PL/SQL compiler to yield faster performance. You've already seen how natively compiled PL/SQL code can execute faster than code that is interpreted and compiled. Now let's take a look at what is possible when you give the compiler greater freedom to "tweak" your PL/SQL programs as it compiles them. Since 10*g* Oracle has given developers the ability to control the level of optimization that is applied via the PLSQL_OPTIMIZE_LEVEL parameter, which has the following valid values:

Level	Description
0	A compatibility setting used to mimic the behaviors of Oracle9*i* and earlier. Most PL/SQL performance gains and features available in 10g and higher are available at this level.
1	Applies a variety of optimizations to PL/SQL programs, including the elimination of unnecessary computations and exceptions, but generally does not rearrange the original code.
2	This is the default setting. All the optimizations of Level 1, plus a variety of additional optimizations that may significantly reorganize the original code.
3	All the optimizations of Levels 1 and 2, plus a variety of additional optimization techniques that—at lower levels—would need to be explicitly requested.

One of the specific optimizations triggered at Level 2 is subroutine inlining. Subroutine inlining is optimization that replaces modularized subroutines with copies of the subroutine. The intent is to eliminate the inherent overhead when calling modularized program units. The effects should be most dramatic when the subprogram is called repeatedly as part of a large-volume loop. The primary caveat is that subroutine inlining can only occur if the subroutine being called is within the same program unit as the caller.

When a stored program is installed/recompiled, the compiler optimization level defaults from the database configuration, which can be ascertained with the following query:

```
select value
  from v$parameter
 where name = 'plsql_optimize_level';
```

Alternatively, you can set a specific optimizer level by altering the current session:

```
alter session set plsql_optimize_level=X;
```

Remember, the optimizer level setting only comes into play at the next compilation. It does not impact compiled programs already in the database. Use the ALTER command to recompile any existing program units with the current optimizer setting.

So that you can see what the various optimizer levels bring to the table, I will demonstrate using some stored functions that are compiled at each of the levels and then executed. Note I'm using native compilation throughout this test. First up is a simple function that uses a basic FOR loop and a nested function to compute a running total of the numbers between 1 and 100 million. This procedure does not interact with any database tables.

```
CREATE OR REPLACE FUNCTION optcomp_1 return number is
  v_total_n number;
  PROCEDURE update_total(p_curr_tot_n in out number,
                         p_salary_n   in     number) is
  BEGIN
    p_curr_tot_n := p_curr_tot_n + p_salary_n;
  END update_total;
BEGIN
  v_total_n := 0;
  for i in 1..100000000 loop

    update_total(p_curr_tot_n => v_total_n,
                 p_salary_n   => i);
  end loop;
  return(v_total_n);
END optcomp_1;

Procedure      Level Iterations Fastest    Slowest    Average
-------------- ----- ---------- ---------- ---------- ----------
optcomp_1      0     10         34.4       34.81      34.598
optcomp_1      1     10         27.14      27.52      27.333
optcomp_1      2     10         19.17      19.43      19.287
optcomp_1      3     10         11.53      11.67      11.614
```

Clearly, the performance increases with each optimizer level. Unfortunately, Oracle does not publish the exact optimizations that are being applied to the code at each level, but it is possible to get some insight, particularly with respect to subroutine inlining.

The technique calls for enabling all PL/SQL warnings prior to compilation:

```
alter session set plsql_code_type=native;
alter session set plsql_optimize_level=3;
alter session set plsql_warnings = 'enable:all';

alter function optcomp_1 compile;
SP2-0807: Function altered with compilation warnings

show errors;
Errors for FUNCTION TUSC_11G_BOOK.OPTCOMP_1:
LINE/COL ERROR
-------- -----------------------------------------------------------------
11/5     PLW-06005: inlining of call of procedure 'UPDATE_TOTAL' was done
3/3      PLW-06006: uncalled procedure "UPDATE_TOTAL" is removed.
```

The compilation warnings confirm that subroutine inlining was performed and the original subroutine removed. At Levels 2 and 3, the optimizer is free to rearrange the code to replace the function call (to UPDATE_TOTAL) with a copy of the subroutine, thereby eliminating the overhead. The overhead is small (remember, we are dealing with 100 million loop iterations in this example), but it does exist.

In the second example, the basic FOR loop is replaced with a cursor to the RESIDENTS table that I have been experimenting with. Recall that this table contains 1 million records. The cursor fetches the salary of each resident and then passes that to a nested subroutine that updates a running total variable:

```
CREATE OR REPLACE FUNCTION optcomp_2 return number is
  v_total_n number;
  cursor c1 is
    select r.resident_id,
           r.salary
      from residents r;
  PROCEDURE update_total(p_curr_tot_n in out number,
                         p_salary_n   in     number) is

  BEGIN
    p_curr_tot_n := p_curr_tot_n + p_salary_n;
  END update_total;
BEGIN
  v_total_n := 0;
  for c1_rec in c1 loop
    update_total(p_curr_tot_n => v_total_n,
                 p_salary_n   => c1_rec.salary);
  end loop;
  return(v_total_n);
END optcomp_2;
```

These are the testing results:

```
Procedure      Level Iterations Fastest    Slowest    Average
-------------- ----- ---------- ---------- ---------- ----------
optcomp_2      0     10         8.2        8.35       8.244
optcomp_2      1     10         7.86       7.92       7.878
optcomp_2      2     10         .88        1.33       .978
optcomp_2      3     10         .84        1.11       .952
```

As before, you can see that performance improves with each optimizer level, with a significant gain as you move beyond Level 1. Looking at the compiler warnings, you will see that the optimizer is inlining both the nested function call (UPDATE_TOTAL) and the cursor definition:

```
LINE/COL ERROR
-------- -----------------------------------------------------------------
15/5     PLW-06005: inlining of call of procedure 'UPDATE_TOTAL' was done
14/3     PLW-06005: inlining of call of procedure 'C1' was done
7/3      PLW-06006: uncalled procedure "UPDATE_TOTAL" is removed.
3/3      PLW-06006: uncalled procedure "C1" is removed.
```

Moving on, the program is revised to no longer fetch the salary in the cursor. The UPDATE_TOTAL nested procedure now has the additional task of fetching the salary for each resident based upon the resident identifier:

```
CREATE OR REPLACE FUNCTION optcomp_3 return number is
  v_total_n number;
  cursor c1 is
    select r.resident_id
      from residents r;
  PROCEDURE update_total(p_curr_tot_n in out number,
                         p_resident_n in number) is
    v_salary_n number;
  BEGIN
    select r.salary
      into v_salary_n
      from residents r
     where r.resident_id = p_resident_n;
    p_curr_tot_n := p_curr_tot_n + v_salary_n;
  END update total;

BEGIN
  v_total_n := 0;
  for c1_rec in c1 loop
    update_total(p_curr_tot_n => v_total_n,
                 p_resident_n => c1_rec.resident_id);
  end loop;
  return(v_total_n);
END optcomp 3;
```

These are the testing results:

```
Procedure       Level Iterations Fastest     Slowest     Average
--------------- ----- ---------- ----------- ----------- -----------
optcomp_3       0     10         34.7        38.18       35.068
optcomp 3       1     10         34.22       34.28       34.248
optcomp_3       2     10         24.84       24.89       24.872
optcomp 3       3     10         24.52       24.62       24.589
```

This less efficient design definitely takes longer to execute, but it still achieves a significant performance improvement once the optimizer reaches Level 2. You see almost no further improvement as you move to Level 3, however. The PL/SQL compilation warnings reveal that the cursor and the UPDATE_TOTAL procedure call are being inlined just as before. Optimizations or not, the limiting factor here is the 1 million individual queries being issued to perform piecemeal fetching of resident salaries.

The final iteration of the test program replaces the cursor loop with a basic FOR loop spanning the range 0 to 1 million. This is possible because the resident IDs are densely packed in this range.

```
CREATE OR REPLACE FUNCTION optcomp_4 return number is
  v_total_n number;
  PROCEDURE update_total(p_curr_tot_n in out number,
                         p_resident_n in number) is
    v_salary_n number;
  BEGIN
    select r.salary
      into v_salary_n
      from residents r
     where r.resident_id = p_resident_n;
    p_curr_tot_n := p_curr_tot_n + v_salary_n;
  END update_total;
BEGIN
  v_total_n := 0;
  for i in 1..1000000 loop
    update_total(p_curr_tot_n => v_total_n,
                 p_resident_n => i);
  end loop;
  return(v_total_n);
END optcomp_4;
```

These are the testing results:

```
Procedure       Level Iterations Fastest    Slowest    Average
--------------- ----- ---------- ---------- ---------- ----------
optcomp_4       0     10         25.08      25.11      25.098
optcomp_4       1     10         24.97      25         24.986
optcomp_4       2     10         24.29      24.50      24.422
optcomp_4       3     10         23.61      23.69      23.636
```

This program shows the least amount of improvement as the optimization level increases. As in the previous example, the real limitation here is the high volume of one-off queries that are being issued to retrieve each resident's salary. Regardless, optimization Level 3 has once again turned in the best performance. The specific optimizations being reported by the compiler are shown here:

```
LINE/COL ERROR
-------- -----------------------------------------------------------------
16/5     PLW-06005: inlining of call of procedure 'UPDATE_TOTAL' was done
3/3      PLW-06006: uncalled procedure "UPDATE_TOTAL" is removed.
```

Let's investigate subprogram inlining a bit further. As noted earlier, inlining becomes possible at optimization Level 2. That doesn't mean that it will happen at Level 2, just that the optimizer will consider it. The optimizer could choose not to perform inlining based upon some analytical result. If inlining is going to be performed automatically by the optimizer, it would most likely occur at Level 3. Suppose automatic inlining were occurring and the impact was reduced performance. You could reduce the optimization level to prevent the inlining, but you may sacrifice other optimizations in the process. The preferred solution is to stop the inlining and nothing else. You can accomplish this with the INLINE pragma. The INLINE pragma provides a mechanism by which the developer can coerce or prevent inlining. In the case of coercion, it is nothing more than that—a suggestion that the optimizer perform inlining, but the optimizer has the final word. In the case of prevention, however, the optimizer must obey. To demonstrate, I slightly revised the OPTCOMP_1 function that I experimented with earlier to add an INLINE pragma to prevent the inlining of the UPDATE_TOTAL function:

```
CREATE OR REPLACE FUNCTION optcomp_5 return number is
  v_total_n number;
  PROCEDURE update_total(p_curr_tot_n in out number,
                         p_salary_n   in     number) is
  BEGIN
    p_curr_tot_n := p_curr_tot_n + p_salary_n;
  END update_total;
BEGIN
  v_total_n := 0;
  for i in 1..100000000 loop
    pragma inline(update_total, 'no');
    update_total(p_curr_tot_n => v_total_n,
                 p_salary_n   => i);
  end loop;
  return(v_total_n);
END optcomp_5;
```

These are the testing results:

```
Procedure        Level Iterations Fastest     Slowest     Average
---------------- ----- ---------- ----------- ----------- ----------
optcomp_5        0     10         34.2        34.22       34.211
optcomp_5        1     10         27.43       27.52       27.453
optcomp_5        2     10         19.26       19.3        19.282
optcomp_5        3     10         18.98       19          18.987
```

The results are nearly identical to what you saw before, with the sole exception being the results at Level 3. Unlike before, there is almost no improvement as the level changes from 2 to 3. Earlier, Level 3 yielded a performance increase of 8 seconds over Level 2. Reviewing the PL/SQL warnings reveals that the inlining was blocked by the pragma directive:

```
LINE/COL ERROR
-------- -----------------------------------------------------------------
12/5     PLW-06008: call of procedure 'UPDATE_TOTAL' will not be inlined
```

Comparing these warnings to those from the analysis of OPTCOMP_1 reveals that the optimizer chose to perform inlining at Level 3 originally.

Clearly, the optimizer is capable of making notable improvements in PL/SQL performance. The test scenarios that I tried did not uncover any situations in which optimization Level 2 or 3 failed to increase performance, although it is always a possibility. It is probably best to leave the optimizer at Level 2, the default, but those wishing to squeeze out every last bit of performance may want to increase that to Level 3.

Use DBMS_APPLICATION_INFO for Real-Time Monitoring

The DBMS_APPLICATION_INFO package provides a powerful mechanism for communicating point-in-time information about execution in an environment. The following example illustrates this, as it enables a long-running PL/SQL program unit to provide information on the progress of the routine every 1000 records. The PL/SQL code segment updates the application information with the number of records processed and the elapsed time every 1000 records.

The following is an example illustrating the update of all employees' salaries:

```
DECLARE
   CURSOR cur_employee IS
      SELECT employee_id, salary, ROWID
      FROM   s_employee_test;
   lv_new_salary_num NUMBER;
   lv count num      PLS INTEGER := 0;
   lv_start_time_num PLS_INTEGER;
BEGIN
   lv_start_time_num := DBMS_UTILITY.GET_TIME;
   FOR cur_employee_rec IN cur_employee LOOP
      lv_count_num := lv_count_num + 1;
      -- Determination of salary increase
      lv new salary num := cur employee rec.salary;

      UPDATE s_employee_test
      SET    salary      = lv_new_salary_num
      WHERE  rowid = cur employee rec.ROWID;
      IF MOD(lv_count_num, 1000) = 0 THEN
         DBMS_APPLICATION_INFO.SET_MODULE('Records Processed: ' ||
           lv_count_num, 'Elapsed: ' || (DBMS_UTILITY.GET_TIME -
           lv_start_time_num)/100 || ' sec');
      END IF;
   END LOOP;
   COMMIT;
   DBMS_APPLICATION_INFO.SET_MODULE('Records Processed: ' ||
      lv_count_num, 'Elapsed: ' || (DBMS_UTILITY.GET_TIME -
      lv_start_time_num)/100 || ' sec');
END;
/
```

To monitor the progress, query the V$SESSION view, as shown in the following example:

```
SELECT username, sid, serial#, module, action
FROM   V$SESSION
WHERE  username = 'SCOTT';
```

Please note that this query needs to be run in a separate session from the one executing the PL/SQL block.

The following is the output from the V$SESSION view, when queried three different times. The last output is when the PL/SQL program unit was completed.

```
USERNAME    SID SERIAL# MODULE                    ACTION
---------- --- ------- ------------------------- -----------------
SCOTT        7       4 SQL*Plus
SCOTT       10      10 Records Processed: 1000   Elapsed: 0.71 sec

USERNAME    SID SERIAL# MODULE                    ACTION
---------- --- ------- ------------------------- ------------------
SCOTT        7       4 SQL*Plus
SCOTT       10      10 Records Processed: 10000   Elapsed: 4.19 sec

USERNAME    SID SERIAL# MODULE                    ACTION
---------- --- ------- ------------------------- -------------------
SCOTT        7       4 SQL*Plus
SCOTT       10      10 Records Processed: 25000  Elapsed: 9.89 sec
```

Your response time will depend on how fast your system is and how well it is architected. The reason for the two records being returned for each query in the preceding output is that both the execution of the PL/SQL program unit to update employees' salary and the SQL statement to monitor the progress via the V$SESSION view are executed under the SCOTT schema in two different SQL*Plus sessions. The preceding example illustrates a valuable technique to deploy in an environment and provides a real-time monitoring mechanism. It becomes easier to determine accurately how long a program has been running and to estimate how long a program has to complete.

If DBAs do not want users' queries against the V$SESSION view to return information for all users, they can create a view based on the V$SESSION view that limits the retrieval to only the executing user's session information. This can be accomplished by executing the commands as the SYS user. The following syntax creates the new view (the new view is named SESSION_LOG, but any name can be used). Including "USER" in the query that follows returns the name of the session user (the user who logged on) with the data type VARCHAR2:

```
CREATE VIEW session_log AS
SELECT *
FROM   V$SESSION
WHERE  username = USER;
```

The following syntax creates a public synonym:

```
CREATE PUBLIC SYNONYM session log FOR session log;
```

The following syntax grants SELECT permission to all users:

```
GRANT SELECT ON session_log TO PUBLIC;
```

Once the SESSION_LOG view is set up, as shown in the preceding statements, the preceding V$SESSION view query can be changed to SELECT from the SESSION_LOG view, as in the following query, to limit the output to only the user executing the query:

```
SELECT username, sid, serial#, module, action
FROM   session_log;
```

TIP
Use the Oracle-supplied package DBMS_APPLICATION_INFO to log point-in-time information to the V$SESSION view to enable monitoring of long-running processes.

Log Timing Information in a Database Table

Monitoring performance is an ongoing process. Many variables in an environment can change and affect performance over time; therefore, performance should be monitored continuously. Some of the variables include user growth, data growth, reporting growth, application modification/enhancement deployment, and additional load on the system from other applications. With this in mind, an Oracle system must be regularly monitored to ensure performance remains at, or above, an acceptable level. (Oracle ADDM does this for you as well.) One method for monitoring the system performance is to create a mechanism for logging timing statistics for certain aspects of an application. Batch programs are good candidates for this monitoring procedure. The monitoring procedure can be accomplished by inserting timing statistics into a database table. The following example provides the database table logging method by creating a database table and then integrating INSERT statements for the timing of the process into the table. Oracle's own SQL monitoring starts when a SQL statement runs parallel or when it has consumed at least 5 seconds of CPU or I/O time in a single execution. You can monitor the statistics for SQL statement execution using many V$ views (especially V$SQL and V$SQL_MONITOR). See Chapter 12 for many great queries to the V$ views used for Oracle monitoring.

In this example, the important information to log in the database table is the program identifier (some unique method of identifying the program), the date and time the program is executed, and the elapsed time of the execution. One column has been added for this application, namely, the number of records updated. This additional column is important for this application to monitor the growth of employee records being processed. When creating a timing log table for your application, add columns to store additional important processing information that may affect your timing results. Create the following table to log the timing information:

```
CREATE TABLE process_timing_log
   (program_name       VARCHAR2(30),
    execution_date     DATE,
    records_processed  NUMBER,
    elapsed_time_sec   NUMBER);
```

Once you have created the table, you can enhance PL/SQL program units to log the timing information into the PROCESS_TIMING_LOG table, as illustrated in the following program:

```
CREATE OR REPLACE PROCEDURE update_salary AS
   CURSOR cur_employee IS
      SELECT employee_id, salary, ROWID
      FROM   s_employee_test;
   lv_new_salary_num NUMBER;
   lv_count_num      PLS_INTEGER := 0;
   lv_start_time_num PLS_INTEGER;
   lv_total_time_num NUMBER;
BEGIN
   lv_start_time_num := DBMS_UTILITY.GET_TIME;
   FOR cur_employee_rec IN cur_employee LOOP
      lv_count_num := lv_count_num + 1;
      -- Determination of salary increase
      lv_new_salary_num := cur_employee_rec.salary;
      UPDATE s_employee_test
      SET    salary      = lv_new_salary_num
      WHERE  rowid = cur_employee_rec.ROWID;
   END LOOP;
   lv_total_time_num := (DBMS_UTILITY.GET_TIME -
      lv_start_time_num)/100;
   INSERT INTO process_timing_log
      (program_name, execution_date, records_processed,
       elapsed_time_sec)
   VALUES
      ('UPDATE_SALARY', SYSDATE, lv_count_num,
       lv_total_time_num);
   COMMIT;
END update_salary;
/
```

As shown in the preceding code segment, the timer is started at the beginning of the program unit and then stopped at the end of the program unit. The difference between the start and ending times is logged into the PROCESS_TIMING_LOG for each execution of the UPDATE_SALARY program. If the UPDATE_SALARY program unit is executed three times, as shown in the following syntax, then three timing records are inserted into the PROCESS_TIMING_LOG table:

```
EXECUTE update_salary
EXECUTE update_salary
EXECUTE update_salary
```

The following script retrieves the information from the PROCESS_TIMING_LOG table:

```
SELECT program_name,
       TO_CHAR(execution_date,'MM/DD/YYYY HH24:MI:SS') execution_time,
       records_processed, elapsed_time_sec
FROM   process_timing_log
ORDER BY 1,2;

PROGRAM_NAME   EXECUTION_TIME      RECORDS_PROCESSED ELAPSED_TIME_SEC
-------------  ------------------- ----------------- ----------------
UPDATE_SALARY  07/02/2002 19:43:57             25252             8.89
UPDATE_SALARY  07/02/2002 19:44:07             25252             9.11
UPDATE_SALARY  07/02/2002 19:44:15             25252             8.62
```

This output shows one possible result. There is a difference in the elapsed time for the same program execution. If the difference increases over time, this may indicate a need to analyze the program unit further or the application to determine what caused the execution time increase. With logging mechanisms in place, the elapsed time can be monitored at any point in time because the timing information is being logged to a database table.

In the preceding example, the time logged was per program unit. If the program is complex and executed for an extended period of time, you may want to change the logging of timing statistics in the program. The INSERT into the PROCESS_TIMING_LOG table could be performed after a certain number of iterations or to log timing for certain functionality in a program unit.

TIP
Log (INSERT) execution timing information into a database table for long-running PL/SQL program units to integrate a proactive performance-monitoring mechanism into your system. The database table can be reviewed at any point in time to determine if performance has decreased over time.

Another method is to use the DBMS_PROFILER package to get timing statistics per line of PL/SQL code. See Metalink (My Oracle Support) article 104377.1, "Performance of New PL/SQL Features" for more information.

TIP

System load in terms of number of active sessions can have a large impact on the performance of program execution; therefore, modifying the database table logging method to include a column for the number of active sessions can be helpful. You can fill this column by adding one additional query to the program unit being executed to retrieve the count from the V$SESSION view.

Reduce PL/SQL Program Unit Iterations and Iteration Time

Any PL/SQL program unit involving looping logic is a strong candidate for performance improvements. Potential improvements for these types of programs can be accomplished in two ways. The first is to reduce the number of iterations by restructuring the logic to accomplish the same functional result. The second is to reduce the time per iteration. Either reduction often improves performance dramatically.

To bring this point into perspective, think of the following scenario: You need to process 9000 employee records in a PL/SQL routine, and to process each employee takes 2 seconds. This equates to 18,000 seconds, which equates to 5 hours. If the processing per employee is reduced to 1 second, the time to process the 9000 employees is reduced by 9000 seconds, or 2.5 hours … quite a difference!

The following example shows a minor restructuring of a PL/SQL program unit to illustrate reducing per-loop processing and overall processing. The program unit processes a loop 1,000,000 times. Each iteration adds to the incremental counter used to display a message each 100,000 iterations and adds to the total counter used to check for loop exiting. To view DBMS_OUTPUT, make sure you issue the SET SERVEROUTPUT ON command first.

```
CREATE OR REPLACE PACKAGE stop_watch AS
   pv_start_time_num     PLS_INTEGER;
   pv_stop_time_num      PLS_INTEGER;
   pv_last_stop_time_num PLS_INTEGER;
-- This procedure creates a starting point for the timer routine and
-- is usually called once at the beginning of the PL/SQL program unit.
PROCEDURE start_timer;
--
This procedure retrieves a point in time and subtracts the current
-- time from the start time to determine the elapsed time. The
-- interval elapsed time is logged and displayed. This procedure is
-- usually called repetitively for each iteration or a specified
-- number of iterations.
PROCEDURE stop_timer;
END stop_watch;
/
```

The package has been created.

```
CREATE OR REPLACE PACKAGE BODY stop_watch AS
PROCEDURE start_timer AS
BEGIN
   pv_start_time_num      := DBMS_UTILITY.GET_TIME;
   pv_last_stop_time_num := pv_start_time_num;
END start_timer;
PROCEDURE stop_timer AS
BEGIN
   pv_stop_time_num := DBMS_UTILITY.GET_TIME;
   DBMS_OUTPUT.PUT_LINE('Total Time Elapsed: ' ||
      TO_CHAR((pv_stop_time_num - pv_start_time_num)/100,
      '999,999.99') || ' sec   Interval Time: ' ||

      TO_CHAR((pv_stop_time_num - pv_last_stop_time_num)/100,
      '99,999.99') || ' sec');
   pv_last_stop_time_num := pv_stop_time_num;
END stop_timer;
END;
/
```

The package body has been created.

```
SET SERVEROUTPUT ON
DECLARE
   lv_counter_num       PLS_INTEGER := 0;
   lv_total_counter_num PLS_INTEGER := 0;
BEGIN
   stop_watch.start_timer;
   LOOP
      lv_counter_num       := lv_counter_num + 1;
      lv_total_counter_num := lv_total_counter_num + 1;
      IF lv_counter_num >= 100000 THEN
         DBMS_OUTPUT.PUT_LINE('Processed 100,000 Records. ' ||
            'Total Processed ' || lv_total_counter_num);
         lv_counter_num := 0;
         EXIT WHEN lv_total_counter_num >= 1000000;
      END IF;
   END LOOP;
   stop_watch.stop_timer;
END;
/
Processed 100,000 Records. Total Processed 100000
Processed 100,000 Records. Total Processed 200000
Processed 100,000 Records. Total Processed 300000
Processed 100,000 Records. Total Processed 400000
Processed 100,000 Records. Total Processed 500000
Processed 100,000 Records. Total Processed 600000
Processed 100,000 Records. Total Processed 700000
Processed 100,000 Records. Total Processed 800000
Processed 100,000 Records. Total Processed 900000
Processed 100,000 Records. Total Processed 1000000
Total Time Elapsed:         .71 sec   Interval Time:         .71 sec

PL/SQL procedure successfully completed.
```

By changing the program to only add to the LV_TOTAL_COUNTER_NUM variable each time the incremental counter reaches 100,000, overall execution time is reduced:

```
DECLARE
   lv_counter_num       PLS_INTEGER := 0;
   lv_total_counter_num PLS_INTEGER := 0;
BEGIN
   stop_watch.start_timer;
   LOOP
      lv_counter_num       := lv_counter_num + 1;
      IF lv_counter_num >= 100000 THEN
         DBMS_OUTPUT.PUT_LINE('Processed 100,000 Records. Total ' ||
            'Processed ' || lv_total_counter_num);
         lv_total_counter_num := lv_total_counter_num +
            lv_counter_num;
         lv_counter_num := 0;
         EXIT WHEN lv_total_counter_num >= 1000000;
      END IF;
   END LOOP;
   stop_watch.stop_timer;
END;
/
```

The DBMS_OUTPUT.PUT_LINE output for each batch of processed records was not included in the following output:

```
Total Time Elapsed:          .47 sec   Interval Time:        .47 sec

PL/SQL procedure successfully completed.
```

The preceding example illustrates the performance difference achieved by changing the iteration logic to reduce the timing per iteration. The example is basic and shows a 34 percent increase on 1 million iterations. Based on the restructuring and the iterations, this improvement can make a huge difference.

TIP
When a PL/SQL program unit involves extensive looping or recursion, concentrate on reducing the execution time per iteration. The benefits add up fast, and it is easy to do the math to determine the overall improvement potential. Also review the looping or recursion for restructuring to reduce the number of iterations, while keeping the functionality. With the extreme flexibility of PL/SQL and SQL, a variety of ways typically exist to accomplish the same result. If a PL/SQL program unit is not performing optimally, sometimes you have to rewrite the logic another way.

Use ROWID for Iterative Processing

The ROWID variable can improve PL/SQL programs that retrieve records from the database, perform manipulation on the column values, and then complete with an UPDATE to the retrieved record. When retrieving each record, the ROWID can be added to the selected column list. When updating each record, the ROWID can be used in the predicate clause. The ROWID is the fastest access path to a record in a table, even faster than a unique index reference.

The performance improvement of using the ROWID is illustrated in the following example. The example retrieves each of the 25,000 employee records, calculates a new salary for each employee, and then updates the employees' salary. The actual salary calculation is not shown in this example. The first PL/SQL code segment shows the timing results with the UPDATE using the EMPLOYEE_ID column, which has a unique index on the column:

```
DECLARE
   CURSOR cur_employee IS
      SELECT employee_id, salary
      FROM   s_employee_test;
   lv_new_salary_num NUMBER;
BEGIN
   stop_watch.start_timer;
   FOR cur_employee_rec IN cur_employee LOOP
      -- Determination of salary increase
      lv_new_salary_num := cur_employee_rec.salary;
      UPDATE s_employee_test
      SET    salary      = lv_new_salary_num
      WHERE  employee_id = cur_employee_rec.employee_id;
   END LOOP;
   COMMIT;
   stop_watch.stop_timer;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:

```
Total Time Elapsed:        1.71 sec   Interval Time:        1.71 sec
PL/SQL procedure successfully completed.

Total Time Elapsed:        1.59 sec   Interval Time:        1.59 sec
PL/SQL procedure successfully completed.
```

In the following procedure, the same functionality is maintained while changing the UPDATE to perform the UPDATE based on the ROWID. This involves adding the ROWID in the SELECT statement and changing the UPDATE predicate clause.

```
DECLARE
   CURSOR cur_employee IS
      SELECT employee_id, salary, ROWID
      FROM   s_employee_test;
   lv_new_salary_num NUMBER;
BEGIN
   stop_watch.start_timer;
   FOR cur_employee_rec IN cur_employee LOOP
      -- Determination of salary increase
      lv_new_salary_num := cur_employee_rec.salary;
      UPDATE s_employee_test
      SET    salary = lv_new_salary_num
      WHERE  rowid  = cur_employee_rec.ROWID;
   END LOOP;
   COMMIT;
   stop_watch.stop_timer;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:

```
Total Time Elapsed:        1.45 sec   Interval Time:       1.45 sec
PL/SQL procedure successfully completed.

Total Time Elapsed:        1.48 sec   Interval Time:       1.48 sec
PL/SQL procedure successfully completed.
```

As evidenced from the timings, execution is faster using the ROWID. The first PL/SQL code segment UPDATE statement retrieves the result by using the index on EMPLOYEE_ID to get the ROWID and then goes to the table to search by ROWID. The second PL/SQL code segment UPDATE statement goes directly to the table to search by ROWID, thus eliminating the index search. The performance improvement increases when more records are involved and when the index used does not refer to a unique index.

TIP
Use the ROWID variable to enhance performance when SELECTing a record in a PL/SQL program unit and then manipulating the same record in the same PL/SQL program unit.

Standardize on Data Types, IF Statement Order, and PLS_INTEGER

Several minor programming modifications can be introduced into your standard PL/SQL development that can improve performance. Three of these techniques are outlined in this section:

- Ensure the same data types in comparison operations.
- Order IF conditions based on the frequency of the condition.
- Use the PLS_INTEGER PL/SQL data type for integer operations.

Ensure the Same Data Types in Comparison Operations

When variables or constant values are compared, they should have the same data type definition. If the comparison does not involve the same data types, then Oracle implicitly converts one of the values, thus introducing undesired overhead. Any time values are compared in a condition, the values should be the same data type. You should use this standard when developing PL/SQL program units as it is good programming style.

The following procedure illustrates the cost of comparing different data types, namely, a numeric data type to a character value in the IF statement:

```
CREATE OR REPLACE PROCEDURE test_if (p_condition_num NUMBER) AS
   lv_temp_num         NUMBER := 0;
   lv_temp_cond_num    NUMBER := p_condition_num;
BEGIN
   stop_watch.start_timer;
   FOR lv_count_num IN 1..100000 LOOP
      IF lv_temp_cond_num = '1' THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = '2' THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = '3' THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = '4' THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = '5' THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = '6' THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = '7' THEN
         lv_temp_num := lv_temp_num + 1;
      ELSE
         lv_temp_num := lv_temp_num + 1;
      END IF;
   END LOOP;
   stop_watch.stop_timer;
END;
/
```

The following illustrates the execution of the TEST_IF procedure:

```
EXECUTE test_if(8)
```

The following output is the execution result of the TEST_IF procedure:

```
Total Time Elapsed:          .26 sec   Interval Time:         .26 sec
PL/SQL procedure successfully completed.
```

Unnecessary overhead is introduced with the different data types. If the procedure is changed to the same data type comparisons, the following execution is much faster:

```
CREATE OR REPLACE PROCEDURE test_if (p_condition_num NUMBER) AS
   lv_temp_num          NUMBER := 0;
   lv_temp_cond_num     NUMBER := p_condition_num;
BEGIN
   stop_watch.start_timer;
   FOR lv_count_num IN 1..100000 LOOP
      IF lv_temp_cond_num = 1 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 2 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 3 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 4 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 5 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 6 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 7 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSE

         lv_temp_num := lv_temp_num + 1;
      END IF;
   END LOOP;
   stop_watch.stop_timer;
END;
/
```

The following code listing illustrates the execution of the new TEST_IF procedure:

```
EXECUTE test_if(8)

Total Time Elapsed:          .17 sec   Interval Time:         .17 sec
PL/SQL procedure successfully completed.
```

As shown in the preceding examples, the execution is 23 percent faster. The improvement increases as the frequency of execution increases.

Therefore, in the final example, the comparison in the IF statement of LV_TEMP_COND_NUM to a 1,2,3, and so forth, is comparing a NUMBER to a PLS_INTEGER. Some internal Oracle conversion overhead is still taking place. To eliminate this overhead, the 1,2,3 … should be changed to 1.0, 2.0, 3.0 … . When I made this change to the final example, the timing was reduced to 0.16 seconds.

TIP
Ensure all conditional comparisons compare the same data types. Additionally, ensure the data types within the numeric family are comparing the same subtype.

Order IF Conditions Based on the Frequency of the Condition

The natural programming method when developing IF statements with multiple conditions is to order the conditional checks by some sequential order. This order is typically alphabetical or numerically sequenced to create a more readable segment of code, but it usually is not the most optimal order. Especially when using the ELSIF condition several times in an IF statement, the most frequently met condition should appear first, followed by the next most frequent match, and so forth.

In the preceding section, the execution of the procedure was always carried out by passing an 8, which meant every loop had to check all eight conditional operations of the IF logic to satisfy the condition. If you pass a 1, which is equivalent to saying the first condition satisfies all IF executions, you get a more optimized result, as shown in the following example:

```
EXECUTE test_if(1)

Total Time Elapsed:          .05 sec   Interval Time:         .05 sec
PL/SQL procedure successfully completed.
```

The preceding output illustrates a performance improvement from the preceding section with the correct ordering of IF conditions. Therefore, take the extra step of analyzing IF condition order before coding them.

TIP
Ensure the string of PL/SQL IF conditions appear in the order of most frequently satisfied, not a numerical or alphanumerical sequential order.

Use the PLS_INTEGER PL/SQL Data Type for Integer Operations

The typical standard for declaring a numeric data type is to use the NUMBER data type. In PL/SQL release 2.2, Oracle introduced the PLS_INTEGER data type. This data type can be used in place of any numeric family data type declaration, as long as the content of the variable is an integer and remains within the bounds of –2147483648 and +2147483647. Therefore, most counters and operations with integers can use this data type. The PLS_INTEGER involves fewer internal instructions to process, thus improving performance when using this numeric data type. The more references to this variable, the more improvement realized. Operations on NUMBER data types use library arithmetic, whereas operations on the data types PLS_INTEGER, BINARY_FLOAT, and BINARY_DOUBLE use *hardware arithmetic*. For local integer variables, use PLS_INTEGER. For variables that can never have the value NULL, do not need overflow checking, and are not used in performance-critical code, use SIMPLE_INTEGER (see the *Oracle Database PL/SQL Language Reference* for more types and additional information). Note also that if you assign a PLS_INTEGER variable to a NUMBER variable, then PL/SQL converts the PLS_INTEGER value to a NUMBER value (because the internal representations of the values differ). However, whenever possible, you should avoid these implicit conversions.

This improvement for PLS_INTEGER is illustrated in the following PL/SQL code segment. The code segment is the same example as used in the previous two sections, with the data type declarations being changed to PLS_INTEGER from NUMBER.

```
CREATE OR REPLACE PROCEDURE test_if (p_condition_num PLS_INTEGER) AS
   lv_temp_num          PLS_INTEGER := 0;
   lv_temp_cond_num     PLS_INTEGER := p_condition_num;
BEGIN
   stop_watch.start_timer;
   FOR lv_count_num IN 1..100000 LOOP
      IF lv_temp_cond_num = 1 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 2 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 3 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 4 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 5 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 6 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSIF lv_temp_cond_num = 7 THEN
         lv_temp_num := lv_temp_num + 1;
      ELSE
         lv_temp_num := lv_temp_num + 1;

      END IF;
   END LOOP;
   stop_watch.stop_timer;
END;
/
```

The following illustrates the execution of the TEST_IF procedure:

```
EXECUTE test_if(1)
```

The following performance improvement is evident based on the execution results:

```
Total Time Elapsed:          .03 sec   Interval Time:        .03 sec
PL/SQL procedure successfully completed.
```

TIP
Use the PLS_INTEGER type when processing integers to improve performance. If a number with precision is assigned to a PLS_INTEGER variable, the value will be rounded to a whole number as if the ROUND function had been performed on the number.

Reduce the Calls to SYSDATE

The SYSDATE variable is a convenient method of retrieving the current date and time. Calls to SYSDATE involve some overhead; therefore, if this variable is needed to log the date of certain processing, the call to this variable should be made once at the start of the program rather than at each iteration. This technique of calling SYSDATE once at the start of the program assumes the date logging is desired at the point in time the program started.

The reduction of SYSDATE calls is illustrated in the following example. The example loops through 10,000 iterations, calling SYSDATE (only the date portion of the variable because the TRUNC function is used to truncate the time portion) every iteration.

```
DECLARE
   lv_current_date     DATE;
BEGIN
   stop_watch.start_timer;
   FOR lv_count_num IN 1..10000 LOOP
      lv_current_date := TRUNC(SYSDATE);
   END LOOP;
   stop_watch.stop_timer;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:

```
Total Time Elapsed:          .04 sec   Interval Time:         .04 sec
PL/SQL procedure successfully completed.

Total Time Elapsed:          .01 sec   Interval Time:         .01 sec
PL/SQL procedure successfully completed.
```

The following PL/SQL code segment has been modified to retrieve the SYSDATE only once, at the beginning of the program, and set to another variable each iteration:

```
DECLARE
   lv_current_date     DATE := TRUNC(SYSDATE);
   lv_final_date       DATE;
BEGIN
   stop_watch.start_timer;
   FOR lv_count_num IN 1..10000 LOOP
      lv_final_date := lv_current_date;
   END LOOP;
   stop_watch.stop_timer;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:

```
Total Time Elapsed:          .00 sec   Interval Time:         .00 sec
PL/SQL procedure successfully completed.

Total Time Elapsed:          .01 sec   Interval Time:         .01 sec
PL/SQL procedure successfully completed.
```

As evident in the preceding example, overhead is associated with the SYSDATE call, and the number of calls to SYSDATE should be reduced, if possible.

TIP
Attempt to limit the calls to SYSDATE in iterative or recursive loops because overhead is associated with this variable. Set a PL/SQL date variable to SYSDATE in the declaration and reference the PL/SQL variable to eliminate the overhead.

Reduce the Use of the MOD Function

Certain PL/SQL functions are more costly to use than others. MOD is one function that has better overall performance when applied using additional PL/SQL logic. This is illustrated in the following example. MOD is a useful function, but if it is executed in an IF statement, as illustrated here, additional overhead is introduced.

```
BEGIN
   stop_watch.start_timer;
   FOR lv_count_num IN 1..10000 LOOP
      IF MOD(lv_count_num, 1000) = 0 THEN
         DBMS_OUTPUT.PUT_LINE('Hit 1000; Total: ' || lv_count_num);
      END IF;
   END LOOP;
   stop_watch.stop_timer;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:

```
Hit 1000; Total: 1000
Hit 1000; Total: 2000
Hit 1000; Total: 3000
Hit 1000; Total: 4000
Hit 1000; Total: 5000
Hit 1000; Total: 6000
Hit 1000; Total: 7000
Hit 1000; Total: 8000
Hit 1000; Total: 9000
Hit 1000; Total: 10000
Total Time Elapsed:         .04 sec   Interval Time:        .04 sec
PL/SQL procedure successfully completed.

Total Time Elapsed:         .04 sec   Interval Time:        .04 sec
```

Here, I have modified the preceding PL/SQL code segment to eliminate use of the MOD function and perform the same check with additional PL/SQL logic:

```
DECLARE
   lv_count_inc_num PLS_INTEGER := 0;
BEGIN
   stop_watch.start_timer;
   FOR lv_count_num IN 1..10000 LOOP
      lv_count_inc_num := lv_count_inc_num + 1;
      IF lv_count_inc_num = 1000 THEN
         DBMS_OUTPUT.PUT_LINE('Hit 1000; Total: ' || lv_count_num);
         lv_count_inc_num := 0;
      END IF;
   END LOOP;
   stop_watch.stop_timer;
END;
/

Hit 1000; Total: 1000
Hit 1000; Total: 2000
Hit 1000; Total: 3000
Hit 1000; Total: 4000
Hit 1000; Total: 5000
Hit 1000; Total: 6000
Hit 1000; Total: 7000
Hit 1000; Total: 8000
Hit 1000; Total: 9000
Hit 1000; Total: 10000
Total Time Elapsed:         .01 sec   Interval Time:        .01 sec
PL/SQL procedure successfully completed.

Total Time Elapsed:         .00 sec   Interval Time:        .00 sec
```

As shown in the two preceding examples, the MOD function adds overhead. You can get better performance with PL/SQL IF statements.

Improve Shared Pool Use by Pinning PL/SQL Objects

The SHARED_POOL_SIZE parameter sets the amount of shared pool allocated in the SGA (see Chapter 4 and Appendix A for a detailed look at SHARED_POOL_SIZE and closely related shared pool parameters). The shared pool stores all SQL statements and PL/SQL blocks executed in the Oracle database. Given the method by which Oracle manages the shared pool, as far as aging, the shared pool can become fragmented. In addition, since Oracle will not age any objects that are currently being processed by a session, you may get an Oracle error indicating that the shared pool does not have enough memory for a new object. The exact error message is “ORA-4031: unable to allocate *XXX* bytes of shared memory” (where *XXX* is the number of bytes Oracle is attempting to allocate). If you receive this error, it means you should increase the size of your SGA shared pool as soon as possible. The method to do this prior to Oracle9*i* was to modify the initialization parameter SHARED_POOL_SIZE and then shut down and start up the database. The quick, but costly, method of eliminating this error until the next database shutdown was to flush the SGA shared pool. You accomplished this with the following command (only allowed if ALTER SYSTEM privilege is assigned to a user):

```
alter system flush shared_pool;
```

In Oracle9*i*, you could modify the SHARED_POOL_SIZE parameter without shutting down the database as long as you didn't exceed the SGA_MAX_SIZE. This eliminated the need to do things that you had to do in previous versions. You still had to pin the large objects into the shared pool when the database had started and make sure the shared pool was large enough for all of these statements to be cached. Starting with 10*g*, Oracle uses Automatic Memory Management (AMM). In both 11*g* and 12*c*, you can set the MEMORY_TARGET (but you can also set a minimum for the SHARED_POOL_SIZE). Oracle internally manages the memory parameters for you and can be altered dynamically as long as you don't exceed the value of MEMORY_MAX_TARGET (see Chapter 4 on setting initialization parameters).

Pinning (Caching) PL/SQL Object Statements into Memory

In the event that you cannot maintain a sufficient SHARED_POOL_SIZE to keep all statements in memory, keeping the most important objects cached (pinned) in memory may become necessary. The following example shows how to pin PL/SQL object statements (the procedure PROCESS_DATE is pinned in the example that follows) in memory using the DBMS_SHARED_POOL.KEEP procedure:

```
begin
dbms_shared_pool.keep('process_date','p');
end;
/
```

or

```
execute sys.dbms_shared_pool.keep ('SYS.STANDARD');
```

By pinning an object in memory, the object will not be aged out or flushed until the next database shutdown. Also consider My Oracle Support Note 61760.1: DBMS_SHARED_POOL should be created as user SYS. No other user should own this package. Any user requiring access to the package should be granted EXECUTE privileges by SYS. If you create the package in the SYS schema, and run the sample code in a different schema, you need to

1. Grant the EXECUTE_CATALOG_ROLE role to the user running the example (i.e., TEST), and grant EXECUTE privilege on DBMS_SHARED_POOL to TEST.
2. Fully qualify the package, as in SYS.DBMS_SHARED_POOL.KEEP, because the `dbmspool.sql` script does *not* create a public synonym for this package.

TIP
Use the DBMS_SHARED_POOL.KEEP procedure to pin PL/SQL objects into the shared pool.

NOTE
To use this procedure prior to Oracle 10g, you had to first run the `dbmspool.sql` *script. The* `prvtpool.plb` *script is automatically executed after* `dbmspool.sql` *runs. In 10g through 12c, the* `dbmspool.sql` *script is called by* `catpdbms.sql`*, and* `catpdbms.sql` *is called by* `catproc`*, so the procedure is already created.*

Pinning All Packages

To pin all packages in the shared pool, execute the following as the SYS user (this code comes from My Oracle Support):

```
declare
own varchar2(100);
nam varchar2(100);
cursor pkgs is
    select     owner, object_name
    from       dba_objects
    where      object_type = 'PACKAGE';
begin
    open pkgs;
    loop
        fetch pkgs into own, nam;
        exit when pkgs%notfound;
        dbms shared pool.keep(own || '.' || nam, 'P');
    end loop;
end;
/
```

A more targeted approach, pinning only packages that need to be reloaded, would be better than pinning *all* packages, especially because most DBA interfaces since Oracle9*i* involve PL/SQL packages. At the very least, you should check to make sure you are not trying to pin invalid packages as well. Common packages that are shipped with Oracle (that should be kept) include STANDARD, DBMS_STANDARD, and DIUTIL.

TIP
Use the DBMS_SHARED_POOL.KEEP procedure in PL/SQL to pin all packages when the database is started (if memory/shared pool permits) and to avoid errors involving loading packages in the future.

Identify PL/SQL Objects That Need to Be Pinned

Fragmentation causing several small pieces to be available in the shared pool, and not enough large contiguous pieces, is a common occurrence. The key to eliminating shared pool errors (as noted in the preceding section) is to understand which of the objects will be large enough to cause problems when you attempt to load them. Once you know the problem PL/SQL, you can then pin this code when the database has started (and the shared pool is completely contiguous). Doing this ensures that your large packages are already in the shared pool when they are called, instead of searching for a large contiguous piece of the shared pool (which may not be there later as the system is used). You can query the V$DB_OBJECT_CACHE view to determine PL/SQL that is both large and currently not marked "kept." These are objects that may cause problems (due to their size and need for a large amount of contiguous memory) if they need to be reloaded at a later time. This query only shows the current statements in the cache. The example that follows searches for those objects requiring greater than 100K:

```
select     name, sharable_mem
from       v$db object cache
where      sharable_mem > 100000
and        type in ('PACKAGE', 'PACKAGE BODY', 'FUNCTION',
           'PROCEDURE')
and        kept - 'NO';
```

TIP
Query the V$DB_OBJECT_CACHE view to find objects that are not pinned and are also large enough to cause problems potentially.

Use and Modify DBMS_SHARED_POOL.SIZES

An alternative and very precise indication of shared pool allocation can be viewed through the DBMS_SHARED_POOL.SIZES package procedure. This call accepts a MINIMUM SIZE parameter and displays all cursors and objects within the shared pool of a size greater than that provided. The following is the actual statement issued to retrieve this:

```
select    to char(sharable mem / 1000 ,'999999') sz, decode
          (kept_versions,0,' ',rpad('yes(' || to_char(kept_versions)
          || ')' ,6)) keeped, rawtohex(address) || ',' || to_char
          (hash_value)  name, substr(sql_text,1,354) extra, 1 iscursor
from      v$sqlarea
where     sharable_mem > &min_ksize * 1000
union

select    to_char(sharable_mem / 1000 ,'999999') sz, decode(kept,'yes',
          'yes   ','') keeped, owner || '.' || name || load(' ',29 -
          (length(owner) + length(name) ) ) || '(' || type || ')'
          name, null  extra, 0 iscursor
from      v$db_object_cache v
where     sharable_mem > &min_ksize * 1000
order by  1 desc;
```

The preceding query can be placed into a procedure package, of your own construction, to display a formatted view of cursors and objects within the shared pool.

Find Large Objects

You can use the DBMS_SHARED_POOL.SIZES package procedure (DBMS_SHARED_POOL is the package and SIZES is the procedure within the package) to view the objects using shareable memory higher than a threshold that you set.

Execute the DBMS_SHARED_POOL.SIZES package as displayed next for a threshold of 100K (the output follows):

```
set serveroutput on size 10000;
begin
sys.dbms_shared_pool.sizes(100);
end;
/

SIZE(K)   KEPT        NAME
118       YES         SYS.STANDARD          (PACKAGE)
109                   SELECT    DT.OWNER,DT.TABLE_NAME,DT.TABLESPACE_NAME,
                                DT.INITIAL_EXTTENT,DT.NEXT_EXTENT,DT.NUM_ROWS,
                                DT.AVG_ROW_LEN,
                                SUM(DE.BYTES) PHY_SIZE
                      FROM      DBA_TABLES DT,DBA_SEGMENTS DE
                      WHERE     DT.OWNER = DE.OWNER
                      AND       DT.TABLE_NAME = DE.SEGMENT_NAME
                      AND       DT.TABLESPACE_NAME = DE.TABLESPACE_NAME
                      GROUP BY  DT.OWNER,DT.TABLE_NAME,DT.TABLESPACE_NAME,
                                DT.INITIAL_EXTENT,DT.NEX
                                (0B14559C,3380846737)    (CURSOR)
22                    RDBA.RDBA_GENERATE_STATISTICS  (PACKAGE)
PL/SQL procedure successfully completed.
```

Get Detailed Object Information from DBA_OBJECT_SIZE

Query the DBA_OBJECT_SIZE view to show the memory used by a particular object along with much more detailed information concerning the object:

```
compute sum of source_size on report
compute sum of parsed_size on report

compute sum of code_size on report
break on report
select     *
from       dba_object_size
where      name = 'RDBA_GENERATE_STATISTICS';

OWNER NAME                        TYPE         SOURCE_SIZE   PARSED_SIZE   CODE_SIZE
RDBA  RDBA_GENERATE_STATISTICS   PACKAGE      5023          4309          3593
RDBA  RDBA_GENERATE_STATISTICS   PACKAGE BODY 85595         0             111755
SUM                                           90618         4309          115348
(partial display only...not all columns shown)
```

Get Contiguous Space Currently in the Shared Pool

Why does the shared pool return errors when an object is loaded? The answer is that a large enough piece of the shared pool is not available to fit the piece of code. In the last section you learned how to find the size of the code that you have. You also saw in a previous section how to pin pieces of code into the shared pool. Now, let's look at the query that will tell you which code, of the code that has made it into the shared pool, is very large and either should be pinned or should be investigated and shortened if possible.

The following query accesses an X$ table (see Chapter 13), and you must be the SYS user to access these tables:

```
select     ksmchsiz, ksmchcom
from       x$ksmsp
where      ksmchsiz > 10000
and        ksmchcom like '%PL/SQL%';
```

This query shows that the packages that have been accessed are very large and should be pinned at the time that the database has started. If the last line of this query is eliminated, it will also show the large pieces of free memory (KSMCHCOM = *'free memory'* and KSMCHCOM = 'permanent memory') that are still available (unfragmented) for future large pieces of code to be loaded. See Chapter 13 for more details on the X$ tables and example output.

TIP
Query X$KSMSP to find all large pieces of PL/SQL that have appeared in the shared pool. These are candidates for pinning when the database has started.

Find Invalid Objects

Developers often change a small section of PL/SQL code that fails to compile upon execution, forcing an application failure. A simple query, reviewed daily, helps you spot these failures before the end user does:

```
col        "Owner" format a12
col        "Object" format a20
col        "OType" format a12
col         "Change DTE" format a20
select      substr(owner,1,12) "Owner", substr(object_name,1,20)
            "Object", object type "OType", to char(last ddl time,
            'DD-MON-YYYY HH24:MI:SS') "Change Date"
from        dba_objects
where       status <> 'VALID'
order by    1, 2;
```

The preceding example displays any objects that are invalid, meaning they were never compiled successfully or changes in dependent objects have caused them to become invalid. If you have a procedure called PROCESS_DATE, for example, which was found to be invalid, you could manually recompile this procedure with the following command:

```
alter procedure PROCESS_DATE compile;
```

Once this command is executed and PROCESS_DATE passes the recompile, Oracle would change the procedure automatically from INVALID to VALID.

Another manual method that exists is to call the DBMS_UTILITY.COMPILE_SCHEMA package procedure to recompile all stored procedures, functions, and packages for a given schema:

```
begin
dbms_utility.compile_schema('USERA');
end;
/
```

NOTE
You could also run the `utlrp.sql` *script to recompile all the invalid objects in the database. See the script for restrictions on running this script.*

To find the state of all PL/SQL objects for your schema, execute the following:

```
column    object_name  format a20
column    last_ddl_time heading 'last ddl time'
select    object_type, object_name, status, created, last_ddl_time
from      user_objects
where     object_type in ('PROCEDURE', 'FUNCTION', 'PACKAGE',
          'PACKAGE BODY', 'TRIGGER');

OBJECT_TYPE          OBJECT_NAME          STATUS  CREATED   last ddl
-------------------- -------------------- ------- --------- ---------
PACKAGE              DBMS_REPCAT_AUTH     VALID   12-MAY-02 12-MAY-02
PACKAGE BODY         DBMS REPCAT AUTH     VALID   12-MAY-02 12-MAY-02
TRIGGER              DEFS_PROPAGATOR_TRIG VALID   12-MAY-02 12-MAY-02
PROCEDURE            ORA$_SYS_REP_AUTH    VALID   12-MAY-02 12-MAY-02
TRIGGER              REPCATLOGTRIG        VALID   12-MAY-02 12-MAY-02
```

TIP
You can recompile an entire schema (either all or just the invalid objects) with DBMS_UTILITY.COMPILE_SCHEMA.

Find Disabled Triggers

In some respects, a disabled trigger is far more dangerous than an invalid object because it doesn't fail—*it just doesn't execute!* Disabled triggers can have severe consequences for applications, and consequently business processes, that depend on business logic stored within procedural code.

The following script identifies disabled triggers:

```
col       "Owner/Table" format a30
col       "Trigger Name" format a25
col       "Event" format a15
col       "Owner" format a10
select    substr(owner,12) "Owner", trigger_name "Trigger Name",
          trigger_type "Type", triggering_event "Event",
          table_owner||'.'||table_name "Owner/Table"
from      dba triggers
where     status <> 'ENABLED'
order by  owner, trigger name;
```

If you modify the preceding query to check only the SYS schema and certain columns, as shown next, you get a list of disabled triggers that are provided by Oracle:

```
select      trigger_name "Trigger Name",STATUS,
            trigger_type "Type", triggering_event "Event"
from        dba_triggers
where       status <> 'ENABLED'
and         owner = 'SYS'
order by    owner, trigger_name;

Trigger Name                STATUS   Type              Event
--------------------------- -------- ----------------- ----------------
AURORA$SERVER$SHUTDOWN      DISABLED BEFORE EVENT      SHUTDOWN
AURORA$SERVER$STARTUP       DISABLED AFTER EVENT       STARTUP
NO_VM_CREATE                DISABLED BEFORE EVENT      CREATE
NO_VM_DROP                  DISABLED BEFORE EVENT      DROP
SYS_LOGOFF                  DISABLED BEFORE EVENT      LOGOFF
SYS_LOGON                   DISABLED AFTER EVENT       LOGON
```

To find all triggers for your schema, execute the following code:

```
column     trigger_name       format a15
column     trigger_type       format a15
column     triggering_event   format a15
column     table_name         format a15
column     trigger_body       format a25

select     trigger_name, trigger_type, triggering_event,
           table_name, status, trigger_body
from       user_triggers;

TRIGGER_NAME   TRIGGER_TYPE      TRIGGERING_EVENT  TABLE_NAME STATUS   TRIGGER_BODY
UPDATE_TOTAL   AFTER STATEMENT   INSERT OR UPDATE  ORDER_MAIN ENABLED  begin
                                 OR DELETE                             update total_orders
                                                                       set order_total=10;
                                                                       end;
```

TIP
Query DBA_TRIGGERS (for system-wide objects) or USER_TRIGGERS (for your schema only) to find the state of triggers and avoid errors with disabled triggers. Disabled triggers can have fatal results for an application: they don't fail; they just don't execute.

Use PL/SQL Associative Arrays for Fast Reference Table Lookups

Programs that are designed to process data coming into a system usually incorporate numerous reference table lookups to validate and/or code the incoming data properly. When the reference tables are searched, using a unique key that is a numerical data type, the query performance against the reference tables can be drastically improved by loading the reference tables into PL/SQL *associative arrays* (formerly known as *index-by tables*). Consider an incoming dataset that contains a single numerical column that must be translated to a coded string using a reference table. Here is a program to handle this task using the classic approach of repeated searches against the reference table.

```
DECLARE
  v_code_c ref_table.ref_string%type;
  cursor v_lookup_cur (p_code_n IN number) is
    select ref_string
      from ref_table
     where ref_num = p_code_n;
  cursor v_inbound_cur is
    select *
      from incoming data;
BEGIN
  --Open a cursor to the incoming data.
  for inbound_rec in v_inbound_cur loop
    BEGIN
      --Calculate the reference string from the reference data.
      open v_lookup_cur(inbound_rec.coded_value);
      fetch v_lookup_cur into v_code_c;
      if v_lookup_cur%notfound then
        close v lookup cur;

        raise NO_DATA_FOUND;
      end if;
      close v_lookup_cur;
      dbms_output.put_line(v_code_c);
      --processing logic...
      --Commit each record as it is processed.
      commit;
    EXCEPTION
      when NO_DATA_FOUND then
        null;--Appropriate steps...
      when OTHERS then
        null;--Appropriate steps...
    END;
  end loop;
END;
/
```

Although this program may appear to be written efficiently, it is, in fact, hampered by the repeated queries against the reference table. Even though Oracle may have the entire reference table in memory, due to pinning or prior queries, a certain amount of overhead is still involved with processing the queries.

A more efficient technique is to load the entire reference table into a PL/SQL associative array. The numerical column (that the searches are performed against) is loaded as the array index. When a lookup against the reference data is required, the array is used instead of the actual reference table—the code in the incoming data that must be translated is used as the array index. The inherent nature of working with PL/SQL associative arrays is that if an invalid array index is used (meaning the code in the incoming data does not match any value in the reference table), the NO_DATA_FOUND exception will be raised.

Here is the same processing program rewritten using an associative array to store the reference data:

```
DECLARE
  type v_ref_table is table of ref_table.ref_string%type index by binary_integer;
  v_ref_array v_ref_table;
  v_code_c ref_table.ref_string%type;
  cursor v_lookup_cur is
    select *
      from ref_table;
  cursor v_inbound_cur is
    select *
      from incoming_data;
BEGIN
  --First, load the reference array with data from the reference table.
  for lookup_rec in v_lookup_cur loop
    v_ref_array(lookup_rec.ref_num) := lookup_rec.ref_string;
  end loop;
  --Open a cursor to the incoming data.
  for inbound_rec in v_inbound_cur loop
    BEGIN
      --Calculate the reference string from the reference data.
      v_code_c := v_ref_array(inbound_rec.coded_value);

      dbms_output.put_line(v_code_c);
      --processing logic...
      --Commit each record as it is processed.
      commit;
    EXCEPTION
      when NO_DATA_FOUND then
        null;--Appropriate steps...
      when OTHERS then
        null;--Appropriate steps...
    END;
  end loop;
END;
/
```

The result should be a drastic increase in the processing speed due to the reduced overhead in working with the PL/SQL associative arrays in comparison to the actual database table.

Finally, quite some time ago, the requirement that an associative array be indexed by a numeric value was lifted. Thus, the index of an associative array can be a string value. This capability makes it possible to use the same solution when the coded values that need to be resolved are not necessarily of a numerical nature. Consider the traditional example that some inbound data is carrying a two-character representation of a state code that needs to be resolved and validated. A slight modification to the previous procedure, as shown next, makes this possible. The index type for the array must be a VARCHAR2 type.

```
DECLARE
  type v_ref_table is table of states_table.state_name%type
    index by states_table.state_code%type;
  v_ref_array v_ref_table;
  v_state_c states_table.state_name%type;
  cursor v_lookup_cur is
    select state_code,
           state_name
      from states_table;
  cursor v_inbound_cur is
    select *
      from incoming data;
BEGIN
  --First, load the reference array with data from the reference table.
  for lookup rec in v lookup cur loop
    v_ref_array(lookup_rec.state_code) := lookup_rec.state_name;
  end loop;
  --Open a cursor to the incoming data.
  for inbound_rec in v_inbound_cur loop
    BEGIN
      --Calculate the reference string from the reference data.
      v state c := v ref array(inbound rec.coded value);
      dbms_output.put_line(v_state_c);
      --processing logic...
      --Commit each record as it is processed.
      commit;
    EXCEPTION
      when NO DATA FOUND then

        null;--Appropriate steps...
      when OTHERS then
        null;--Appropriate steps...
    END;
  end loop;
END;
/
```

TIP
Load reference tables into PL/SQL associative arrays for faster lookups. This takes advantage of the performance of array indexes in PL/SQL.

Find and Tune the SQL When Objects Are Used

At times, the hardest part of tuning stored objects is finding the actual code that is stored in the database. This section looks at queries that retrieve the SQL that can be tuned. This section shows how to query views that retrieve information about the actual source code that exists behind the stored objects.

Retrieve the code for a procedure you created called PROCESS_DATE:

```
column     text   format a80
select     text
from       user_source
where      name = 'PROCESS_DATE'
order by   line;
```

This query works for procedures, triggers, or functions. For packages, change the last line in the query to

```
order by type, line;

TEXT
procedure process_date is
  test_num number;
 begin
 test_num := 10;
 if test_num = 10 then
  update order_main
  set       process_date = sysdate
  where    order_num = 12345;
 end if;
 end;
```

The following example retrieves the code for the familiar DBMS_RULE package:

```
column    text format a80
select    text
from      dba_source
where     name  = 'DBMS_RULE'
and       type  = 'PACKAGE'
order by  line;

TEXT
--------------------------------------------------------------------------------
PACKAGE dbms_rule AUTHID CURRENT_USER AS

  PROCEDURE evaluate(
        rule_set_name           IN      varchar2,
        evaluation_context      IN      varchar2,
        event_context           IN      sys.re$nv_list := NULL,
        table_values            IN      sys.re$table_value_list := NULL,
        column_values           IN      sys.re$column_value_list := NULL,
        variable_values         IN      sys.re$variable_value_list := NULL,
        attribute_values        IN      sys.re$attribute_value_list := NULL,
        stop_on_first_hit       IN      boolean := FALSE,
        simple_rules_only       IN      boolean := FALSE,
        true_rules              OUT     sys.re$rule_hit_list,
        maybe_rules             OUT     sys.re$rule_hit_list);

  PROCEDURE evaluate(
        rule_set_name           IN      varchar2,
        evaluation_context      IN      varchar2,
        event_context           IN      sys.re$nv_list := NULL,
        table_values            IN      sys.re$table_value_list := NULL,
        column_values           IN      sys.re$column_value_list,
        variable_values         IN      sys.re$variable_value_list := NULL,
        attribute_values        IN      sys.re$attribute_value_list := NULL,
        simple_rules_only       IN      boolean := FALSE,
        true_rules_iterator     OUT     binary_integer,
        maybe_rules_iterator    OUT     binary_integer);
  FUNCTION get_next_hit(
        iterator                IN      binary_integer)
  RETURN sys.re$rule_hit;
  PROCEDURE close_iterator(
        iterator                IN      binary_integer);
END dbms_rule;

35 rows selected.
```

The following example attempts to retrieve the package body for the DBMS_JOB package:

```
column     text   format a80
select     text
from       dba_source
where      name   = 'DBMS_JOB'
and        type   = 'PACKAGE BODY'
order by   line;

TEXT
PACKAGE BODY dbms_job wrapped
0
abcd

abcd
...
:2 a0 6b d a0 ac :3 a0 6b b2
ee :2 a0 7e b4 2e ac e5 d0
b2 e9 93 a0 7e 51 b4 2e
:2 a0 6b 7e 51 b4 2e 6e a5
57 b7 19 3c b0 46 :2 a0 6b
ac :2 a0 b2 ee ac e5 d0 b2
e9 :2 a0 6b :3 a0 6e :4 a0 :5 4d a5
57 :2 a0 a5 57 b7 :3 a0 7e 51
```

In this example, the package was wrapped (protected) using the WRAP command, and the output is unreadable. If you find yourself tuning the preceding code, you need sleep!

You can use the following query to retrieve the source code for a trigger:

```
column    trigger_name       format a15
column    trigger_type       format a15
column    triggering_event   format a15
column    table_name         format a15
column    trigger_body       format a25
select    trigger_name, trigger_type, triggering_event, table_name, trigger_body
from      user_triggers;

TRIGGER_NAME TRIGGER_TYPE     TRIGGERING_EVEN   TABLE_NAME   TRIGGER_BODY
UPDATE_TOTAL AFTER STATEMENT INSERT OR UPDATE  ORDER_MAIN   begin
                              OR DELETE                       update order_main
                                                              set order_total = 10;
                                                             end;
```

The following example shows how to find the dependencies for PL/SQL objects:

```
column    name               format a20
column    referenced_owner   format a15 heading R_OWNER
column    referenced_name    format a15 heading R_NAME
column    referenced_type    format a12 heading R_TYPE
select    name, type, referenced_owner, referenced_name,referenced_type
from      user_dependencies
order by  type, name;

NAME            TYPE         R_OWNER    R_NAME        R_TYPE
INSERT_RECORD   PROCEDURE    USERA      ORDER_MAIN    TABLE
INSERT_RECORD   PROCEDURE    SYS        STANDARD      PACKAGE
PROCESS_DATE    PROCEDURE    SYS        STANDARD      PACKAGE
PROCESS_DATE    PROCEDURE    USERA      ORDER_MAIN    TABLE
```

TIP
Finding the source code behind PL/SQL package procedures involves querying the USER_SOURCE and DBA_SOURCE views. Finding the source code behind a trigger involves querying the USER_TRIGGERS and DBA_TRIGGERS views. You can find dependencies among PL/SQL objects by querying the USER_DEPENDENCIES and DBA_DEPENDENCIES views.

Consider Time Component When Working with DATE Data Types

When working with the Oracle DATE data type, think of it as a TIME data type, which is more accurate. This is because the DATE data type always stores a complete temporal value, down to the second. It is impossible to insert a date value only into either a PL/SQL variable or a database column that is defined as a DATE. If you do not keep this behavior in mind during application design, the finished product may exhibit undesirable side effects. One of the most common side effects of improper date management within an application is when reports that filter the data by a date value return different results across multiple executions.

When a column or variable of this type (DATE) is initialized with a value, any missing component (if any) is automatically supplied by Oracle. If the initialization value contains only the date component, only then does Oracle supply the time component, and vice versa. This raises the question of how you can tell which component, if any, is missing during the initialization. Quite simply, both components are automatically present only when a date variable is initialized from another date variable. The system variable SYSDATE is one such date variable. Thus, whenever a column or variable is initialized from SYSDATE, it will contain a value representing the date and time when the initialization occurred.

If it is January 10, 1998, at 3:25:22 a.m., and you execute the following command

```
Date_Var_1 date := SYSDATE;
```

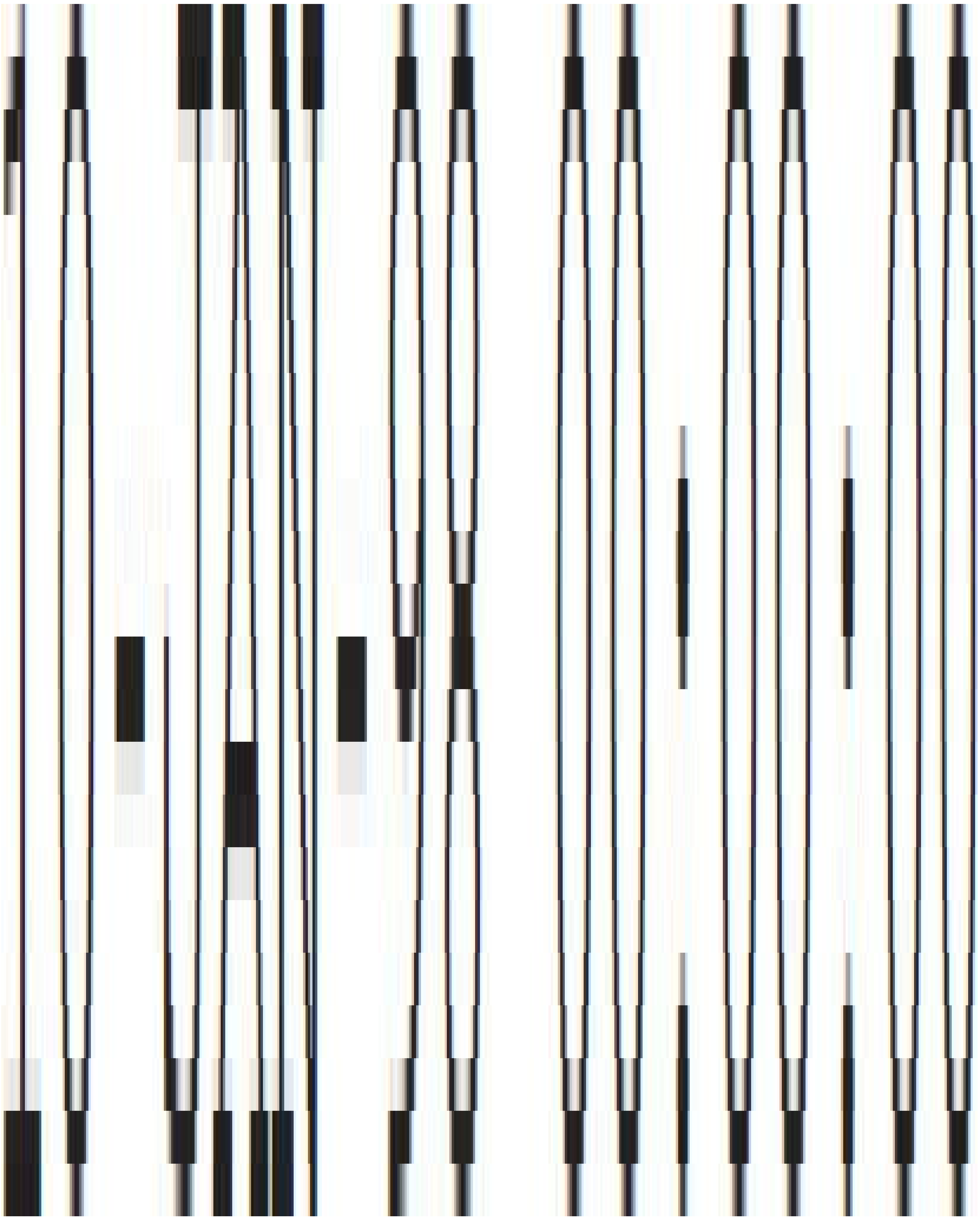
the value contained in the variable DATE_VAR_1 will be

```
10-JAN-1998 03:25:22.
```

You can also initialize a date variable using a text string. For example, if

```
Date_Var_2 date := '10-JAN-98';
```

the value contained in the variable DATE_VAR_2 will be



Here is a simple PL/SQL block that will allow you to see this for yourself:

```
DECLARE
  date_var_2 DATE;
BEGIN
  date_var_2 := '10-JAN-98';
  DBMS_OUTPUT.PUT_LINE('Selected date is '|| to_char(date_var_2, 'DD-MON-YYYY HH24:MI:SS'));
END;
/

10-JAN-1998 00:00:00
```

TIP
A DATE data type always stores a complete temporal value, down to the second. It is impossible to insert a date value only into either a PL/SQL variable or a database column that is defined as a DATE.

At this point, it should be clear that DATE_VAR_1 and DATE_VAR_2 are not equal. Even though they both contain a date component of 10-JAN-98, they are not equal because their time components differ by almost three and a half hours. Herein lies the problem with a program that does not anticipate the time component that is inherent with date values. Consider an application that uses the SYSDATE variable to initialize the accounting date of records inserted into a database table. If a PL/SQL processing program (or a simple SQL SELECT statement) does not take the time component of the records into account, then records will be missed during processing.

Given that the date values in a table *contain time values* other than 12:00 midnight, the following statements would miss records. The problem is that the time is not the same and these statements all miss records.

```
select      *
from        table
where       date_column = SYSDATE;
select      *
from        table
where       date_column = trunc(SYSDATE);
select      *
from        table
where       date_column = '10-JAN-98';
select      *
from        table
where       date_column between '01-JAN-98' and '10-JAN-98';
```

The solution is to truncate the time on both sides of the WHERE clause.

One way to prevent this problem is to negate the difference in time components on both sides of the conditional test:

```
select      *
from        table
where       trunc(date_column) = trunc(SYSDATE);
select      *
from        table
where       trunc(date_column) = '10-JAN-98';
select      *
from        table
where       trunc(date_column) between '01-JAN-98' and '10-JAN-98';
```

One note on these examples: If you modify the NLS_DATE_FORMAT to a different value than the default, these examples might not work. I used "*dd-mon-yy hh*:*mi*:*ss*" as my format, and the modified queries returned no rows. When I logged out and back in to reset the NLS_DATE_FORMAT setting, the same queries then returned rows.

The tuned solution is where the time is truncated on the noncolumn side of the WHERE clause. This technique has the undesired effect of suppressing any indexes that might otherwise improve query performance—the TRUNC function on the COLUMN_NAME suppresses the index on the column. The desired technique is to adjust the filter conditions to include all possible times within a given date (note in the example that .000011574 of one day is 1 second):

```
select      *
from        table
where       date_column between trunc(SYSDATE) and

            trunc(SYSDATE + 1) - .000011574;

select      *
from        table
where       date_column between to_date('10-JAN-98') and
            to_date('11-JAN-98') - .000011574;

select      *
from        table
where       date_column between to_date('01-JAN-98') and
            to_date('11-JAN-98') - .000011574;
```

TIP
The Oracle DATE data type has both date and time included in it. Avoid suppressing indexes when trying to match dates. The key is never to modify the column side in the WHERE clause. Do all

modifications on the noncolumn side. As you saw in Chapter 2, you can add a function-based index to overcome this issue.

Use PL/SQL to Tune PL/SQL

You can also use PL/SQL to time your PL/SQL and ensure that it is performing to your standards. Here is a simple example of how you can write a script that allows you to test and tune your procedures (a procedure called GET_CUSTOMER in this example) directly from SQL*Plus (or PL/SQL within SQL*Plus):

```
set serveroutput    on
declare
cust_name char(100);
begin
dbms_output.put_line('Start Time:
    '||to_char(sysdate,'hh24:mi:ss'));
    get_customer(11111,cust_name);
    dbms_output.put_line('Complete Time:
    '||to_char(sysdate,'hh24:mi:ss'));
    dbms_output.put_line(cust_name);
end;
/
```

TIP
Use PL/SQL to display the start and end times for your PL/SQL. Basically, don't forget to use PL/SQL to tune your PL/SQL. Use things like the package DBMS_PROFILER (mentioned earlier in this chapter) to get timing statistics per line of PL/SQL code.

NOTE
You could also use DBMS_HPROF. The profiler reports the dynamic execution profile of a PL/SQL program organized by function calls, accounting for SQL and PL/SQL execution times separately. The `plshprof` command-line utility is in the $ORACLE_HOME/bin/ directory and generates an HTML report from either one or two profiler output files.

Understand the Implications of PL/SQL Object Location

In the old days at TUSC, we generally recommended storing the PL/SQL objects on the server side, for many of the obvious reasons. The server is usually much more powerful and objects are reused much more often (especially when pinned into the shared pool). The security methods employed are also more straightforward. Sending the PL/SQL to be processed on the client side can be dependent on the power of the client and can lessen the number of roundtrips from client to server. But, when written correctly, the calls may be limited back to the server (see the next section for an example). There is certainly a continuing debate on this one, but with the evolving thin client, the server is probably the only place to store the PL/SQL. Figure 10-1 diagrams how PL/SQL is executed when stored on the server side. Some additional reasons for storing code on the server are listed here:

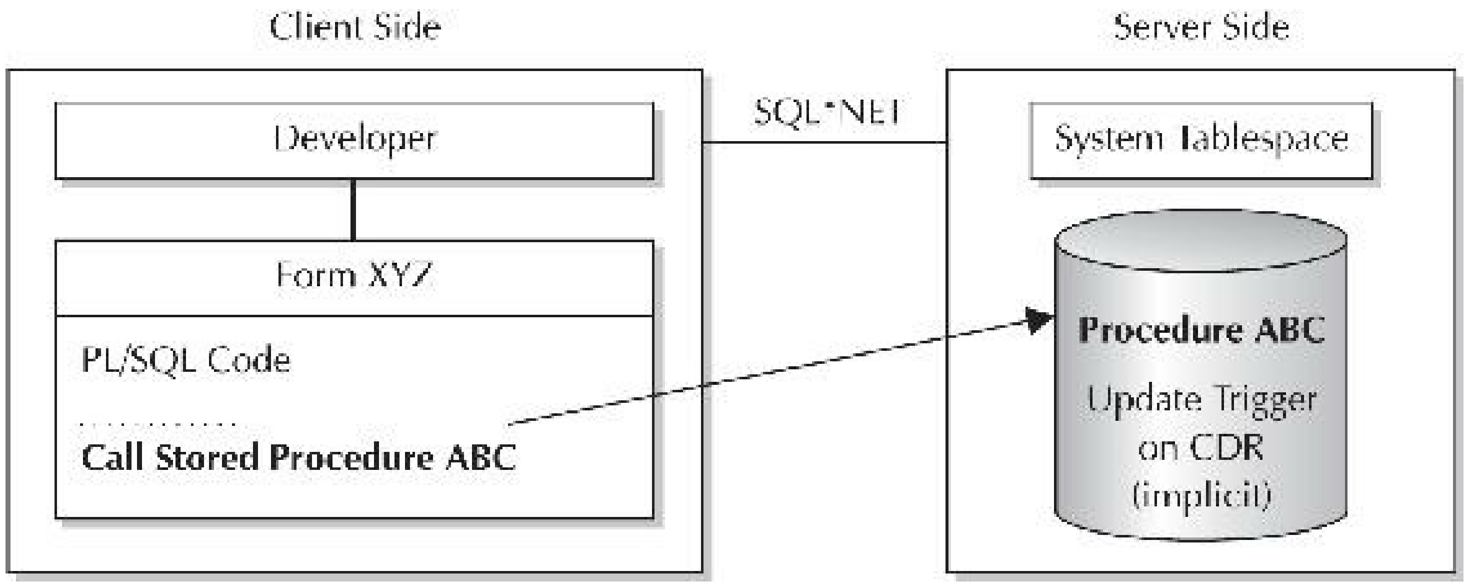


FIGURE 10-1. *Executing an object on the server side*

- Performance is improved because the code is already compiled code (p-code).
- You can pin objects in the Oracle SGA.
- It enables transaction-level security at the database level.
- You have less redundant code and fewer version control issues.
- You can query the source code online because it is stored in the data dictionary.
- Performing impact analysis is easier since the code is stored in the data dictionary.
- It uses less memory because only one copy of the code is in memory.
- If packages are used, then the entire package is loaded upon initially being referenced.

TIP

Where to store the PL/SQL code is an ongoing debate. Generally, the server side is the preferred place to store the code, and it may become the only choice as thin clients become more prevalent.

Use Rollback Segments to Open Large Cursors

This section is intended for developers and DBAs who are not using Oracle's automatic undo management. Any skilled PL/SQL developer should be familiar with the need to size and use rollback segments properly when attempting large INSERTs/UPDATEs/DELETEs to the database. If a rollback segment of the appropriate size is not explicitly set prior to the performance of a large data manipulation operation, the operation may fail. The error code usually returned is "ORA-01562: failed to extend rollback segment." The reason for the failure is that transactions that do not explicitly set the rollback segment use one that is randomly assigned by Oracle. If this randomly assigned rollback segment is insufficiently sized to hold the entire transaction, the operation fails. You can eliminate errors of this type by anticipating the amount of data that will be changed, choosing an appropriately sized rollback segment (the DBA_ROLLBACK_SEGS view is helpful in this regard), and setting this rollback segment just prior to the DML statement. The following example demonstrates the proper set of statements:

```
commit;
set transaction use rollback segment rbs1;
update big_table
set column_1 = column_1 * 0.234;
commit;
```

You can also determine the current UNDO retention period by querying the TUNED_UNDORETENTION column of V$UNDOSTAT. In DBA_TABLESPACES, query the column RETENTION, which contains a value of GUARANTEE/NOGUARANTEE to get the retention guarantee setting for the UNDO tablespace. The NOT APPLY value is used for tablespaces other than the UNDO tablespace.

It is a little known fact that Oracle uses rollback segments when cursors are employed, even if DML statements are not being issued from within the cursor loop. The rollback segments are used as a type of work area as a cursor loop is being executed. Thus, a cursor loop will quite possibly fail if a rollback segment of insufficient size is used to read the cursor. The failure does not occur immediately—only after numerous iterations of the cursor loop have been performed. Because the error message that is returned is the same as what would be returned when a single DML statement fails, many developers are fooled into thinking that the error lies elsewhere in their code. Valiant efforts are made to manage transaction sizes properly *within* the cursor loops, but to no avail. To successfully open a large cursor, it is imperative to set a large rollback segment just prior to the opening of the cursor:

```
commit;
set transaction use rollback segment rbs_big;
for C1_Rec in C1 loop
-- your processing logic goes here ...
end loop;
```

If large amounts of data are being manipulated within the cursor loop, the code should be setting rollback segments within the cursor loop as well. This prevents the DML statements from utilizing the same rollback segment that is being used to ensure that the large cursor can be read.

TIP
If you are not using automatic undo management, then you may need to specify a large enough rollback segment when opening a large cursor.

Active Transaction Management: Process Large Quantities of Data

When coding procedures that will process large quantities of data, remember to take into account the size of the rollback segments. The rollback segments are the weak link in a program that performs mass data manipulation. A procedure that performs a single COMMIT statement at the end just won't do if it is processing millions of rows of data. It could be argued that a single transaction could be used to process mass quantities of data, provided the rollback segments were large enough. This logic has two flaws: (1) rarely is it feasible to devote gigabytes of valuable drive space to serve as undo space; and (2) should a hardware or software error occur, then the entire dataset would have to be reprocessed. Thus, active transaction management is always the desired technique when processing large quantities of data; it yields efficient utilization of drive space (devoted to undo segments) and provides for automatic recovery in the event of hardware/software failures. Also ensure that the undo tablespace has enough space to accommodate the UNDO_RETENTION setting.

Active transaction management is a coding technique that consists of three components: setting transactions for cursor and DML statements, performing intermittent database COMMITs, and utilizing a table column as a processing flag to indicate which records have been processed. Consider the following database procedure:

```
declare
  counter number;
  cursor C1 is
    select     rowid,column_1,column_2,column_3
    from       big_table
    where      process_time is NULL;
begin
  Counter := 0;
  commit;
  set transaction use rollback segment rbs_big;
  for C1_Rec in C1 loop
    -- Commit every 1000 records processed.
    if (Counter = 0) or (Counter >= 1000)
      then
        commit;
        set transaction use rollback segment rbs_medium;
        Counter := 0;
      else
        Counter := Counter + 1;
    end if;
    -- Processing logic...
    update big_table
    set process_time = sysdate
    where rowid = C1_Rec.rowid;
  end loop;
  commit;
end;
/
```

The SET TRANSACTION statements ensure that an appropriately sized rollback segment is used for both cursor reading and DML statements on systems that use rollback segments. The database COMMIT for every 1000 records processed does two things: prevents the DML statements from exceeding the capacity of the rollback segment (or UNDO segment) and divides the records being processed into discrete units in the event that there is a hardware/software failure. Finally, the PROCESS_TIME column serves as the processing flag that allows the procedure to identify records that have not yet been processed. With automatic undo management, the database manages UNDO segments in an UNDO tablespace. When you start a transaction, it is assigned automatically to an available UNDO segment. You cannot specify which UNDO segment should be used, and you do not need to do so.

TIP
Maintaining sufficient space for rollback or undo segments can be critical in transactional processing. Limiting the amount of data manipulated between COMMITs is key to avoiding Snapshot Too Old errors.

Use Temporary Database Tables for Increased Performance

PL/SQL tables are great for specific cases, especially when repeated iterations are involved and the amount of data is relatively small. As outlined earlier in this chapter, the memory cost (per session) can add up fast if not used properly. When a temporary storage area is needed to house large volumes of records for a short period of time, the method of creating, indexing, and querying a temporary database table should be viewed as a viable and useful option. I have seen far too many developers abandon the common method of temporary database tables after the introduction and expansion of PL/SQL tables; remember, PL/SQL tables are not the preferred method in all cases.

Oracle writes UNDO data for temporary tables to facilitate transaction recovery, rollback to savepoints, read consistency, and reclaiming of space. Thus, transactions in temporary tables generate REDO data because you need to log the changes made to the rollback or undo segments. The redo generated should be less than the redo generated for DML on permanent tables.

Limit the Use of Dynamic SQL

Oracle provides the Oracle-supplied package DBMS_SQL and the native dynamic SQL command EXECUTE IMMEDIATE, both of which provide for or allow the creation of dynamic SQL and PL/SQL commands. These are extremely powerful features, but also dangerous if not used appropriately. When designing and developing Oracle applications, one of the hardest decisions that must be made is where to draw the line on building in dynamic capabilities and flexibility. Developing dynamic and flexible applications is extremely helpful from a functional perspective. However, the more dynamic and flexible an application, the more potential for performance degradation.

A completely accurate and functional application is considered a failure if it does not perform at acceptable levels. Users will reject an application if they have to wait to do their job. I am not advocating the elimination of dynamic or flexible applications, but a balance must exist. Build flexibility into applications when necessary, not just to make every application module more flexible for the future in case business rules may change. Only build flexibility into applications when you are sure the flexibility is needed and the performance impact will be negligible.

Both the DBMS_SQL package and the EXECUTE IMMEDIATE command provide the dynamic and flexible means in PL/SQL program units. Use these features when needed, but do not abuse them, unless you want to set yourself up for failure.

TIP

If you integrate the DBMS_SQL package into a PL/SQL program unit to create SQL statements dynamically for a production application, remember that optimizing the generated SQL statements will be difficult. Instead, use bind variables with dynamic SQL to minimize Shared Pool resource contention and maximize performance.

Use Pipelined Table Functions to Build Complex Result Sets

Occasionally, I encounter situations in which a DML SELECT statement is incapable of providing the necessary information. Typically, this occurs when the data doesn't reside in database tables or the number of transformations necessary to get table data into a usable form exceeds the capabilities of SQL and inline functions. Historically, the solution to such a problem would have been the creation of a preprocessor that, when called, would accumulate the data in some type of intermediate table, perhaps a global temporary table, for subsequent extraction using a simple DML SELECT. However, pipelined table functions not only allow you to combine these two steps but also allow you to eliminate the overhead associated with maintaining the data in an intermediate table.

Pipelined table functions are functions that produce a collection of rows (such as a nested table) that can be queried like a physical database table or assigned to a PL/SQL collection variable. You can use a table function in place of the name of a database table in the FROM clause of a query or in place of a column name in the SELECT list of a query.

To demonstrate, I will start with the assumption that this simple table is the only table in my schema:

```
create table states
(
state_code varchar2(2)   not null,
state_name varchar2(100) not null,

constraint states_pk  primary key (state_code),
constraint states_uk1 unique (state_name),
constraint states_chk1 check (state_code = upper(state_code))
);
```

The problem to be solved is that I need a way to create a SQL script to reproduce all of the custom constraints in my schema, subject to the following requirements:

- The script is to be created on an application server, not the database server, by a Java Server Pages (JSP) approach.
- The script needs to ensure that dependencies between constraints are taken into account.
- The script should leave disabled constraints in a disabled state when they are reproduced.
- The script should protect against revalidation of existing data when enabled check and foreign key restraints are reproduced.

Now, it *might* be possible to solve this problem with a huge SQL query using multiple table joins and several UNION clauses and a healthy dose of DECODE statements, but the end result would most likely be a monstrosity that would be difficult to maintain. So I will opt for a more elegant solution that involves pipelined table functions that, as you will see, are founded in some very basic PL/SQL functionality. By using a pipelined table function, I simplify what the JSP needs to do to get the desired information from the database … issue a simple DML SELECT statement. The pipelined table function will return the DDL commands to the JSP in the proper format, adhering to all the requirements. From the JSP's perspective, the pipelined table function looks and behaves like a table, so it can simply issue the query and iterate over the returning result set, writing the commands to a file as they are fetched.

A pipelined table function is declared by specifying the PIPELINED keyword. The PIPELINED keyword indicates that the function returns rows iteratively. The return type of the pipelined table function must be a supported collection type, such as a nested table or a varray (it cannot be an associative array type). This collection type can be declared at the schema level or inside a package. Inside the function, you return individual elements of the collection type. Here is the package header for the solution to the problem. Note that the GET_CONSTRAINT_DDL function returns a collection type and uses the PIPELINED keyword.

```
CREATE OR REPLACE PACKAGE ddl_extract_pkg is

  --Record and array types to support pipelined tabled functions.
  type sg_constraint_ddl_rec is record (ddl_name varchar2(100),
                                        ddl_text varchar2(1000));
  type sg_constraint_ddl_array is table of sg_constraint_ddl_rec;

  --Public routines.
  FUNCTION get_constraint_ddl return sg_constraint_ddl_array pipelined;

END ddl_extract_pkg;
/
```

In PL/SQL, the PIPE ROW statement causes a pipelined table function to return a row and continue processing. The statement enables a PL/SQL table function to return rows as soon as they are produced. The PIPE ROW statement may be used only in the body of pipelined table functions; an error is raised if it is used anywhere else. The PIPE ROW statement can be omitted for a pipelined table function that returns no rows. A pipelined table function may have a RETURN statement that does not return a value. The RETURN statement transfers the control back to the consumer and ensures the next fetch gets a NO_DATA_FOUND exception.

Before looking at the package body, I will briefly discuss some of the key components of the solution:

- First, to avoid the tedious assembly of reconstructive DDL from various dictionary tables, the DBMS_METADATA package is utilized. The DBMS_METADATA package is a supplied package that does the work of building DDL from the dictionary. It requires some initial PL/SQL-based configuration calls that would have invalidated its use in the "do it in a monstrous SQL statement" approach. By using the DBMS_METADATA package, you ensure that you will capture all of the nuances of reconstructive DDL (such as storage parameters, tablespaces, and segment attributes) if desired.
- Once the base reconstructive DDL has been obtained from DBMS_METADATA, it will be

processed using string commands to implement the specified functionality.

- The internal processing of the pipelined function is where the dependency order of the constraints must be taken into account. The order in which records are returned by the function (via the PIPE ROW statement) defines the order in which the calling DML SELECT statement receives them.
- As cautioned in the *Oracle Database PL/SQL Language Reference*:

  A pipelined table function always references the current state of the data. If the data in the collection changes after the cursor opens for the collection, then the cursor reflects the changes. PL/SQL variables are private to a session and are not transactional. Therefore, read consistency, well known for its applicability to table data, does not apply to PL/SQL collection variables.

Now for the package body:

```
CREATE OR REPLACE PACKAGE BODY ddl_extract_pkg is

  --scrub_raw_ddl function.
  --
  --Description: This function performs basic scrubbing routines on a
  --             DDL command returned by dbms_metadata.get_ddl.
  --
  --Syntax: scrub_raw_ddl(p_status_c, p_cons_type_c, p_ddl_c);
  --
  --Where: p_status_c      = The current status (Enabled/Disabled).
  --       p_cons_type_c   = The constraint type (P, U, C, R).
  --       p_ddl_c         = The constraint reconstruction DDL.
  --
  FUNCTION scrub_raw_ddl (p_status_c     IN varchar2,
                          p_cons_type_c  IN varchar2,
                          p_ddl_c        IN varchar2) return varchar2 is
    v_new_ddl_c varchar2(1000);
  BEGIN
  --Capture the passed DDL.
  v_new_ddl_c := p_ddl_c;
  --Trim off any carriage returns.
  v_new_ddl_c := replace(v_new_ddl_c, chr(10), null);
  --Trim off any whitespace.
  v_new_ddl_c := trim(v_new_ddl_c);
  --For Check and Relational constraints, if the constraint is
  --currently disabled then we will leave it that way.
  --Otherwise, we will enable it but without the re validation of existing data.
  if ( p_cons_type_c in ('C', 'R') ) then
    if ( ( p_status_c = 'ENABLED' ) ) then
      if ( instr(v_new_ddl_c, ' NOVALIDATE') = 0 ) then
        v_new_ddl_c := v_new_ddl_c||' NOVALIDATE';
      end if;
    end if;
  end if;
  --Properly terminate the command.
  v_new_ddl_c := v_new_ddl_c||';';
  --Return.
  return(v_new_ddl_c);
END scrub_raw_ddl;

--get_constraint_ddl function.
--
--Description: Pipelined table function returning proper DDL commands to
--             reconstruct the custom constraints (PK, UK, CHK, FK) for all
--             tables within the current schema.
--
FUNCTION get_constraint_ddl return sg_constraint_ddl_array pipelined is

  v_mdc_i     integer;
  v_raw_sql_c varchar2(1000);

  --The function returns a collection of records of type X.
  --So, in the code we will return single records of type X.
  v_out_record sg_constraint_ddl_rec;

  --Cursor to control the extraction order to prevent dependency errors.
  --Check constraints, then PK, then UK, then FK.
  --We do this to prevent dependencies errors.
  cursor v_extract_order_cur is
    select 1            as a_cons_order,
           'C'          as a_cons_type,
           'CONSTRAINT' as a_cons_group
      from dual
     union all
    select 2, 'P', 'CONSTRAINT'
      from dual
     union all
    select 3, 'U', 'CONSTRAINT'
```

```
      from dual
     union all
    select 4, 'R', 'REF_CONSTRAINT'
      from dual
     order by 1;

  --Cursor to access the custom constraints from the data dictionary.
  cursor v_constraints_cur (p_type_c   IN varchar2) is
    select owner,              table_name,
           constraint_name,    constraint_type,
           status,             validated
      from user_constraints
     where table_name        = 'STATES'
       and constraint_type   = p_type_c
       and generated        <> 'GENERATED NAME';

BEGIN

  --Configure the dbms_metadata package.
  v_mdc_i := dbms_metadata.session_transform;
  dbms_metadata.set_transform_param(v_mdc_i, 'PRETTY',                 false);
  dbms_metadata.set_transform_param(v_mdc_i, 'SEGMENT_ATTRIBUTES',     false);
  dbms_metadata.set_transform_param(v_mdc_i, 'STORAGE',                false);
  dbms_metadata.set_transform_param(v_mdc_i, 'TABLESPACE',             false);
  dbms_metadata.set_transform_param(v_mdc_i, 'CONSTRAINTS_AS_ALTER', true);
  dbms_metadata.set_transform_param(v_mdc_i, 'CONSTRAINTS',            true);
  dbms_metadata.set_transform_param(v_mdc_i, 'REF_CONSTRAINTS',        true);
  dbms_metadata.set_transform_param(v_mdc_i, 'SQLTERMINATOR',          false);

  --Open the cursor that controls the extraction order...
  for extract_order_rec in v_extract_order_cur loop
    --Open the cursor to access the constraints of the
    --current type (PK, UK, etc).
    for constraints_rec in v_constraints_cur(extract_order_rec.a_cons_type) loop
      --Initialize the next pipeline record to be returned.
      v_out_record.ddl_name := constraints_rec.constraint_name;
      v_out_record.ddl_text := null;
      --Get the raw DDL for the current constraint.
      v_raw_sql_c := dbms_metadata.get_ddl(extract_order_rec.a_cons_group,
                                           constraints_rec.constraint_name,
                                           constraints_rec.owner);
      --Scrub the raw DDL.
      --The cleaned DDL will be placed into the record
      --being returned to the pipeline.
      v_out_record.ddl_text := scrub_raw_ddl(constraints_rec.status,
                                             extract_order_rec.a_cons_type,
                                             v_raw_sql_c);
      --Return the constructed command to the pipeline.
      pipe row(v_out_record);
    end loop;
    end loop;
    return;
  END get_constraint_ddl;
END ddl_extract_pkg;
/
```

After the package is installed, executing it is as simple as issuing a DML SELECT statement … almost. There are a couple of minor nuances to remember when accessing a pipelined table function from SQL:

- The SQL TABLE collection expression must be used to inform Oracle that the collection being returned from a pipelined table function should be treated as a table for purposes of query and DML operations.
- The desired columns to be accessed from the collection must be explicitly enumerated. The column list wildcard (*) cannot be used.

```
select x.ddl_name,
       x.ddl_text
  from table(ddl_extract_pkg.get_constraint_ddl) x
 order by 1;

DDL_NAME     DDL_TEXT
------------ ---------------------------------------------------
STATES_CHK1  ALTER TABLE "TRS3_PROC"."STATES" ADD CONSTRAINT "S
             TATES_CHK1" CHECK (state_code = upper(state_code))
              ENABLE NOVALIDATE;

STATES_PK    ALTER TABLE "TRS3_PROC"."STATES" ADD CONSTRAINT "S
             TATES_PK" PRIMARY KEY ("STATE_CODE") ENABLE;

STATES_UK1   ALTER TABLE "TRS3_PROC"."STATES" ADD CONSTRAINT "S
             TATES_UK1" UNIQUE ("STATE_NAME") ENABLE;
```

TIP
Avoid intermediate tables by using pipelined table functions to build complex result sets.

Leave Those Debugging Commands Alone!

During the development of nearly any PL/SQL module, it inevitably becomes littered with a plethora of debugging commands. More important than the debugging commands themselves is the strategic location chosen by the developer to maximize the benefit of the debugging. For complex algorithms, effective debugging often becomes artistic in nature, and only someone intimately familiar with the code knows the precise location of debug statements to yield maximum benefit. Unfortunately, prior to putting the code into production, those strategically placed debugging statements must be either removed or disabled (commented out) because PL/SQL lacks the conditional compilation that is a given in many programming languages. Until 11*g*, that is! In 11*g* and 12*c*, Oracle has given the PL/SQL developer the power to leave those debugging commands in place so that they can be reactivated on the fly should an issue arise.

With conditional compilation, you can enter an if-then control structure that is only evaluated at compile time. The intent is to use the if-then control structure to control which textual statements (from the THEN or ELSE clauses) are included in the program as it compiles. The conditional compilation control structure is identified by the conditional compilation trigger character ($), which is prepended to the keywords (IF, THEN, ELSE, ELSIF, END, and ERROR) of a standard if-then block (the exception being that the block terminator is END in lieu of END IF). The Oracle PL/SQL compiler performs a preliminary scan of the source code looking for the conditional compilation trigger character, $. If any valid trigger characters are found, then the compiler evaluates the compilation condition to determine which code text, if any, should be included in the actual compilation of the code.

Here is the basic structure of the conditional compilation block:

```
$if test_expression $then text_to_include
  [ $elsif test_expression $then text_to_include ]
  [ $else text_to_include ]
$end
```

Conditional compilation uses either a *selection directive* or an *inquiry directive* to determine which text is to be included in the compiling program. The selection directive allows a static expression to be evaluated at compile time.

Here is the simplest form of a conditional compilation command that uses the selection directive:

```
$if static boolean expression $then text to include; $end
```

At compile time, if STATIC_BOOLEAN_EXPRESSION evaluates to TRUE, then the TEXT_TO_INCLUDE is included in the compiling program; otherwise, the TEXT_TO_INCLUDE is skipped. To demonstrate, I'll start with a package specification that will be used exclusively to store conditional compilation constants for debugging purposes:

```
CREATE OR REPLACE PACKAGE debug_pkg IS
  debug constant boolean := true;
END debug_pkg;
/
```

Next, I create the package specification for some fictional component of a business application:

```
CREATE OR REPLACE PACKAGE worker_pkg as
  PROCEDURE run_prc;
END worker_pkg;
/
```

I follow that with the package body that includes a conditional compilation command referencing the static constant in the debugging package:

```
CREATE OR REPLACE PACKAGE BODY worker_pkg as
  PROCEDURE run_prc is
  BEGIN

    dbms_output.put_line('Processing started.');
    $if debug_pkg.debug $then dbms_output.put_line('Debugging is on.'); $end
    dbms_output.put_line('Processing completed.');
  END;
END worker_pkg;
/
```

Since the static constant was set to TRUE at the time I compiled this package body, the extra DBMS_OUTPUT command is included in the compiled program. This can be verified by executing the RUN_PRC procedure:

```
set serverout on;
exec worker_pkg.run_prc;

Processing started.
Debugging is on.
Processing completed.
PL/SQL procedure successfully completed
```

Changing the DEBUG_PKG package causes all dependent objects to recompile, and, as that occurs, the current value of the conditional compilation control constant is used to determine if the debugging statements are compiled into the recompiled code:

```
CREATE OR REPLACE PACKAGE debug_pkg IS
  debug constant boolean := false;
END debug_pkg;
/
```

This time around, because the static constant was set to FALSE, the extra DBMS_OUTPUT command is not included in the compiled program as the WORKER_PKG package automatically recompiles. This can be verified by executing the RUN_PRC procedure again:

```
set serverout on;
exec worker_pkg.run_prc;

Processing started.
Processing completed.
PL/SQL procedure successfully completed
```

Let's pause for a moment and perform a traditional activity of querying the data dictionary to retrieve the source of a stored package:

```
select text
  from user_source
 where name = 'WORKER_PKG'
   and type = 'PACKAGE BODY'
 order by line;

TEXT
--------------------------------------------------------------------------------
PACKAGE BODY worker_pkg as
  PROCEDURE run_prc is
  BEGIN

    dbms_output.put_line('Processing started.');
    $if debug_pkg.debug $then dbms_output.put_line('Debugging is on.'); $end
    dbms_output.put_line('Processing completed.');
  END;
END worker_pkg;

8 rows selected
```

What I discovered is that the _SOURCE (such as USER_SOURCE or DBA_SOURCE) dictionary tables can no longer be relied upon to reveal the precise code that is executing within the database. The _SOURCE dictionary tables are, after all, just that … the source code. To ascertain the exact code that has been compiled, taking into account conditional compilation, Oracle now provides the DBMS_PREPROCESSOR package:

```
set serverout on

BEGIN
  dbms_preprocessor.print_post_processed_source('PACKAGE BODY',
                                                 USER,
                                                'WORKER_PKG');
END;
/

PACKAGE BODY worker_pkg as
  PROCEDURE run_prc is
  BEGIN
    dbms_output.put_line('Processing started.');

    dbms_output.put_line('Processing completed.');
  END;
END worker_pkg;

PL/SQL procedure successfully completed
```

Now back to the debugging package. To have a bit more granularity over which procedures are debugged, I simply need to introduce some procedure-specific control constants:

```
CREATE OR REPLACE PACKAGE debug_pkg IS
  debug_run_prc constant boolean := true;
  debug_xxx_prc constant boolean := false;
  debug_yyy_prc constant boolean := false;
  debug_zzz_prc constant boolean := false;
END debug_pkg;
/
```

And then I update the WORKER_PKG package to utilize the new constants:

```
CREATE OR REPLACE PACKAGE BODY worker_pkg as
  PROCEDURE run_prc is
  BEGIN
    dbms_output.put_line('Processing started.');
    $if debug_pkg.debug_run_prc $then
      dbms_output.put_line('Debugging is on.');

    $end
    dbms_output.put_line('Processing completed.');
  END;
END worker_pkg;
/
```

Let's make sure that everything is still working as expected:

```
set serverout on;
exec worker_pkg.run_prc;

Processing started.
Debugging is on.
Processing completed.
PL/SQL procedure successfully completed
```

Keep in mind that a physical dependency exists between the package containing the static constants and the packages referencing them for conditional compilation. Thus, if you alter the DEBUG_PKG package to change the setting for a single constant, it is still going to cause a cascading recompilation of all procedures/functions that are dependent upon that package—regardless of whether or not the changed constant is referenced in the dependent package. In an application with a large population of stored code, this may be undesirable behavior. In such scenarios, you can disperse the static constants across more packages, or as of Oracle Database 10*g* Release 2, you can switch to another method of controlling conditional compilation: *inquiry directives*.

First, I start by cleaning up a bit:

```
drop package debug_pkg;

Package dropped
```

The conditional compilation inquiry directive allows the test conditions to be tied to the compilation environment via the following predefined directive names:

- Any of the Oracle PL/SQL compilation initialization parameters, such as PLSQL_CCFLAGS, PLSQL_CODE_TYPE, or PLSQL_WARNINGS
- The module line number from PLSQL_LINE
- The current source unit name from PLSQL_UNIT (note that this directive name returns NULL for anonymous blocks)
- A custom name-value pair introduced via PLSQL_CCFLAGS

For this example, I will construct a custom name-value pair via the PLSQL_CCFLAGS initialization parameter:

```
alter session set PLSQL_CCFLAGS = 'MyDebugMode:TRUE';
```

Next I modify the test procedure to switch to an inquiry directive:

```
CREATE OR REPLACE PACKAGE BODY worker_pkg as
  PROCEDURE run_prc is

  BEGIN
    dbms_output.put_line('Processing started.');
    $if $$MyDebugMode $then
      dbms_output.put_line('Debugging is on.');
    $end
    dbms_output.put_line('Processing completed.');
  END;
END worker_pkg;
/
```

And a quick test reveals that everything is working per expectations:

```
set serverout on;
exec worker_pkg.run_prc;

Processing started.
Debugging is on.
Processing completed.

PL/SQL procedure successfully completed.
```

Unlike when I was using selection directives tied to a static constant, altering the value of my custom inquiry directive does not cause automatic recompilation of the package:

```
alter session set PLSQL_CCFLAGS = 'MyDebugMode:FALSE';

Session altered.

set serverout on;
exec worker_pkg.run_prc;

Processing started.
Debugging is on.
Processing completed.
PL/SQL procedure successfully completed.
```

Until another stimulus causes the package to recompile, the change in the custom inquiry directive will not be realized:

```
alter package worker_pkg compile;

Package altered.

set serverout on;
exec worker_pkg.run_prc;

Processing started.
Processing completed.
PL/SQL procedure successfully completed.
```

Optionally, to adjust the behavior of a specific package without altering the session, you can specify the PL/SQL persistent compiler parameters during a forced recompilation of the module:

```
alter package worker_pkg compile PLSQL_CCFLAGS = 'MyDebugMode:TRUE' reuse settings;

Package altered.

set serverout on;
exec worker_pkg.run_prc;

Processing started.
Debugging is on.
Processing completed.
PL/SQL procedure successfully completed.
```

The REUSE SETTINGS clause is used to bypass the normal compiler behavior of dropping and reloading (from the session) all the persistent compiler parameters. Thus, the only compiler parameter that is updated during the forced recompile is the one that was specified as part of the ALTER command.

The error directive provides a quick method for supplying debugging output within your procedures. For example, if you create a procedure that uses some PL/SQL functionality that was introduced in Oracle Database 12*c*, but this procedure also has to run on an Oracle 10.2 database, then you could use the error directive to write an error message identifying the database release as not supported by the procedure. See Example 2-59 in the *Oracle Database PL/SQL Language Reference* for 12*c*.

TIP
Suppress debugging commands in PL/SQL code with conditional compilation.

TIP
Use the static constants defined in DBMS_DB_VERSION as selection directives to control conditional compilation. The DBMS_DB_VERSION package specifies the Oracle version numbers and other information, which is useful for simple conditional compilation selections based on Oracle versions.

The "Look and Feel": Just for the Beginners

Since many developers and DBAs who may read this book are beginners at PL/SQL, I am also including examples of a piece of PL/SQL code, a procedure, a function, a package, and a trigger. I believe it is important that you have a feel for what these objects look like and how they differ, especially if you haven't seen some of them before. This section is intentionally placed as the last section of this chapter as a short reference section only and to give you a feel for how each looks. The goal is not to teach you how to write PL/SQL (please refer to Joe Trezzo's *PL/SQL Tips and Techniques* [McGraw-Hill, 1999] for that).

Both procedures and functions can take parameters and can be called from PL/SQL. However, procedures typically perform an action. The parameters used in procedures can be in(put), out(put), or in(put)/out(put) parameters, whereas functions typically compute a value and the parameters can only be in(put) parameters. As a matter of fact, you can't even specify the "direction" of the parameters. Functions only permit the passing of one return value. Functions are "selectable," so you can create your own user-defined functions that return information (you can have multiple RETURN statements in a function, but each RETURN statement can only pass a single expression).

Functions can also be used when creating indexes so the index key is sorted in a fashion that matches your queries.

PL/SQL Example

Here is an example of a piece of PL/SQL code:

```
declare
   acct_balance       NUMBER(11,2);
   acct               CONSTANT NUMBER(4)  := 3;
   debit_amt          CONSTANT NUMBER(5,2)  := 500.00;
begin
  select  bal into acct_balance
  from    accounts
  where   account_id = acct
  for     update of bal;
    if acct_balance >= debit_amt THEN
    update      accounts
    set   bal = bal - debit_amt
    where       account_id = acct;
    else
    insert into temp values
         (acct, acct_balance, 'Insufficient funds');
             -- insert account, current balance, and message
    end if;
  commit;
end;
/
```

Create a Procedure Example

Here is an example of how to create a procedure. I have listed it here in case you have never witnessed one before:

```
create or replace procedure
    get_cust (in_cust_no in char, out_cust_name out char,
    out_cust_addr1 out char, out_cust_addr2 out char,
    out_cust_city out char, out_cust_st out char,
    out_cust_zip out char, out_cust_poc out char) IS
begin
  select  name, addr1, addr2, city, st, zip, poc
  into    out_cust_name, out_cust_addr1, out_cust_addr2,
          out_cust_city, out_cust_st, out_cust_zip,
          out_cust_poc
  from    customer cust, address addr

  where   cust.cust_no = addr.cust_no
  and     addr.primary_flag  = 'Y'
  and     cust.cust_no = in_cust_no;
end       get_cust;
/
```

Execute the Procedure from PL/SQL Example

Here is an example of how to execute a PL/SQL procedure from within a block of PL/SQL code. As before, I have listed it here in case you have never witnessed one before:

```
get_cust (12345, name, addr1, addr2, city, st, zip, poc);
```

Create a Function Example

Here is an example of how to create a function. Once again, I have listed it here in case you have never witnessed one before:

```
create or replace function  get_cust_name (in_cust_no number)
return char
IS
  out_cust_name cust.cust_last_name%type;
begin
  select   cust_last_name
  into     out_cust_name
  from     cust
  where    customer_id = in_cust_no;
  return   out_cust_name;
end get_cust_name;
```

Execute the GET_CUST_NAME Function from SQL Example

Here is an example of how to execute the GET_CUST_NAME function:

```
select     get_cust_name(12345)
from       dual;
```

Create a Package Example

Here is an example of how to create a package:

```
create or replace package emp_actions IS  -- package specification
   procedure hire_employee
         (empno NUMBER, ename CHAR, ...);
   procedure retired employee (emp id NUMBER);
end emp_actions;
/
create or replace package body emp_actions IS  -- package body
   procedure hire employee
         (empno NUMBER, ename CHAR, ...)

is
   begin
      insert into emp VALUES (empno, ename, ...);
   end hire_employee;
   procedure fire_employee (emp_id NUMBER) IS
   begin
      delete from emp WHERE empno = emp_id;
   end fire_employee;
end emp_actions;
/
```

Database Trigger Example Using PL/SQL

Here is an example of how to create a trigger using PL/SQL:

```
create trigger audit_sal
   after update of sal ON emp
   for each row
begin
   insert into emp_audit VALUES( ...)
end;
```

Tips Review

- In 12*c*, we also can combine invoker rights (AUTHID CURRENT_USER) with the Function Result Cache (RESULT_CACHE).
- It is now possible to create a PL/SQL subprogram inline SELECT statement utilizing the WITH clause declaration in 12*c*.
- Named notation continues to be the preferred method for passing parameters to subroutines. You can now extend this best practice approach to SQL statements to yield consistency across the entire code base.

- In 12*c*, you can define an identity clause against a table column defined using a numeric type, instead of code that creates and uses a sequence object (Create Sequence privilege is required to create Identity Columns—since they are in fact sequential values or sequences).
- The new CONTINUE statement creates loop constructs that are more streamlined, but there are no performance gains to be realized at this time.
- Experienced and novice developers alike should leverage the PL/SQL compile-time warnings to catch obscured programming problems before code deployment.
- The introduction of compound triggers in conjunction with execution order control are welcome enhancements.
- Use the Oracle-supplied package DBMS_APPLICATION_INFO to log point-in-time information to the V$SESSION view to enable monitoring of long-running processes.
- Log (INSERT) execution timing information into a database table for long-running PL/SQL program units to integrate a proactive performance-monitoring mechanism into your system. The database table can be reviewed at any point in time to determine if performance has decreased over time.
- System load in terms of number of active sessions can have a large impact on the performance of program execution; therefore, modifying the database table logging method to include a column for the number of active sessions can be helpful. You can fill this column by adding one additional query to the program unit being executed to retrieve the count from the V$SESSION view.
- When a PL/SQL program unit involves extensive looping or recursion, concentrate on reducing the execution time per iteration. The benefits add up fast, and it is easy to do the math to determine the overall improvement potential. Also review the looping or recursion for restructuring to reduce the number of iterations, while keeping the functionality. With the extreme flexibility of PL/SQL and SQL, a variety of ways typically exist to accomplish the same result. If a PL/SQL program unit is not performing optimally, sometimes you have to rewrite the logic another way.
- Use the ROWID variable to enhance performance when SELECTing a record in a PL/SQL program unit and then manipulating the same record in the same PL/SQL program unit.
- Ensure that all conditional comparisons compare the same data types. Additionally, ensure that the data types within the numeric family are comparing the same subtype.
- Ensure the string of PL/SQL IF conditions appear in the order of most frequently satisfied, not a numerical or alphanumerical sequential order.
- Use the PLS_INTEGER type when processing integers to improve performance. If a number with precision is assigned to a PLS_INTEGER variable, the value will be rounded to a whole number as if the ROUND function had been performed on the number.
- Attempt to limit the calls to SYSDATE in iterative or recursive loops because overhead is associated with this variable. Set a PL/SQL date variable to SYSDATE in the declaration and reference the PL/SQL variable to eliminate the overhead.

- Use the DBMS_SHARED_POOL.KEEP procedure to pin PL/SQL objects into the shared pool.
- Use the DBMS_SHARED_POOL.KEEP procedure in PL/SQL to pin all packages when the database is started (if memory/shared pool permits) and to avoid errors involving loading packages in the future.
- Query the V$DB_OBJECT_CACHE view to find objects that are not pinned and are also large enough to potentially cause problems.
- Query X$KSMSP to find all large pieces of PL/SQL that have appeared in the shared pool. These are candidates for pinning when the database has started.
- You can recompile an entire schema (either all or just the invalid objects) with DBMS_UTILITY.COMPILE_SCHEMA.
- Query DBA_TRIGGERS (for system-wide objects) or USER_TRIGGERS (for your schema only) to find the state of triggers and avoid errors with disabled triggers. Disabled triggers can have fatal results for an application: they don't fail; they just don't execute.
- Load reference tables into PL/SQL associative arrays for faster lookups. This takes advantage of the performance of array indexes in PL/SQL.
- Finding the source code behind PL/SQL package procedures involves querying the USER_SOURCE and DBA_SOURCE views. Finding the source code behind a trigger involves querying the USER_TRIGGERS and DBA_TRIGGERS views. You can find dependencies among PL/SQL objects by querying the USER_DEPENDENCIES and DBA_DEPENDENCIES views.
- A DATE data type always stores a complete temporal value, down to the second. It is impossible to insert a date value only into either a PL/SQL variable or database column that is defined as a DATE.
- The Oracle DATE data type has both date and time included in it. Avoid suppressing indexes when trying to match dates. The key is never to modify the column side in the WHERE clause. Do all modifications on the noncolumn side. As you saw in Chapter 2, you can add a function-based index to overcome this issue.
- Where to store the PL/SQL code is an ongoing debate. Generally, the server side is the preferred place to store the code, and it may become the only choice as thin clients become more prevalent.
- If you are using automatic undo management and flashback together, you may need to increase the size of a fixed UNDO tablespace (and the UNDO retention period, or an autoextend UNDO tablespace with a MAXSIZE limit). Snapshot Too Old errors during a flashback indicate that you need to ensure sufficient UNDO data is retained to support these flashback operations.
- Maintaining sufficient space for rollback or undo segments can be critical in transactional processing. Limiting the amount of data manipulated between COMMITs is key to avoiding Snapshot Too Old errors.
- If you integrate the DBMS_SQL package into a PL/SQL program unit to create SQL statements

dynamically for a production application, remember that optimizing the generated SQL statements will be difficult. Instead, use bind variables with dynamic SQL to minimize Shared Pool resource contention and maximize performance.

- Use bind variables with dynamic SQL to minimize resource contention and maximize performance.
- Avoid intermediate tables by using pipelined table functions to build complex result sets.
- Suppress debugging commands in PL/SQL code with conditional compilation.
- Use the static constants defined in DBMS_DB_VERSION as selection directives to control conditional compilation. The DBMS_DB_VERSION package specifies the Oracle version numbers and other information, which is useful for simple conditional compilation selections based on Oracle versions.

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CHAPTER
11

Oracle Cloud, Exadata, Tuning RAC, and Using Parallel Features

With Oracle's acquisition of Sun, a paradigm shift occurred in the database market, the hardware world, and the IT industry as a whole. While this current shift is well under way, signs are showing that a larger shift is on its way based on this acquisition. On September 18, 2016, Larry Ellison introduced Oracle Database 12*c*R2, available on the cloud first via the Oracle Database Exadata Express Cloud Service, which leverages the Sun acquisition and was rolled out at an outrageously low starting price of only $175/month—including *all* database options. This is the first step to consolidating Oracle on Oracle Cloud, filled with Sun servers. Not unknown to Wall Street, this acquisition and corresponding shift is called *industry consolidation*.

In the world of hardware, Oracle has widened its influence (their FS1 Flash Server is almost a petabyte of flash storage) and will challenge the Fortune 50 companies as one of the top performers as they continue to advance their own hardware to advance Oracle Cloud (with security at the silicon level). With Java, Oracle's influence could quickly move into the consumer world, if they choose. Oracle's recent partnership with GE has taken them into the Internet of Things (IOT) world and closer to the consumer world. Exadata was the beginning of Oracle's move into the hardware world. Oracle has quickly followed that up with many versions of Exadata, Exalogic machines, Oracle Database Appliance, Exadata Storage Expansion Rack, Flash Server, ZFS Storage Appliance, Zero Data Loss Recovery Appliance, and SuperCluster, to name just a few. Their slogan "software and hardware engineered together" is certainly an accurate description of how well Exadata is performing, but it also reveals a barrier to entry for other companies that might try to compete. Exadata is hardware that combines the power of the database and features at the hardware level that other hardware providers will not be able to replicate easily (or at all). I've now worked on a quarter, half, and full rack of Exadata machines and every one of them performed with *client-gasping* performance. Every client I've talked to who is using Exadata is already considering adding more machines to other areas of their business. Exadata has quickly become the fastest-selling product Oracle has ever had (over 10,000 sold)!

Oracle has touched upon hardware in the past with the likes of ncube and the "ahead of its time" Network Computer (NC), perhaps the precursor to Google's Chromebook. With the acquisition of Sun, Oracle dove into the water head first, introducing the Exadata box (prior to the acquisition of Sun, Oracle partnered with HP on Exadata V1). With the second and third versions of Exadata, the Exadata Storage Expansion Rack, Exalogic, and the latest Oracle Unbreakable Linux Kernel, Oracle became a serious contender, if not the leader, in taking the entire stack—software to hardware. In September 2011, Oracle introduced the Oracle Database Appliance for small businesses and for departmental servers, and their new SPARC SuperCluster T4-4, which includes 16 T4 processors with 8 cores each (each core has 8 threads). This Solaris-based machine has 1200 threads total on the entire SuperCluster when you add all cores on the machine (more on the latest version of SuperCluster later in the chapter).

In early October 2011 at OpenWorld, Oracle introduced the Oracle Exalytics Business Intelligence Machine, which included the TimesTen In-Memory Database, Oracle Business Intelligence Enterprise Edition (OBIEE), and Essbase Analytics in 1T of memory—can you say instant BI! Oracle also introduced the Oracle Public Cloud (OPC) in 2011, now rebranded Oracle Cloud. Other hardware of note includes the Big Data Appliance for unstructured data using Hadoop and NoSQL, Pillar Storage Systems for SAN data, ZFS for NAS, and StorageTek server expandable to ten units that can store up to 1E of data with a 2:1 compression! In 2015, Oracle announced the previously mentioned FS1 Flash Array with nearly 1P of flash (912T) and started acquisitions targeting cloud companies. In 2016, Oracle announced the X6-2 Exadata (as well as the X6-8) with an all-flash option and the SuperCluster M7 (with security in the silicon) and announced that the 12*c*R2 database would first be offered on the Oracle Cloud. I'll cover each of these new offerings briefly so you can see where they might fit in the future. Please see Oracle.com for the latest hardware offerings; this chapter serves as a basis for what will surely change quickly over time.

In this chapter, I'll also cover the Big Data Appliance, Oracle Cloud, Real Application Clusters (RAC), and parallel features in Oracle. Oracle first introduced their parallel server in Oracle 6.1 (beta) and Oracle 6.2 (limited customer release production) but only widely used it on VAX/VMS. Not until Oracle9*i*, when they rewrote the code for the RAC product almost completely (95 percent I am told), did Oracle truly have a clustering product. In Oracle 10*g*, RAC not only matured but had become the cornerstone for grid computing (entire grids of servers using the Oracle RAC or clustering architecture). In 12*c*, RAC has become Oracle's competitive advantage (as its clustered version has on Oracle's MySQL Enterprise Edition database). RAC is also the centerpiece of Exadata, Exalogic, and SuperCluster hardware. In fact, Exadata became a quick way to have an eight-node RAC cluster almost instantly (Exadata X6-2; more on this shortly). In addition to using many servers to help increase availability and improve performance, Oracle has also improved the parallel query technology that was first introduced with Oracle release 7.1. In Oracle 12*c*, most operations can be parallelized and even tuned by the Adaptive Optimizer, including queries (parallel SQL execution), DML, DDL operations, intra-partition parallelism, parallelism for data replication and recovery, and data loading; multiple parallel query server processes can even execute against the same partition.

The tips covered in this chapter include the following:

- The march to the cloud and the Oracle Cloud (understanding what fits your needs)
- Exadata terminology and basics about the latest Exadata hardware platform, X6
- Basics about the Exadata Storage Expansion Rack
- Leveraging Smart Scans
- How fast is the Flash Cache
- Using storage indexes

- Using Hybrid Columnar Compression (HCC)
- Using I/O Resource Management (IORM)
- Leveraging Exadata security, utilities, and best practices
- Basics about the Oracle Database Appliance
- Basics about the SuperCluster using the SPARC chip
- Overview of the Big Data Appliance, ZFS, and StorageTek
- Real Application Clusters (RAC) overview and architecture
- Tuning the RAC interconnect and finding RAC wait events
- Basic concepts of parallel operations
- Parallel DDL and DML statements and operations
- Managing parallel server resources and parallel statement queuing
- Parallelism and partitions
- Creating table and index examples using parallel operations
- Parallel DML statements and examples
- Monitoring parallel operations via the V$ views
- Using EXPLAIN PLAN and AUTOTRACE on parallel operations
- Tuning parallel execution and initialization parameters
- Parallel loading
- Performance comparisons and monitoring parallel operations
- Optimizing parallel operations

The March to the Cloud (Past and Present)

I remember a CEO once telling me to watch for things the third time they come around as they often stick by then. The first push for outsourcing and hosting started around 30 years ago (mid-1980s to early 1990s). Some companies (around 5 to 20 percent, depending on industry and location) outsourced their IT operations to a third-party company. Some outsourced IT operations to local companies with off-shore workers to help reduce the price. This push lasted 5 to 10 years and then subsided after the market improved for most companies and horror stories circulated from those who outsourced. I recall in the late 1980s helping a company build a "screen scraper" to get their data back from a hosting company that was charging them exorbitant fees for a full download of their own data. Back then, people didn't always buy the software; instead, they used it remotely and their data stayed remote. The cloud was very prevalent in the 1980s—it just wasn't called "the cloud."

Then around 18 years ago (late '90s), the push for hosting and outsourcing came again. This time it was Wall Street pushing the latest dotcom hosting companies. The difference the second time around was that you didn't have to outsource IT (if you didn't want to), but instead could locate servers in a more economical way (to some warehouse that had underground diesel tanks that would ensure the power could never go off). Some companies (around 10 to 30 percent, depending on industry and location) hosted their IT operations to a third-party company (often high-flying dotcom startups). The hosting company would provide a "cage" where your secure servers would reside (you could even go visit them). Some even hosted cages to local companies with off-shore workers, to help reduce the price even further. This push also lasted 5 to 10 years and subsided after the market improved for most companies and horror stories circulated of those crashed-and-burned dotcom startups. The biggest problem this time was being able to access your own systems so that you could get development or administration work completed in a reasonable amount of time (and deciding what to do once the dotcom crash started). It was a major event to go visit your servers in one of these highly secure warehouses. People would point through the cages at all the blinking lights.

Now there is a new push to the cloud (again led by Wall Street, but prompted by Amazon profits in the cloud). This includes using either "hosting" or "outsourcing" of IT operations. Cloud providers are ensuring that this time is different. The new cloud players (*the four horsemen of the cloud*) are the gold standard of the IT industry: Oracle, Amazon, Microsoft, and Google. They now say that everyone will be on the cloud soon (similar to predictions 5 years ago that everyone would own a tablet instead of a laptop, or even 2 years ago that a watch would replace your smartphone). Are things really different this time, or is this a repeat of the tablet market that will plateau at 20 or 30 percent? One certainty is that the number of mobile applications is growing fast and the smartphone market continues to dwarf all other markets. A sign that things may be different this time was revealed at Oracle OpenWorld in September 2016, which featured Larry Ellison showing Oracle Cloud performance that was staggering when compared to Amazon and pricing on Exadata that was so low it shocked the Oracle world (but, will they keep it that low?).

Let's look at why there is such a big push for the cloud (some of these include "perceived" benefits to customers that move to the cloud):

1. There are better profit margins for cloud companies than they had prior to selling cloud (similar to hosting, outsourcing, and off-shoring). This is actually, by far, the number one reason for the cloud bandwagon; the cloud provider makes a killing, usually with unexpected add-on costs to customers (Wall Street loves this, and they are not in it for the long haul—either rise fast or get out of their way). Amazon has proven that profits from cloud services are huge!
2. Using cloud services lowers (perceived?) costs for IT operations (again, this is similar to hosting, outsourcing, and off-shoring). This is the number two reason why the cloud is big. Profits for the cloud customers go up as IT costs go down (at least initially).
3. It's easier to administer and provide better customer service from IT when shifted to the cloud (debatable, as the past two times were). While it's easier to maintain the cloud (since it's difficult to change things), not much ever changes (which keeps costs down). Updates can happen automatically.
4. You are not tied to a specific company (yeah, right!). Currently, this is the case, but with consolidation, that could change (again, Wall Street loves the cloud because you probably won't be able to get back out of the cloud, or you'll pay dearly to get out, or they'll be out of the cloud company's stock by the time you get out, so they really don't care).

Now let’s look at what is truly different this time around (and will fuel the longevity of the cloud):

1. Cloud services are great for smaller companies that can’t afford a real IT department. They can obtain IT servers and operations to any scale they’ll ever need.
2. Connecting to social media and accessing marketing big data are faster over the cloud, as are leveraging this data and connecting it to mobile applications.
3. On Oracle Cloud, every company can have an encrypted backup that’s secure and offsite. This is a big plus to the many companies that still don’t have this protection.
4. Development can spin up a production-size server for testing for a couple of hours. This is a huge benefit, but still only relatively inexpensive.
5. Spinning up a data warehouse or two for a week is inexpensive.
6. You pay for what you use, scale up easily when you need to, and scale down easily when you need to (better than in the past). Because of the size of cloud companies, this works very well now compared to the first two times around.
7. Testing an extremely large server for a few hours to see if it’s worth buying is relatively inexpensive (compared to the costs of buying it).
8. Testing the new version of a product or a new database version with the current version of an application is easy. You can also test new versions of the database or middleware for new features or capabilities.
9. You can benefit from the economies of scale when consolidating many of your databases (you can do this on-premises, of course, yet many companies don’t).
10. Using Oracle Cloud, it’s easier to share pluggable databases (PDBs) with other companies for partnering.
11. The current generation of developers and DBAs is cloud-ready. They would rather use Google Docs in the cloud than require a machine running Microsoft Word everywhere they go. They don’t want to be tied to a specific computer, and they already do everything in the cloud.
12. Cloud companies will push companies that use their cloud toward success because they mutually benefit. CFOs get the tax benefit of OPEX (cloud) versus CAPEX (on-premises).

In the end, whether the cloud helps or detracts from your competitive advantage really depends on your costs, personnel, operations, and all of the preceding points. If your current IT operations are part of your competitive advantage (as is true for many large companies), you may hurt your company by moving to the cloud, if you’re not careful. But, if your IT operations are overworked, hindering your innovation, or mired in red tape, you may benefit from moving to the cloud. The CEO, CFO, CIO, department head, etc., individually or as a group, needs to make a serious and educated evaluation that discerns between all of the salient factors. The CFO will almost always agree to cloud adoption, as there are many short-term profits to be had that few CFOs will be able to resist. DBAs need to be well educated about the cloud so that they can offer sound advice when upper management starts pushing.

As previously discussed, whether they realize it or not, everyone does *something* in the cloud already (that is, the hybrid cloud model, a mix of cloud/on-premises, is already at 100 percent). Many things are done on the Internet (in the cloud), so predictions that a large number of companies will at least embrace a hybrid cloud have already been true for a decade or two.

The following questions about the cloud remain in many people's minds:

- Will the price stay low when the market consolidates? (Probably not.)
- Will it be easy in the future to move my data back if I want? (Hard to say.)
- Will it increase my competitive advantage to move further into the cloud? (Probably.)

With those questions yet to be answered fully, these are your options:

- Stay private.
- Go all-in on the public cloud (immediate OPEX benefit).
- Use a hybrid of public/private (true of almost everyone already—but, what's the split?).
- Lease a server owned by Oracle but located on your own site (OPEX benefit on-premises; this is known as Cloud at the Customer).

Hopefully, you're convinced from this overview that a portion of applications and IT operations will be hosted on the cloud and that the cloud is here to stay. It's prudent to be prepared for this generational switch to cloud computing and the direction in which some things will progress in the future.

The Oracle Cloud

As mentioned in the chapter introduction, on September 18, 2016, Larry Ellison introduced the Oracle Database Exadata Express Cloud Service running the 12*c*R2 database for only $175/month, including all database options. This includes one PDB of Oracle Enterprise Edition running on Exadata with 20G of database storage and 120G of data transfer (there are increased data use and transfer options for a higher price; see https://cloud.oracle.com for the latest pricing). With Larry's announcement, one of the fastest servers on the planet, running the latest version of the database became the first cloud server that could begin a major Oracle IT march to the cloud. The ability to run or test applications on an Exadata database machine for such a low price will be too good for *any* Oracle development department to pass up. Moving your encrypted backup to the cloud now becomes a 2017 exercise. Oracle also introduced, on the same day, Application Performance Monitoring (APM) for DevOps. APM enables DBAs and developers to pinpoint performance problems at every layer of the application (you'll see screenshots later in this chapter).

Oracle's Database as a Service (DBaaS) offering is Oracle Database Cloud Service. Setting up a Database Cloud Service instance for the first time takes a few hours. Setting one up the second time takes a few minutes. Initially you need to set up the networking and security, which allows access to all products in the cloud, not just Oracle. I believe that Oracle Database Cloud Service will be a huge opportunity for many shops to quickly spin up development servers for DevOps (Development Operations—a new term meaning a mix of development and operations).

Oracle announced 12*c* Release 2 of the database will be released on the cloud first (September 18, 2016). *This is not just a cloud-first event, but an Oracle-first event*. This is similar to when Oracle started releasing less important platform database software (AIX comes to mind) later than

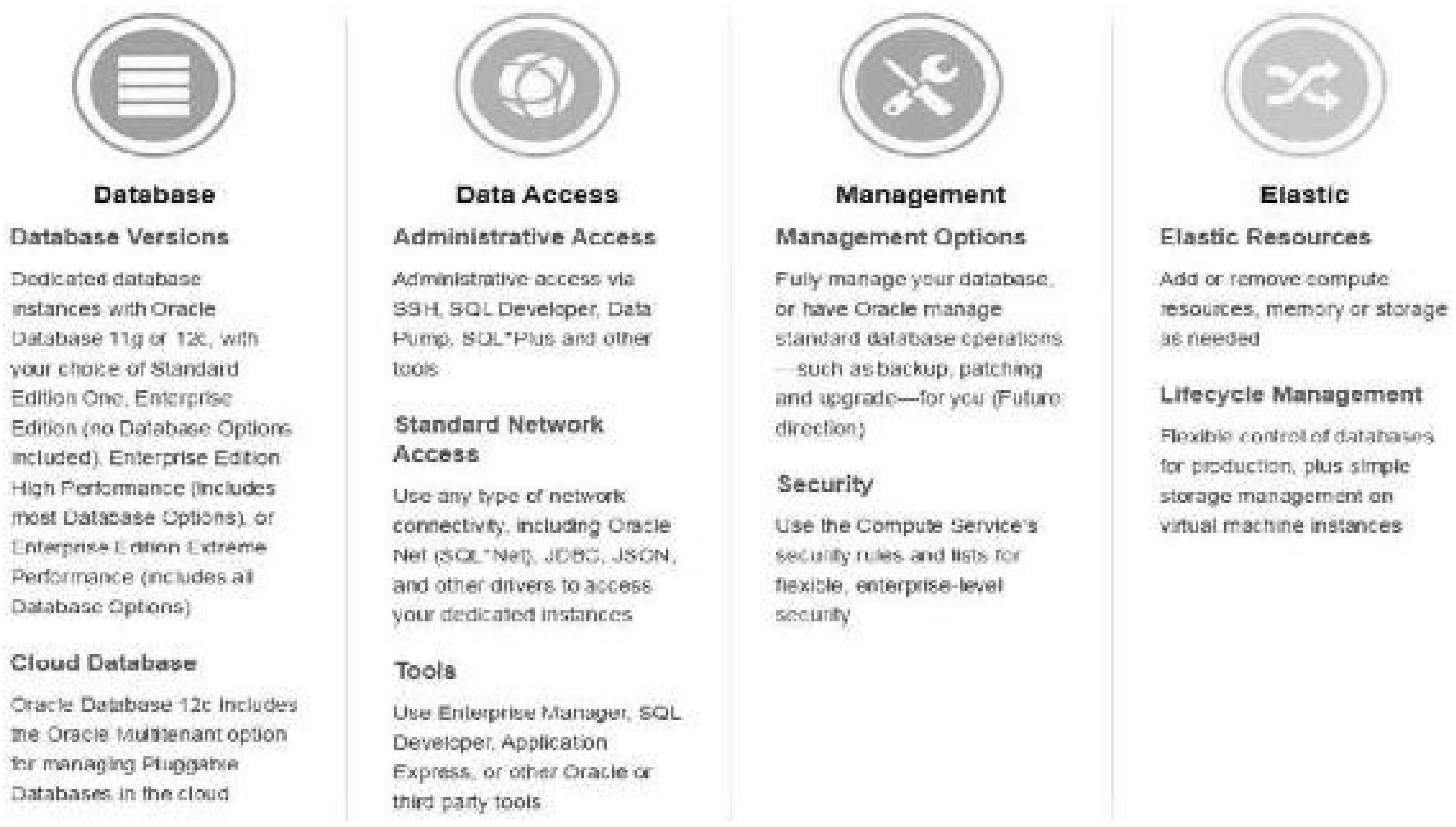
Linux. Another example is Oracle releasing 12*c* on Express Edition (the free version) much later than Standard Edition (SE) or Enterprise Edition (EE). Oracle has a way of creating a bend in the road that you'll probably soon be following to some degree. Also, Oracle has available currently in the cloud a database that you can use anytime (https://livesql.oracle.com) to learn SQL and PL/SQL. When I tried it September 24, 2016, it was already the 12.1.0.2 database. The cloud helps us to learn and test things much faster!

Now let's keep you from becoming a dinosaur and teach you how to create your first Database in the Cloud (also known as a Database Cloud Service instance). To begin to use the Oracle Cloud, you can simple go to either of the following:

https://cloud.oracle.com/tryit (next click Try It in the database section to try out the Oracle Cloud for 30 days—the database is listed under PaaS and IaaS)

https://cloud.oracle.com/database (click Try It to *only* try the database)

The first thing to notice is that there are many video tutorials available. There is also a lot of information about the different roles needed for the cloud. Think of how long it would take you to spin up everything that you see in the Database Cloud Service instance shown in Figure 11-1.


Database

Database Versions

Dedicated database instances with Oracle Database 11g or 12c, with your choice of Standard Edition One, Enterprise Edition (no Database Options included), Enterprise Edition High Performance (includes most Database Options), or Enterprise Edition Extreme Performance (includes all Database Options)

Cloud Database

Oracle Database 12c includes the Oracle Multitenant option for managing Pluggable Databases in the cloud

Data Access

Administrative Access

Administrative access via SSH, SQL Developer, Data Pump, SQL*Plus and other tools

Standard Network Access

Use any type of network connectivity, including Oracle Net (SQL*Net), JDBC, JSON, and other drivers to access your dedicated instances

Tools

Use Enterprise Manager, SQL Developer, Application Express, or other Oracle or third party tools

Management

Management Options

Fully manage your database, or have Oracle manage standard database operations—such as backup, patching and upgrade—for you (Future direction)

Security

Use the Compute Service's security rules and lists for flexible, enterprise-level security

Elastic

Elastic Resources

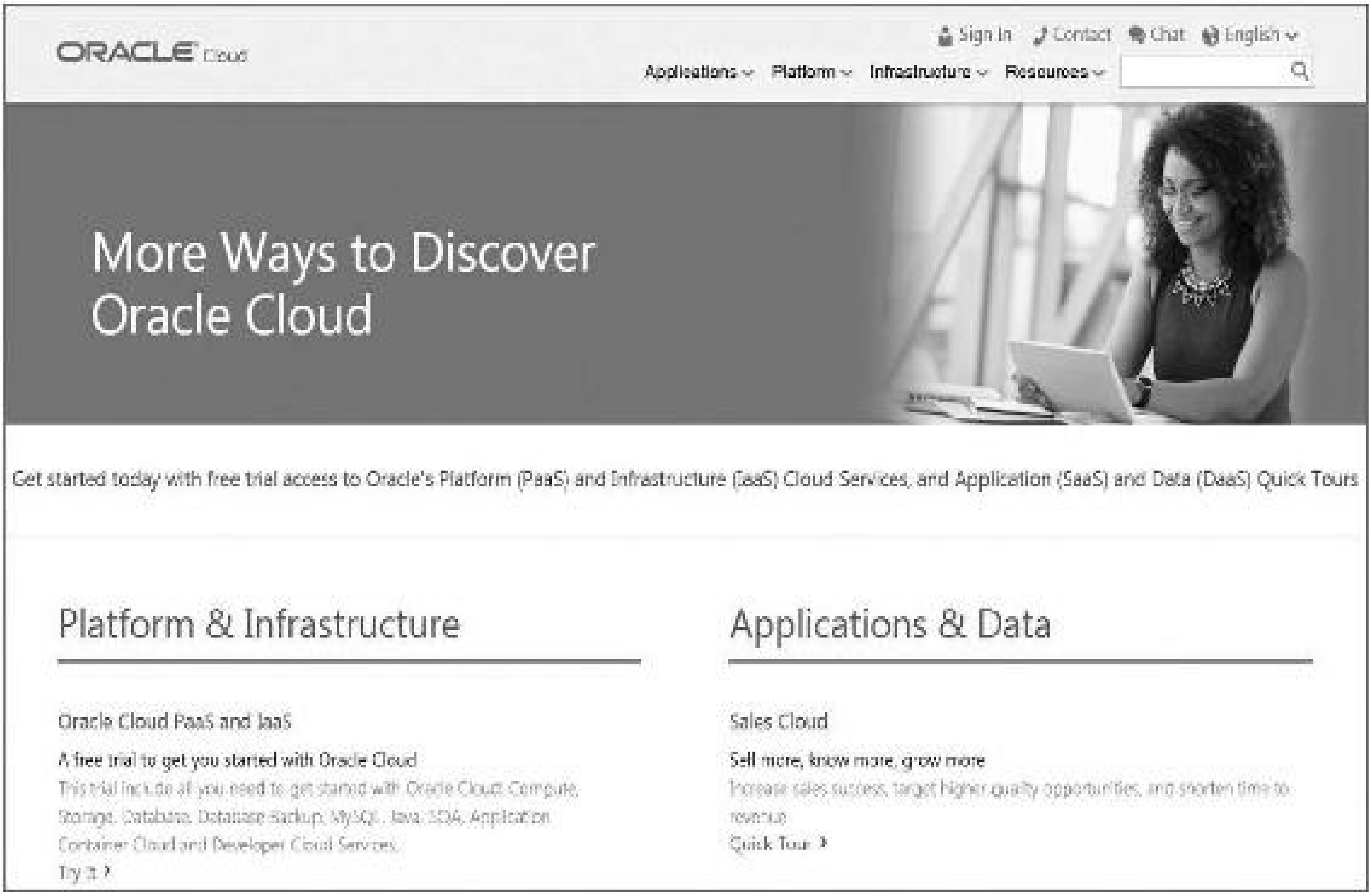
Add or remove compute resources, memory or storage as needed

Lifecycle Management

Flexible control of databases for production, plus simple storage management on virtual machine instances

FIGURE 11-1. *Your Database Cloud Service*

Go to **http://cloud.oracle.com/tryit** to see the introductory page shown in Figure 11-2, where you can click the Try It button as seen in Figure 11-2.



More Ways to Discover Oracle Cloud

Get started today with free trial access to Oracle's Platform (PaaS) and Infrastructure (IaaS) Cloud Services, and Application (SaaS) and Data (DaaS) Quick Tours

Platform & Infrastructure

Oracle Cloud PaaS and IaaS

A free trial to get you started with Oracle Cloud

This trial include all you need to get started with Oracle Cloud: Compute, Storage, Database, Database Backup, MySQL, Java, SOA, Application Container Cloud and Developer Cloud Services.

Try it ›

Applications & Data

Sales Cloud

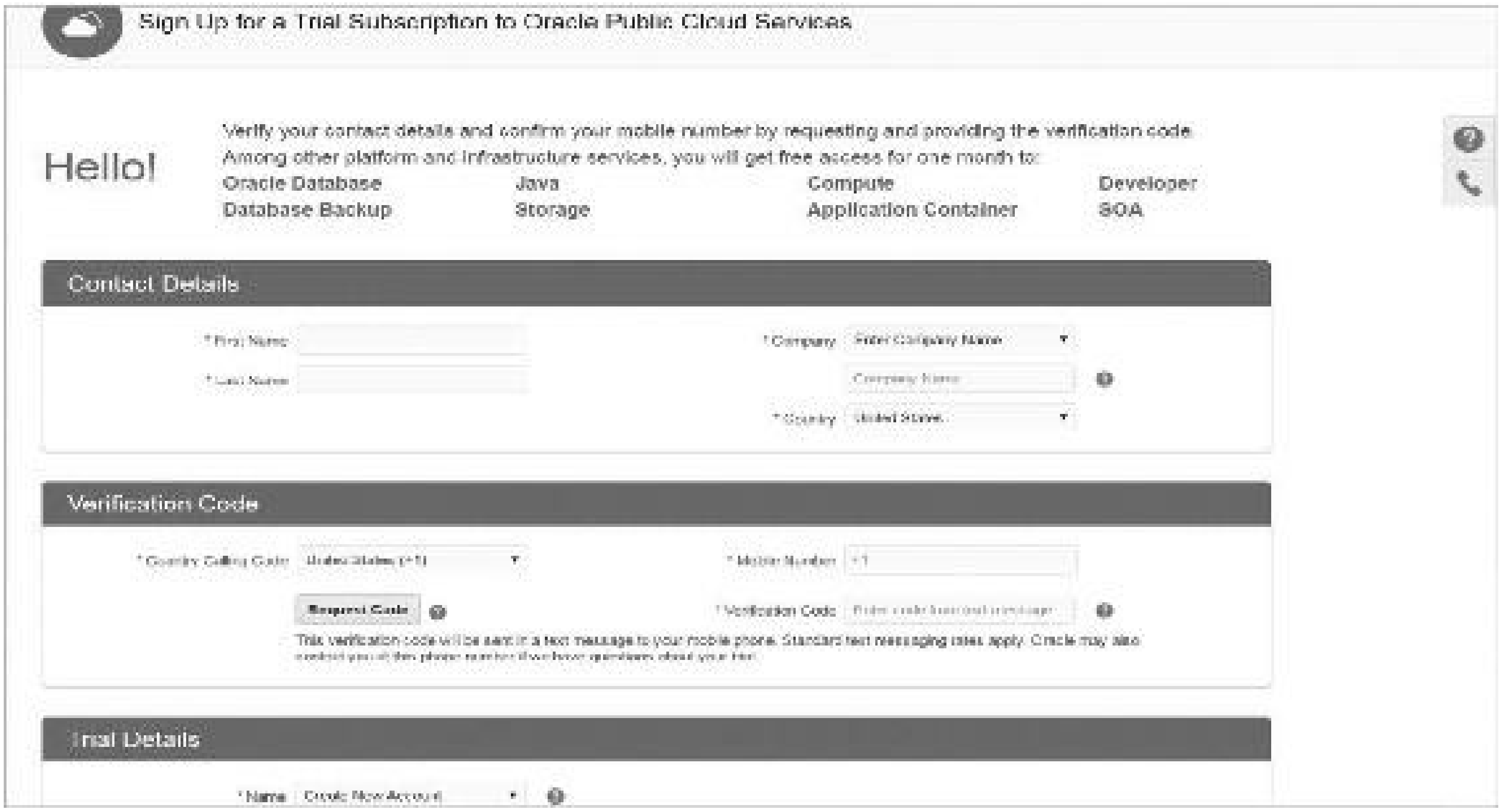
Sell more, know more, grow more

Increase sales success, target higher quality opportunities, and shorten time to revenue

Quick Tour ›

FIGURE 11-2. *Oracle Free 30-Day Trial button*

Next, choose Database (Your Oracle Database in the Cloud) to set up a Database Cloud Service instance. Information about your 30-Day Trial comes up next. It includes an overview of the process as well as the ability to start the Database as a Service Trial. You'll also be asked to log in to your Oracle account. After you sign on with your single sign-on to Oracle, you'll be prompted to fill in the connection information requested, as shown in Figure 11-3. You'll then click on Request Code to receive a verification code that goes to your phone. You then create a new account, agree to the terms and conditions, and then click on the Sign Up button (not shown in Figure 11-3, but at the bottom of this screen). You will receive an email with a link that will take you to the Oracle Cloud.



Sign Up for a Trial Subscription to Oracle Public Cloud Services

Hello!

Verify your contact details and confirm your mobile number by requesting and providing the verification code.
Among other platform and infrastructure services, you will get free access for one month to:

Oracle Database	Java	Compute	Developer
Database Backup	Storage	Application Container	SOA

Contact Details

* First Name
* Last Name
* Company: Enter Company Name
Company Name
* Country: United States

Verification Code

* Country Calling Code: United States (+1)
* Mobile Number: +1
Request Code
* Verification Code: Enter code from text message
This verification code will be sent in a text message to your mobile phone. Standard text messaging rates apply. Oracle may also contact you at this phone number if we have questions about your trial.

Trial Details

* Name: Create New Account

FIGURE 11-3. *Sign up for Oracle Public Cloud Services.*

Congrats! You now have a Cloud Account. Oracle will send an e-mail to you so that you can sign in to the cloud. Once approved, your e-mail connects you to sign in to the Oracle Cloud (Figure 11-4). You can also sign into the cloud by going to the following link in the future:

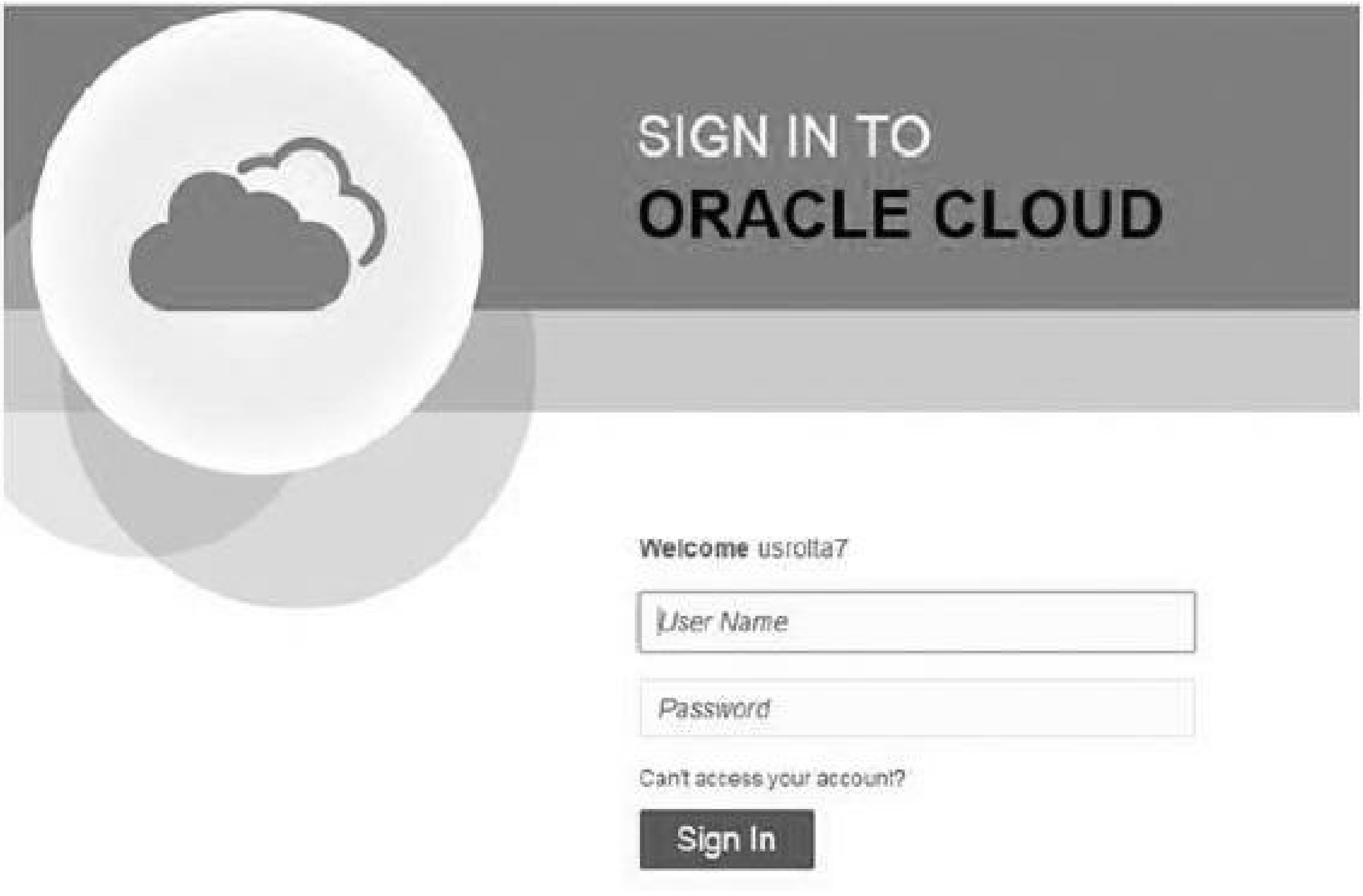


FIGURE 11-4. *Sign in to the Oracle Cloud*.

https://dbaas.oraclecloud.com

You'll get a welcome message and an immediate offer to get some free training if you need it (see Figure 11-5). Included in the Quick Start lesson is everything required to ensure you know how to set up Database as a Service. Those items include setting up SSH and using PuTTY (depending on the cloud service, SSH and PuTTY may not be available), Creating a Service Instance, Finding the Connection Details about your Database Instance, Enabling Secure Access, Connecting via SQL Developer, Performing Operations on your Cloud Database, and Monitoring your Database Service. Once you're ready, click Get Started.

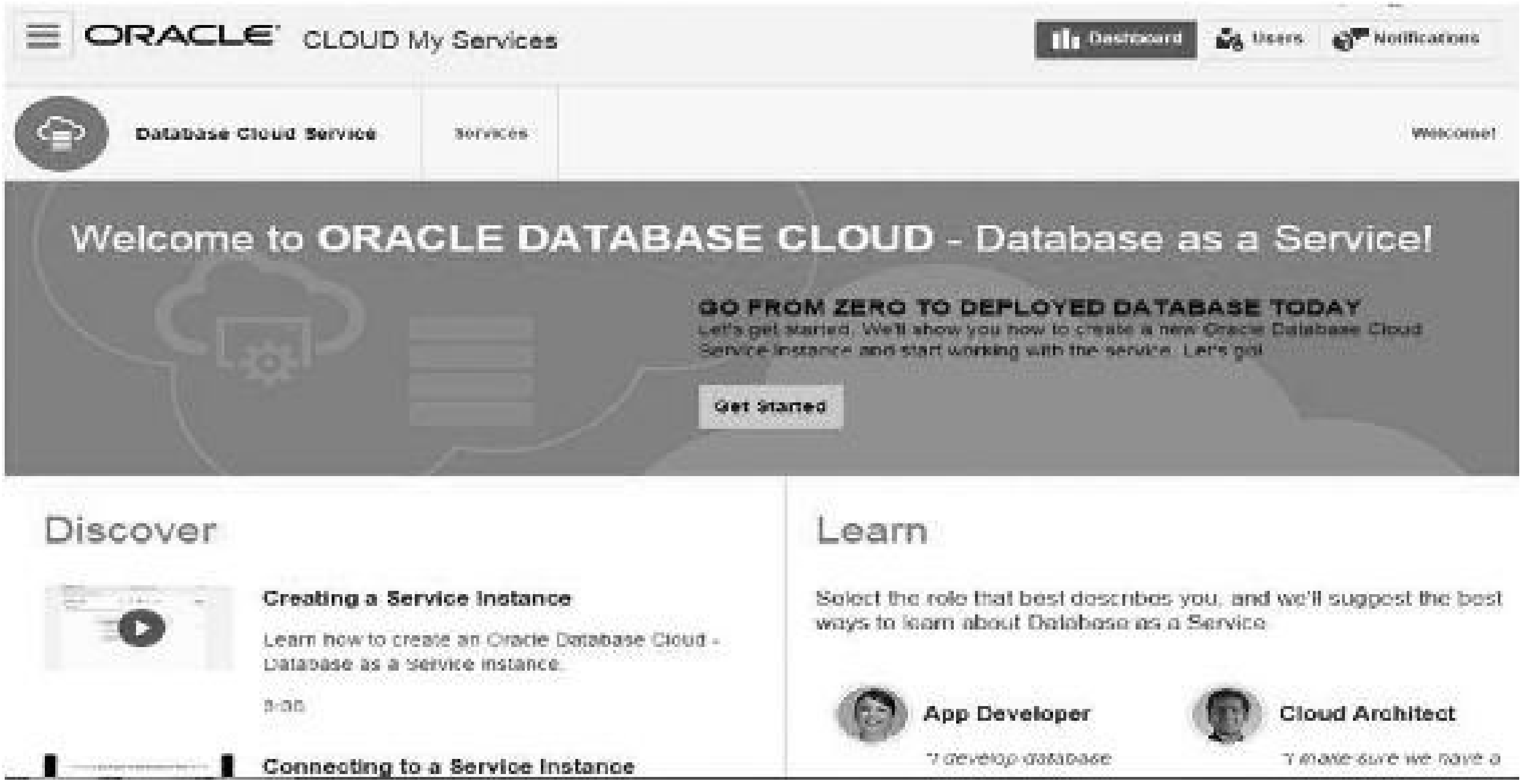

ORACLE CLOUD My Services
Dashboard
Users
Notifications
Database Cloud Service
Services
Welcome!
Welcome to ORACLE DATABASE CLOUD - Database as a Service!
GO FROM ZERO TO DEPLOYED DATABASE TODAY
Let's get started. We'll show you how to create a new Oracle Database Cloud Service instance and start working with the service. Let's go!
Get Started
Discover
Creating a Service Instance
Learn how to create an Oracle Database Cloud - Database as a Service instance.
Connecting to a Service Instance
Learn
Select the role that best describes you, and we'll suggest the best ways to learn about Database as a Service
App Developer
"I develop database
Cloud Architect
"I make sure we have a

FIGURE 11-5. *Click Get Started after going through the training.*

Next, on the page shown in Figure 11-6, click Create Service to launch the Create Database Cloud Service Instance wizard. First, choose whether you want a VM preinstalled or want to set it up using DBCA. Also choose a billing frequency (hourly or monthly).

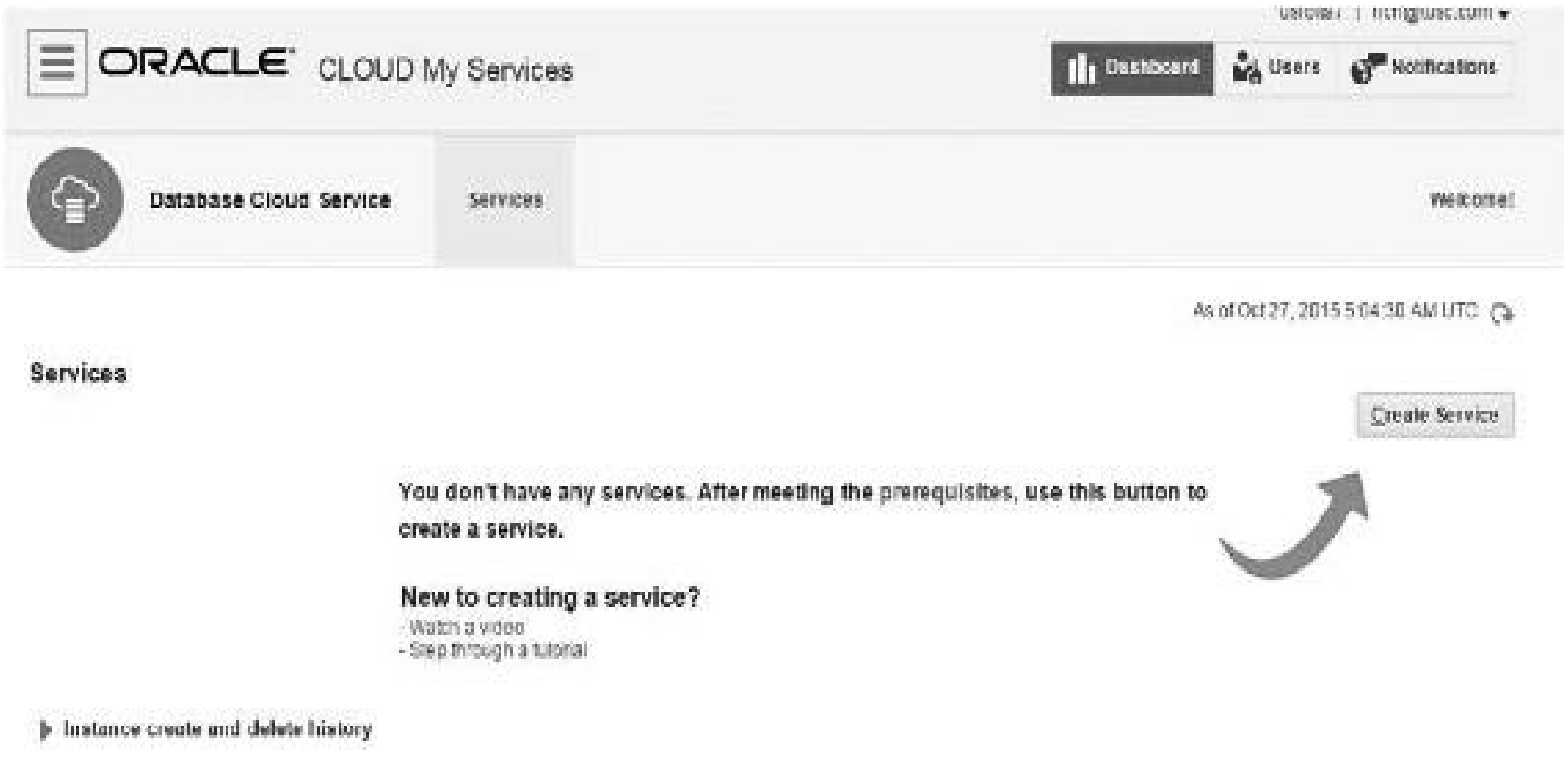
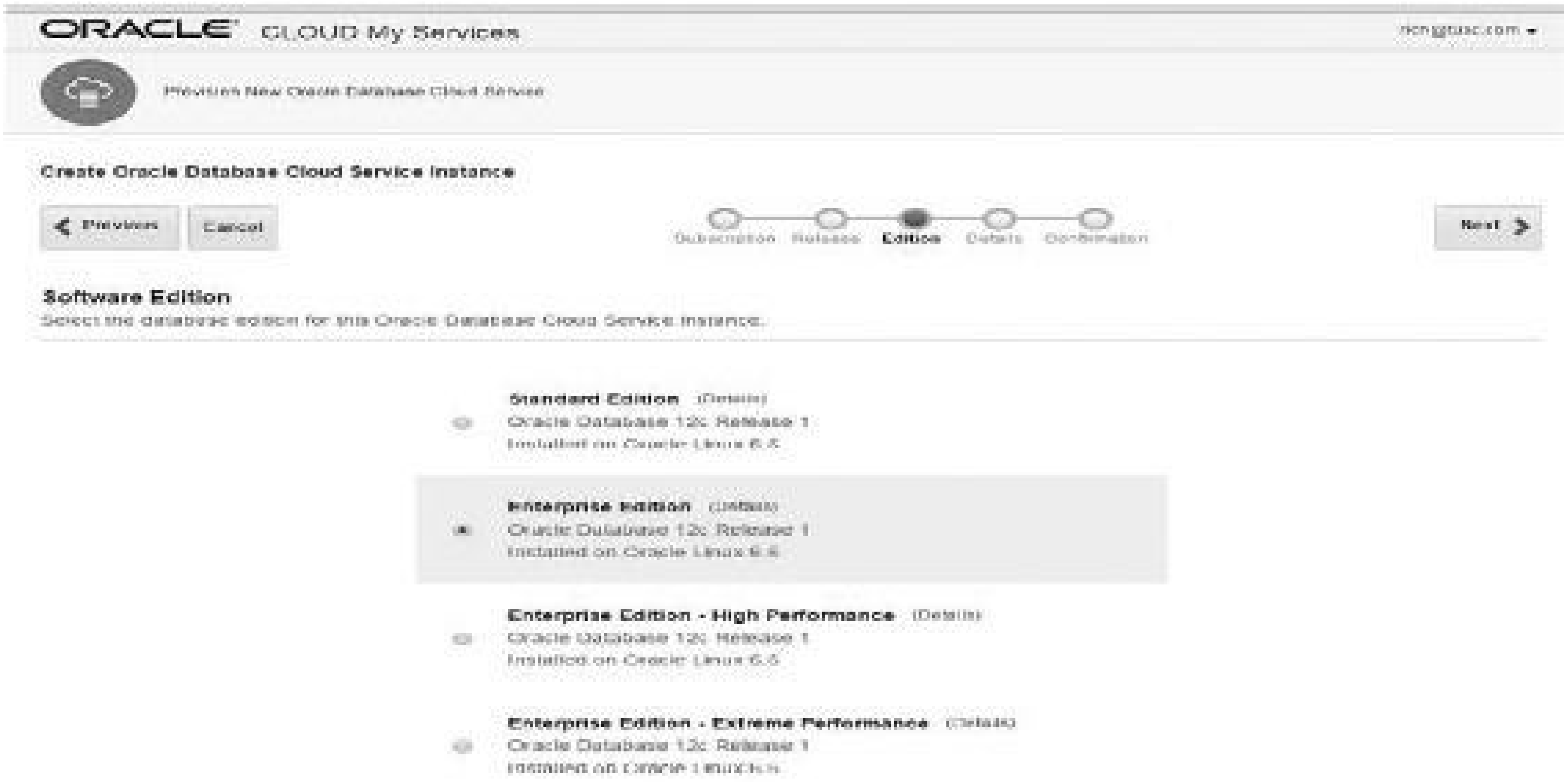

ORACLE CLOUD My Services
Dashboard
Users
Notifications
Database Cloud Service
Services
Welcome!
As of Oct 27, 2015 5:04:38 AM UTC
Services
Create Service
You don't have any services. After meeting the prerequisites, use this button to create a service.
New to creating a service?
- Watch a video
- Step through a tutorial
Instance create and delete history

FIGURE 11-6. *Click Create Service to build your first Database Service instance in the Cloud.*

Next, choose either 11*g* (11.2.0.4) or 12*c* (12.1.0.2) as the database and then choose the edition of the database (Figure 11-7). Click Next.



Create Oracle Database Cloud Service Instance

Software Edition

Select the database edition for this Oracle Database Cloud Service instance.

Standard Edition (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

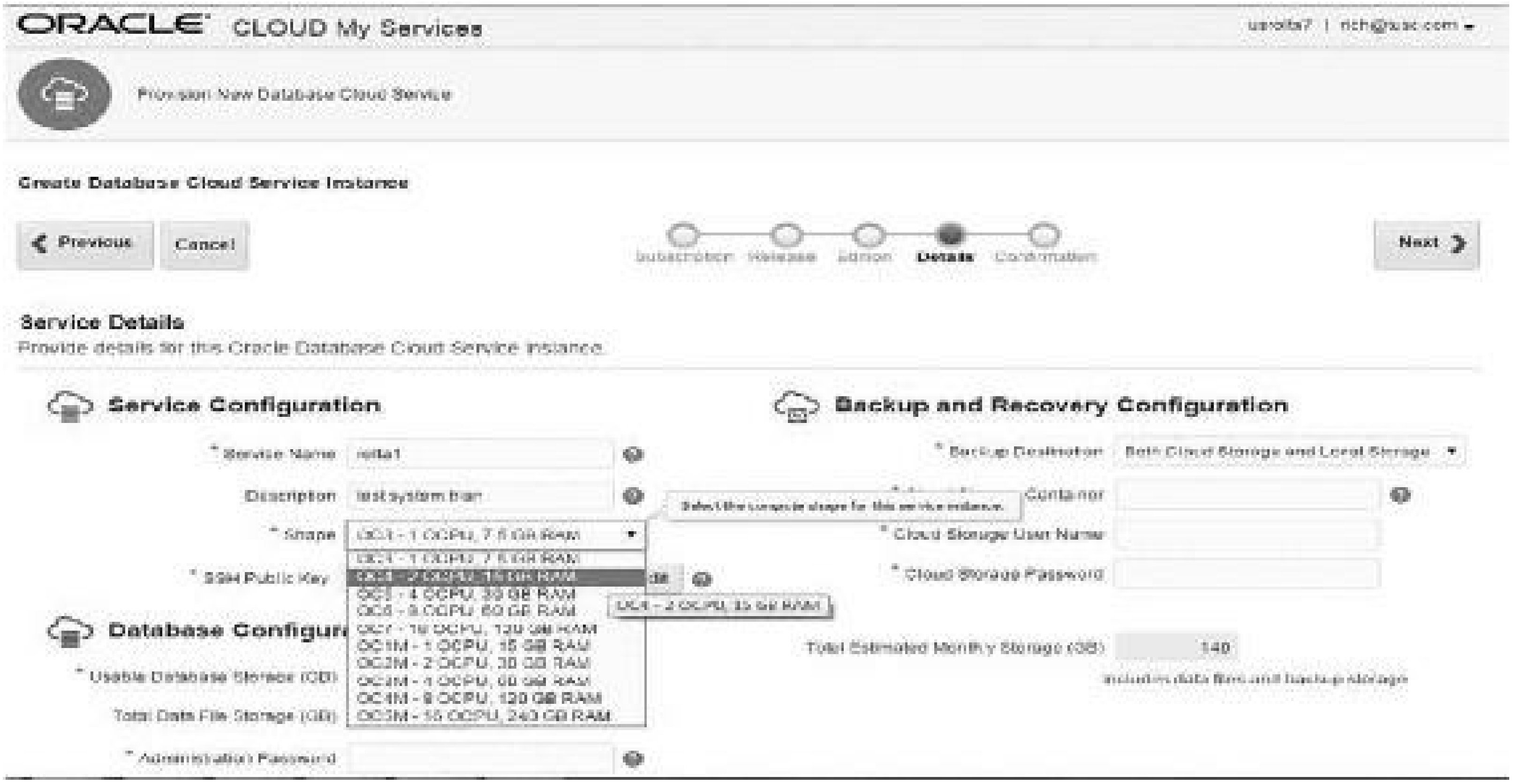
Enterprise Edition (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

Enterprise Edition - High Performance (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

Enterprise Edition - Extreme Performance (Details)
Oracle Database 12c Release 1
Installed on Oracle Linux 6.6

FIGURE 11-7. *Choose the edition of the database release (pricing differs for each).*

Next, on the Service Details page (see Figure 11-8), choose the service name, size/shape of the server (very price specific), passwords, backup and recovery configuration, whether you'll use an encrypted file to build the database from your on-premises database, etc. You can also set up a Standby Database using Data Guard, enable GoldenGate, and install the demo PDB. Click Next.


ORACLE CLOUD My Services

Provision New Database Cloud Service

Create Database Cloud Service Instance

Service Details
Provide details for this Oracle Database Cloud Service instance.

Service Configuration

* Service Name	roita1
Description	test system train
* Shape	OC3 - 1 OCPU, 7.5 GB RAM
* SSH Public Key	

Select the compute shape for this service instance.

OC3 - 1 OCPU, 7.5 GB RAM
OC4 - 2 OCPU, 15 GB RAM
OC5 - 4 OCPU, 30 GB RAM
OC6 - 8 OCPU, 60 GB RAM
OC7 - 16 OCPU, 120 GB RAM
OC1M - 1 OCPU, 15 GB RAM
OC2M - 2 OCPU, 30 GB RAM
OC3M - 4 OCPU, 60 GB RAM
OC4M - 8 OCPU, 120 GB RAM
OC5M - 16 OCPU, 240 GB RAM

OC4 - 2 OCPU, 15 GB RAM

Database Configuration

* Usable Database Storage (GB)	
Total Data File Storage (GB)	
* Administration Password	

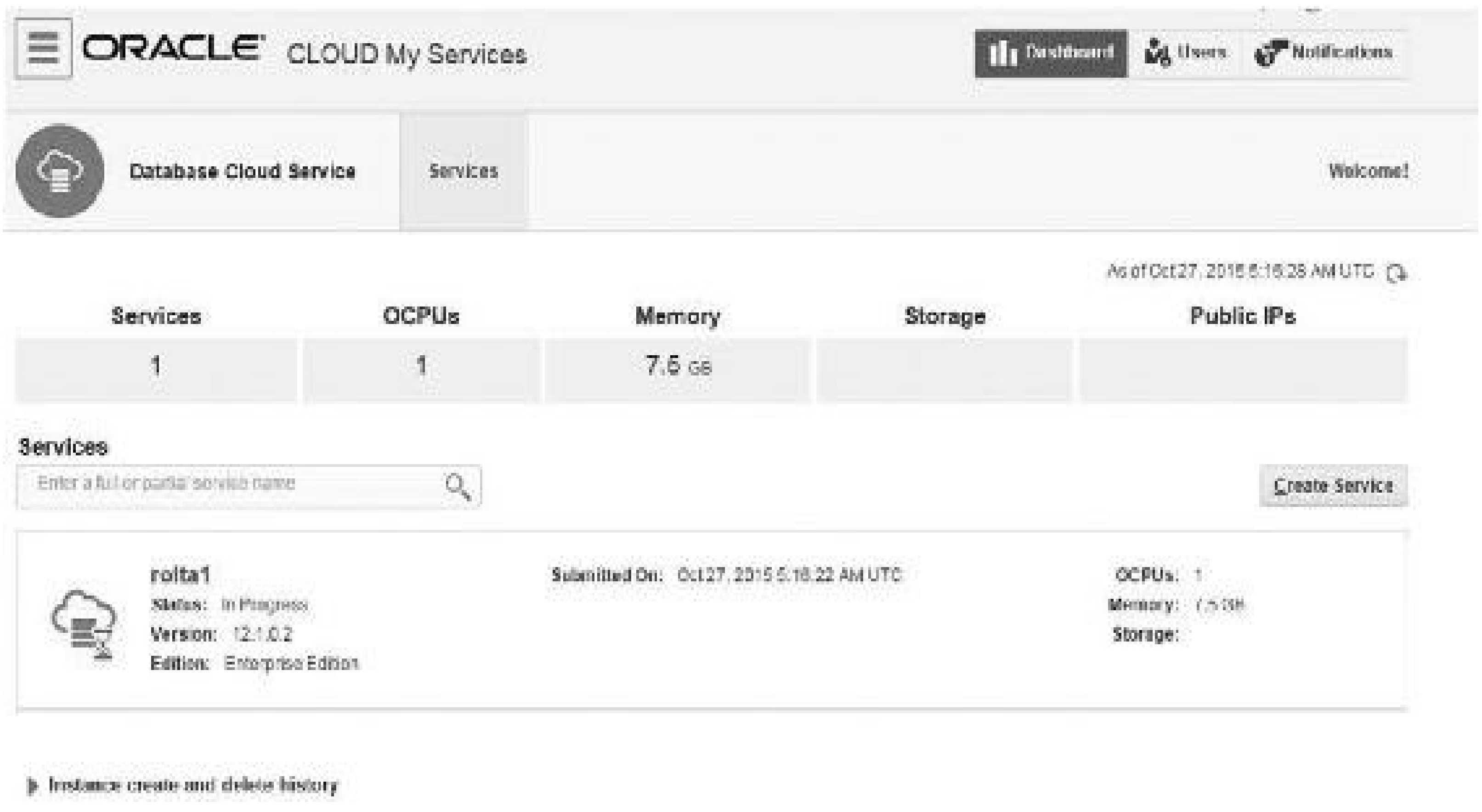
Backup and Recovery Configuration

* Backup Destination	Both Cloud Storage and Local Storage
* Cloud Storage Container	
* Cloud Storage User Name	
* Cloud Storage Password	
Total Estimated Monthly Storage (GB)	140

Includes data files and backup storage

FIGURE 11-8. *Choose the specific size and configuration of the database (pricing varies).*

You'll next be shown that the process of building your Database Cloud Service instance is in progress (Figure 11-9) and then you'll be told that your database is ready to use.


ORACLE CLOUD My Services

Database Cloud Service

Welcome!

As of Oct 27, 2015 5:16:28 AM UTC

Services	OCPUs	Memory	Storage	Public IPs
1	1	7.5 GB		

Services

roita1
Status: In Progress
Version: 12.1.0.2
Edition: Enterprise Edition

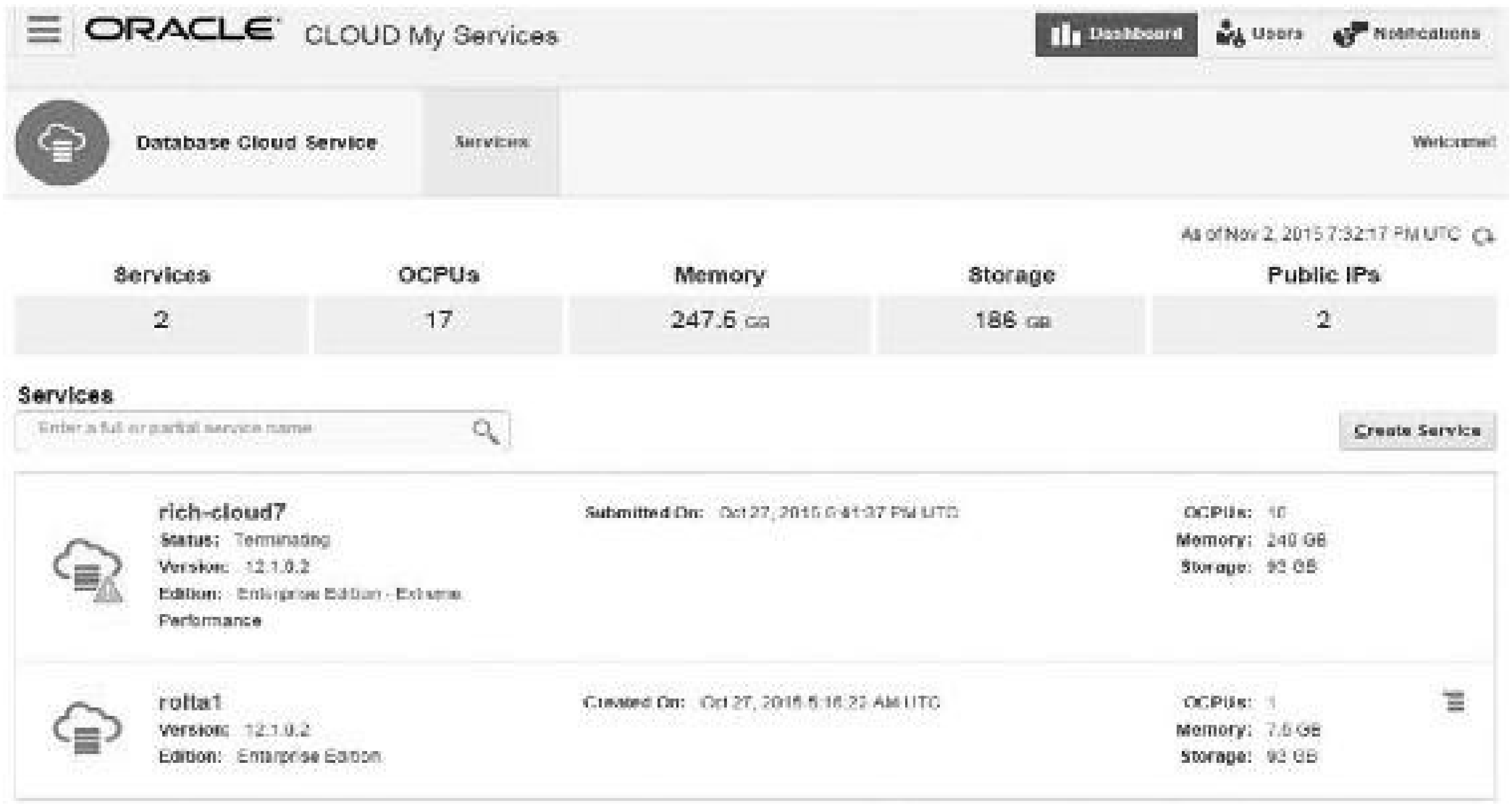
Submitted On: Oct 27, 2015 5:16:22 AM UTC

OCPUs: 1
Memory: 7.5 GB
Storage:

Dashboard
Users
Notifications
Services
Enter a full or partial service name
Create Service
Instance create and delete history

FIGURE 11-9. *A Database Cloud Service instance being created*

Figure 11-10 shows my successfully created Database Cloud Service instance after I've created two different services (I'm in the process here of terminating one of them in Figure 11-10). Details for all services are listed.



As of Nov 2, 2015 7:32:17 PM UTC

Services	OCPUs	Memory	Storage	Public IPs
2	17	247.5 GB	186 GB	2

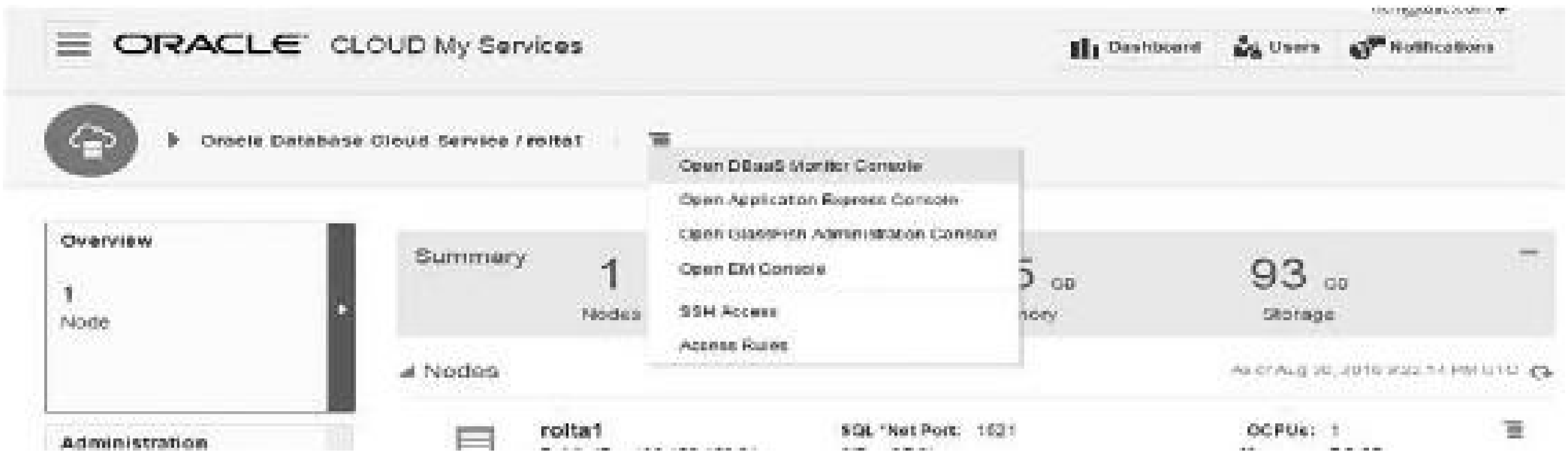
Services

rich-cloud7
Status: Terminating
Version: 12.1.0.2
Edition: Enterprise Edition - Extreme Performance
Submitted On: Oct 27, 2015 6:41:37 PM UTC
OCPUs: 16
Memory: 240 GB
Storage: 93 GB

rolta1
Version: 12.1.0.2
Edition: Enterprise Edition
Created On: Oct 27, 2015 5:16:22 AM UTC
OCPUs: 1
Memory: 7.5 GB
Storage: 93 GB

FIGURE 11-10. *I have two database services in my Oracle Cloud instance.*

As shown in the pull-down menu in Figure 11-11, I can now access (among other options) Enterprise Manager (EM) to manage the Database Cloud Service Instance (see Chapter 5 for EM details that can be monitored). Note that this is not the full Oracle Enterprise Manager (OEM or EM); it's more like 12c Database Express, so you may want to ensure that it does what you need.


ORACLE CLOUD My Services
Dashboard
Users
Notifications
Oracle Database Cloud Service / rolta1
Open DBaaS Monitor Console
Open Application Express Console
Open GlassFish Administration Console
Open EM Console
SSH Access
Access Rules
Overview
Administration

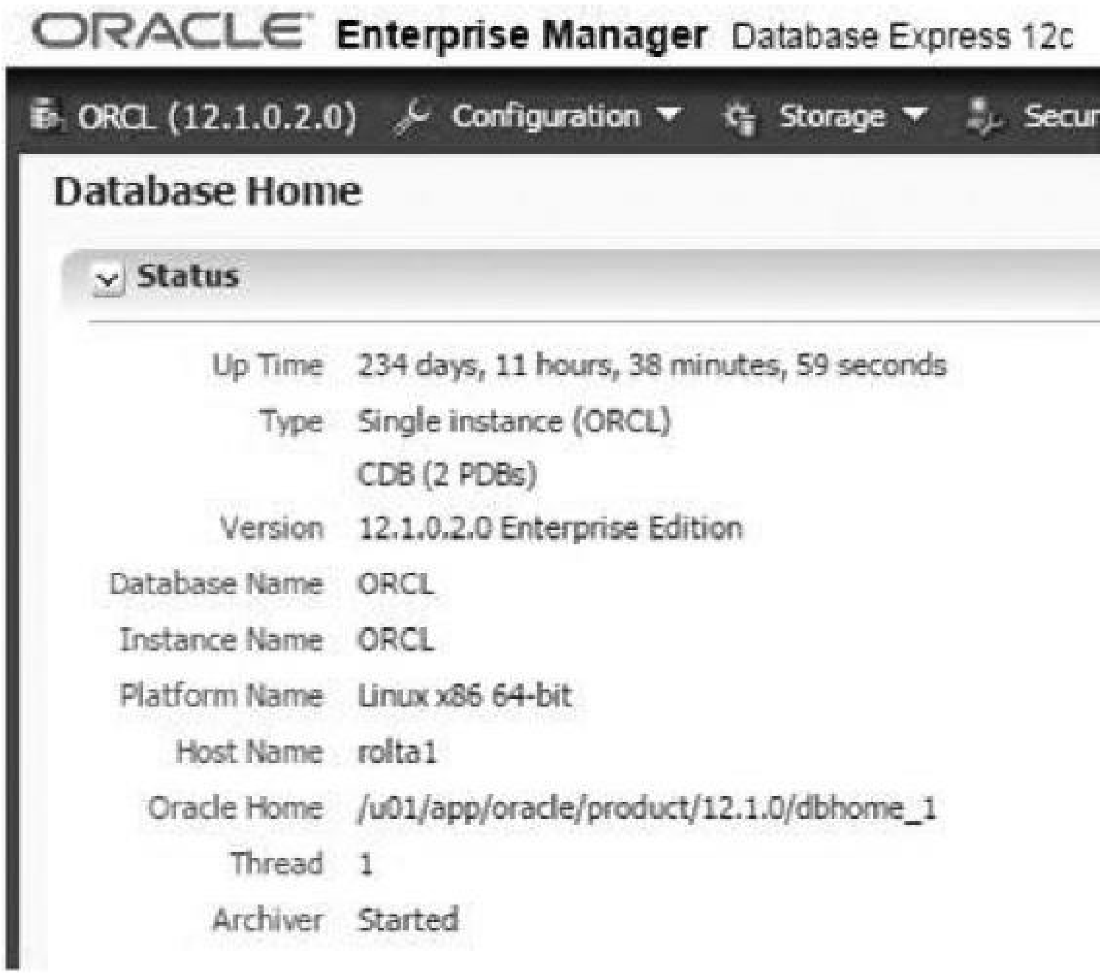
1
Node

Summary
1 Nodes
5 GB Memory
93 GB Storage

Nodes
rolta1
SQL *Net Port: 1521
OCPUs: 1

FIGURE 11-11. *Menu to open the EM Console from the Database Cloud Service*

Clicking Open EM Console shows that my database Instance in the cloud has been up over 234 days (Figure 11-12). Also note that many of the settings and locations for files and the default that you would use if you installed the database.



Up Time	234 days, 11 hours, 38 minutes, 59 seconds
Type	Single instance (ORCL)
	CDB (2 PDBs)
Version	12.1.0.2.0 Enterprise Edition
Database Name	ORCL
Instance Name	ORCL
Platform Name	Linux x86 64-bit
Host Name	rolta1
Oracle Home	/u01/app/oracle/product/12.1.0/dbhome_1
Thread	1
Archiver	Started

FIGURE 11-12. *Information in the EM Console in the Cloud (EM Express)*

I can click "CDB (2 PDBs)" and get to the details of the containers. Note that one of the PDBs in Figure 11-12 is the DEMOS PDB that I chose to install when I created the Database Cloud Service instance and the other is PDB1. I can take a look at Memory Management to see the various settings and allocation of memory similar to EM in my on-premises database (Figure 11-13).

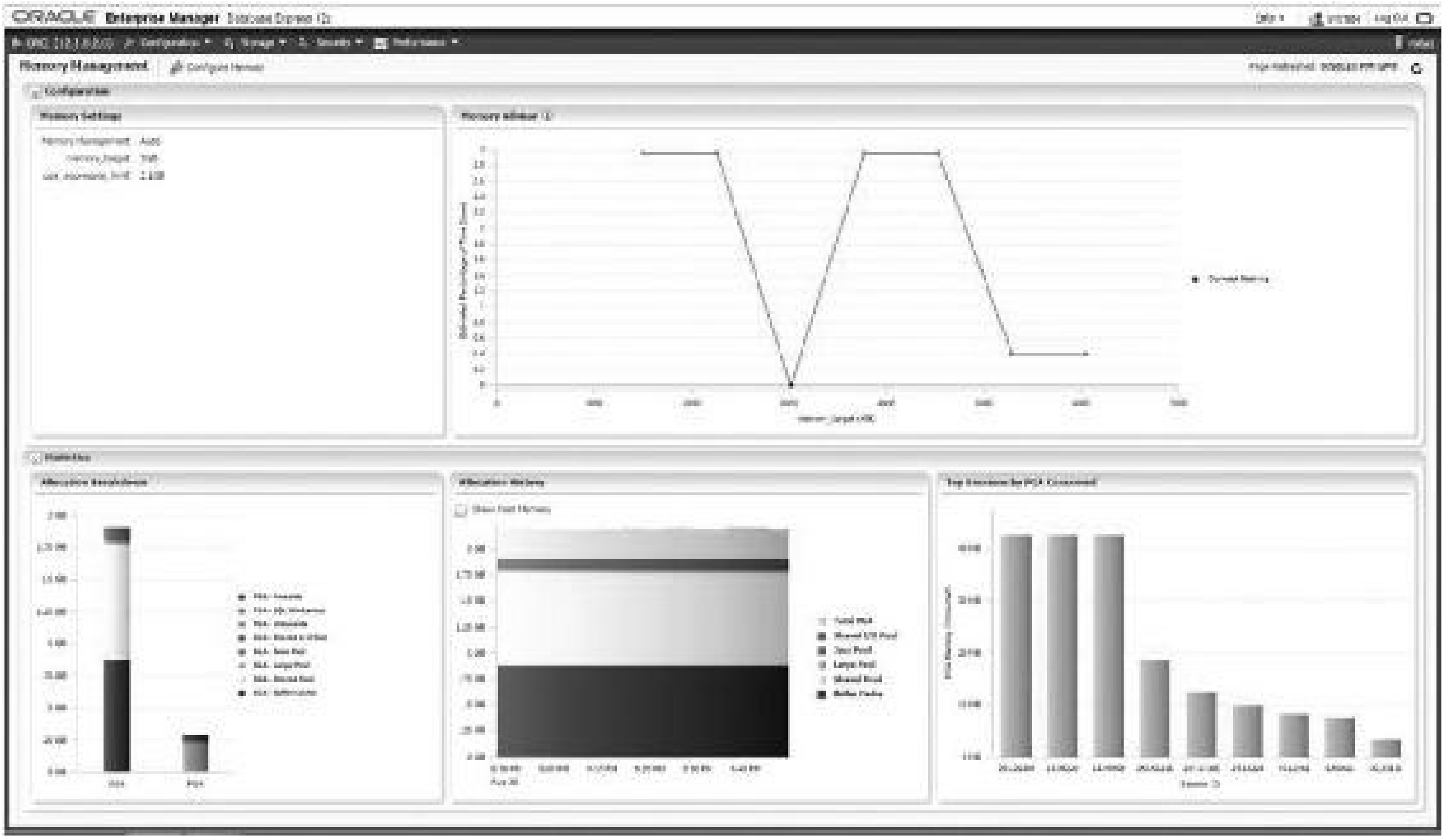


FIGURE 11-13. *Information in the EM Console in the Cloud (EM Express)*

As you can see, you have many different choices (refer to Chapter 5 for greater detail). You can easily check things like memory initialization parameters to see if the In-Memory Size is set (if you are using the In-Memory column store). You can then click Set to change a parameter.

Similar, but separate from EM, you can also use a new Oracle Cloud Service Solution called *Oracle Management Cloud*. In the initial launch of the Oracle Management Cloud at OpenWorld 2015, three services were packaged and released focusing on the highest customer pain points: Application Performance Monitoring, Log Analytics, and IT Analytics. There were three more announced at OpenWorld 2016. With them, customers gain real-time insight into application and infrastructure performance, optimizing (development, applications, and IT resources), and effectively planning for future business needs with data normalized and analyzed in visualizations that make the most sense to business stakeholders. Oracle Management Cloud services are powered by a big data platform behind the scenes providing real-time monitoring, rapid diagnostics, operational insight, and business analytics capabilities. Data uploaded is stored securely in a single unified big data platform and is automatically correlated and processed by a robust and scalable data pipeline that enables high-throughput processing of large amounts of data for analysis. Within the Oracle Management Cloud is Application Performance Monitoring (see Figure 11-14), which can be used to see greater detail in the cloud at every tier of operations. This is a cloud-only product. It shows performance and details at the database, application server, application, and even page level of the customer screen (thanks Oracle for the previous two screenshots).

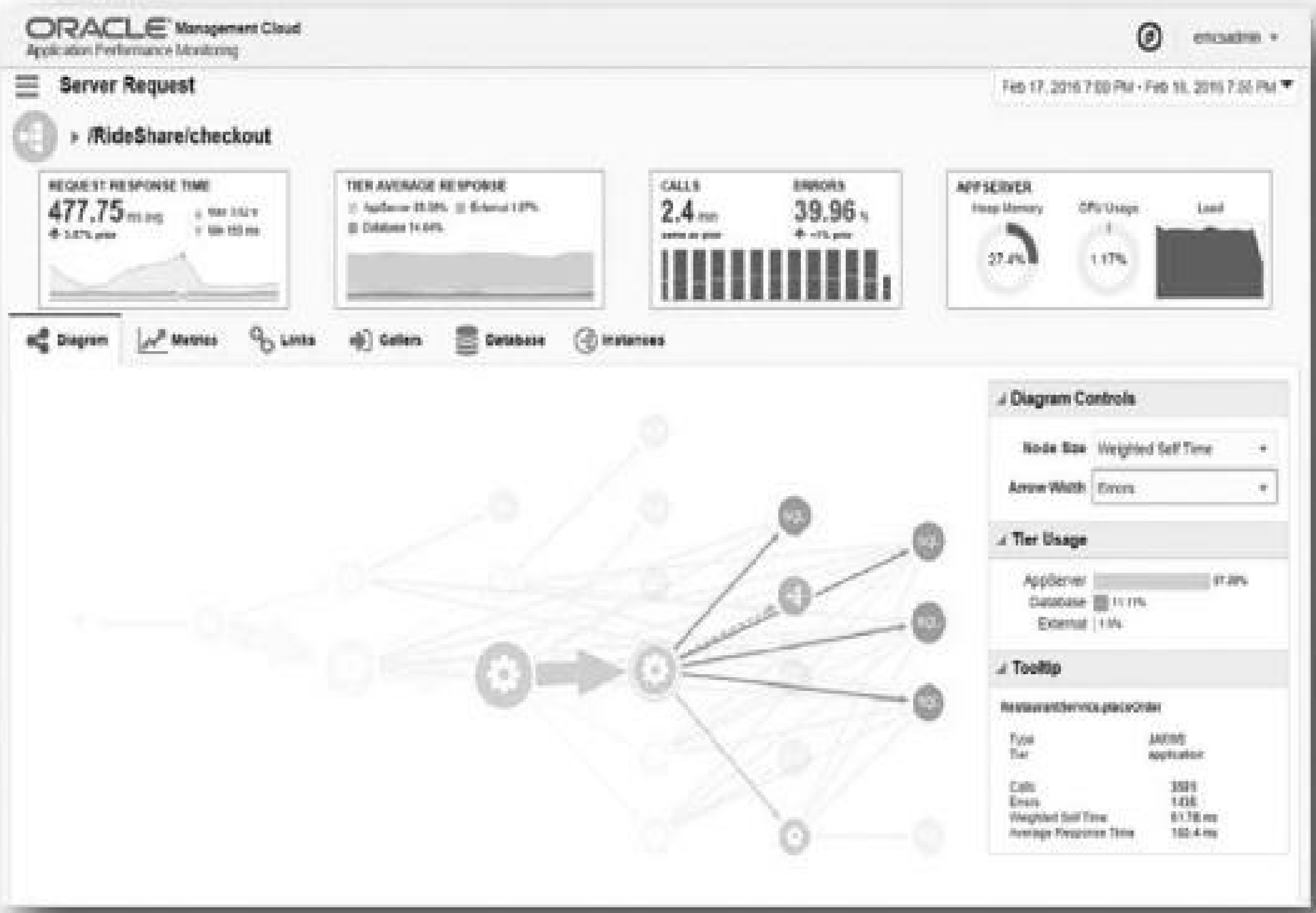
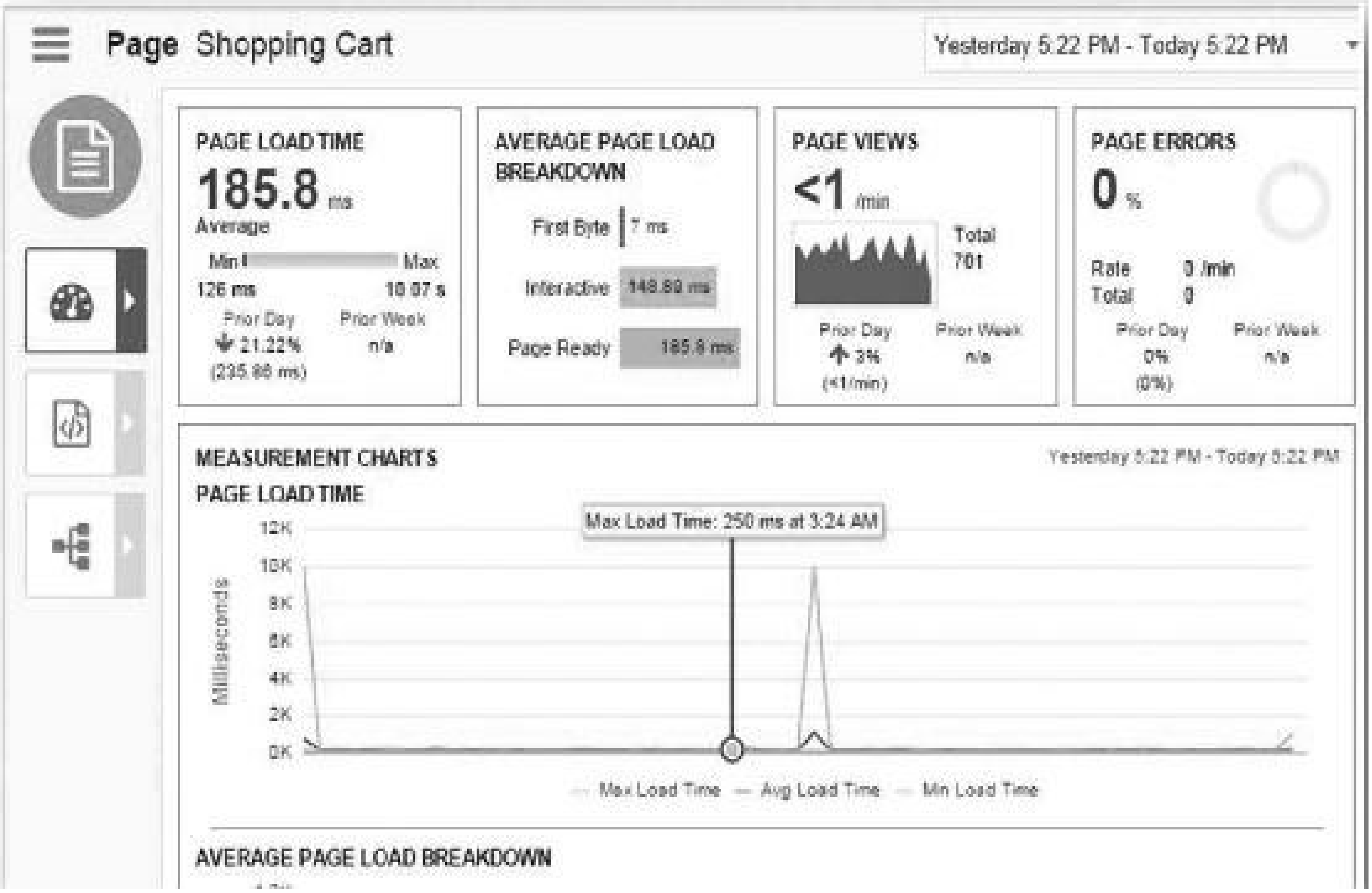


FIGURE 11-14. *Application Performance Monitoring, a cloud-only product*

You can also get additional details of the customer experience in viewing the application with a special focus on the application web page, as shown in Figure 11-15.


Page Shopping Cart

Yesterday 5:22 PM - Today 5:22 PM

PAGE LOAD TIME
185.8 ms
Average
Min 126 ms — Max 10.07 s
Prior Day: ↓ 21.22% (235.86 ms) — Prior Week: n/a

AVERAGE PAGE LOAD BREAKDOWN
First Byte: 7 ms
Interactive: 148.89 ms
Page Ready: 185.8 ms

PAGE VIEWS
<1 /min
Total 701
Prior Day: ↑ 3% (<1/min) — Prior Week: n/a

PAGE ERRORS
0 %
Rate 0 /min
Total 0
Prior Day: 0% (0%) — Prior Week: n/a

MEASUREMENT CHARTS — Yesterday 5:22 PM - Today 5:22 PM
PAGE LOAD TIME
Max Load Time: 250 ms at 3:24 AM

AVERAGE PAGE LOAD BREAKDOWN

FIGURE 11-15. *APM customer shopping cart*

By using this detailed information, you can gauge the customer experience and head off potential problems with performance or errors before the customer complains.

The Oracle Cloud is here to stay! As the next few years go by, Oracle will only accelerate their cloud and mobile offerings to better serve you. It's hard to predict how much of the corporate workload will make it to the cloud (predictions range from 40 to 90 percent) or how fast that corporations will be able to move that workload to the cloud generally are 5 to 10 years), but the acceleration of technology could also accelerate this migration. It's important to become educated on all of these products so that you can discern for your company which products fit now and which ones deserve a wait-and-see approach. The Oracle Cloud is standards-based (you can move things from the Oracle Cloud to the Amazon cloud). Charges are on an hourly or monthly subscription basis (and you can even put the server on your own site). I certainly foresee there will be more cloud services and more cloud customers by the time you read this.

TIP

Get ready for the cloud by trying a simple DBaaS instance at http://cloud.oracle.com/tryit for free or by trying the new 12cR2 Oracle Database Exadata Express Cloud Service for $175/month.

Exadata Database Machine

Oracle's Exadata Database Machine (Exadata) transformed Oracle into a serious hardware contender. By June 2011, Oracle had already sold their 1000th Exadata machine, by mid-2014 they had sold more than 10,000 Exadata machines, and the market has been growing since then as well. As mentioned, the Exadata machine now delivers 4.5M flash IOPS. This figure is sure to have changed by the time you read this. Oracle is accelerating the hardware world as they did the software world; you can now build anything you can dream of!

Exadata Terminology and the Basics

When I think of an Exadata Database Machine full rack (X6-2 at the time of writing in the fall of 2016), I think of it as a "prebuilt eight-node RAC cluster with Super SAN or all flash option." The Exadata Database Machine includes all the power one needs to run an Oracle database environment and is also a highly flexible architecture (it has an eighth rack option all the way to multiple racks of Exadata interconnected as one).

The X6-2 model architecture includes (standard configuration—you can go larger!):

- Eight compute nodes, with a total of 352 cores for 8 servers and 2T (up to 6T) of DRAM per rack clustered together using Oracle GI clustering and RAC at the database tier.
- An additional 280 CPU cores (see next point for detail on each cell) per rack dedicated to storage with a super-fast, low-latency interconnect network (2 × 40 Gb/sec each way).
- 14 storage cells providing database and SQL-aware storage, each with 2 CPU sockets × 10 core CPUs × 14 storage cell = 280 CPUs on the storage. Two storage options are available:
  - **Disk storage** 1.3P of disk space: 12 disks × 8 TB × 14 storage cells, 7200 RPM drives per cell plus 4 × 3.2T NVMe PCIe flash cards
  - **All flash storage** 180T of Flash Cache (up to 358T is possible): 14 storage cells × 4 × 3.2T NVMe PCIe flash SSD

The X6-8 Exadata Rack is much like the X6-2 except that it comes with two or four database nodes, each with 8 × 18 core CPUs (144 CPU cores) and 2T of DRAM. My take on it: if you need it and can afford it—you want it (all flash X6-2, SuperCluster M7, or all flash FS1 are the best Oracle hardware solutions on the planet!).

NOTE

The Exadata X6's have an all Flash Cache option (180T to 358T) instead of 168 × 8T disks (1.3P), combined with write through/write back capability. It has almost eliminated all physical I/O performance.

The Exadata X6's also include 4 × 1/10 GbE copper Ethernet interfaces, 2 × 10 GbE optical Ethernet ports, and Integrated Lights Out Management (ILOM) for remote administration capabilities. How fast is it? In general, it's 5 to 100 times faster than much of the data warehousing competition and 20 times faster than most OLTP competition. A full rack Exadata can deliver up to 4.5M IOPS (I/Os per second) and a throughput of 350 GB/sec.

What makes it so fast? Fast hardware, many CPUs, Flash Cache, lots of DRAM (parallel query in DRAM in 11.2), compression (saves 10×–70×), partition pruning (saves 10×–100×), storage indexes (saves 5×–10×), and Smart Scan (saves 4×–10×). You can turn a 1T search into a 500M search or even 50M when you leverage all these features. If anything, I think Oracle might be understating the true power of this hardware (Oracle calls it a "database machine").

Exadata Statistics

In 2008, Oracle released V1 of the Exadata; the original Exadata was on HP hardware. In 2009, Oracle released Exadata V2, which was an *all* Oracle/Sun solution after the Sun acquisition. The following year, in 2010, Exadata X2 was released, which was a hardware upgrade. In 2010, Oracle also introduced the X2-8 model. Around 2011, Oracle released the Exadata Storage Expansion Rack, with the goal of providing the flexibility of growing storage capacity without needing to upgrade compute capacity. In 2012, Oracle released Exadata X3, with significant improvements to usage and capacity of Flash Cache, which earned it the name "in-memory database." At the same time, December 2013, Oracle released version X4, which included hardware upgrades and improved capacity and performance characteristics. One of the subtler changes in this version was that the interconnect used two InfiniBand IP links, in active/active mode. In January 2015, Oracle released version X5, which introduced all flash storage. Once again, the improvements came in the form of newer, faster Non-Volatile Memory Express (NVMe) flash cards and drives. The all flash drive option officially eliminated the option to use high-performance disks over high-capacity disks. Another key development with the X5 was the concept of "elastic configuration," which fundamentally frees the customer from the rigid structure implied by quarter rack or half rack or full rack. The customer can mix and match compute versus storage nodes based on actual need and have capacity on demand. Earlier this year, Oracle released Exadata X6 (April 2016), which increased the core count on the compute nodes and doubled the Flash Cache capacity as well the pure flash storage capacity.

The X6-2 Exadata model comes in the following sizes and models:

- A full rack, which has eight compute servers (2 socket and 14 storage cells)
- A half rack, which has four compute servers and seven storage cells
- A quarter rack, which comes with two compute servers and three storage cells
- An eighth rack, which is the same hardware as a quarter rack, with half the CPU and half the disk activated

Traditionally, the largest issues with respect to scaling the Exadata have been hardware cost and licensing cost:

- The supported scaling model was eighth rack → quarter rack → half rack → full rack. This assumed a built-in scaling of both CPU and storage.
- Any specific DB options had to be licensed for all CPUs, needed or not.
- As a result, the licensing cost increases were significant.

To address the licensing pain point, Oracle came out with the following innovative approaches and options:

- Starting with the X5 model class, called "Elastic Configuration," Oracle allowed the end user to define the number of compute nodes versus the number of storage nodes in a rack.
- Starting with the X5 model, Oracle also developed on-demand capacity licensing.
- Around the time of the release of Exadata X6, Oracle supported the use of Oracle Virtual Machine (OVM) with Exadata.

An X6-2 full rack Exadata Database Machine includes:

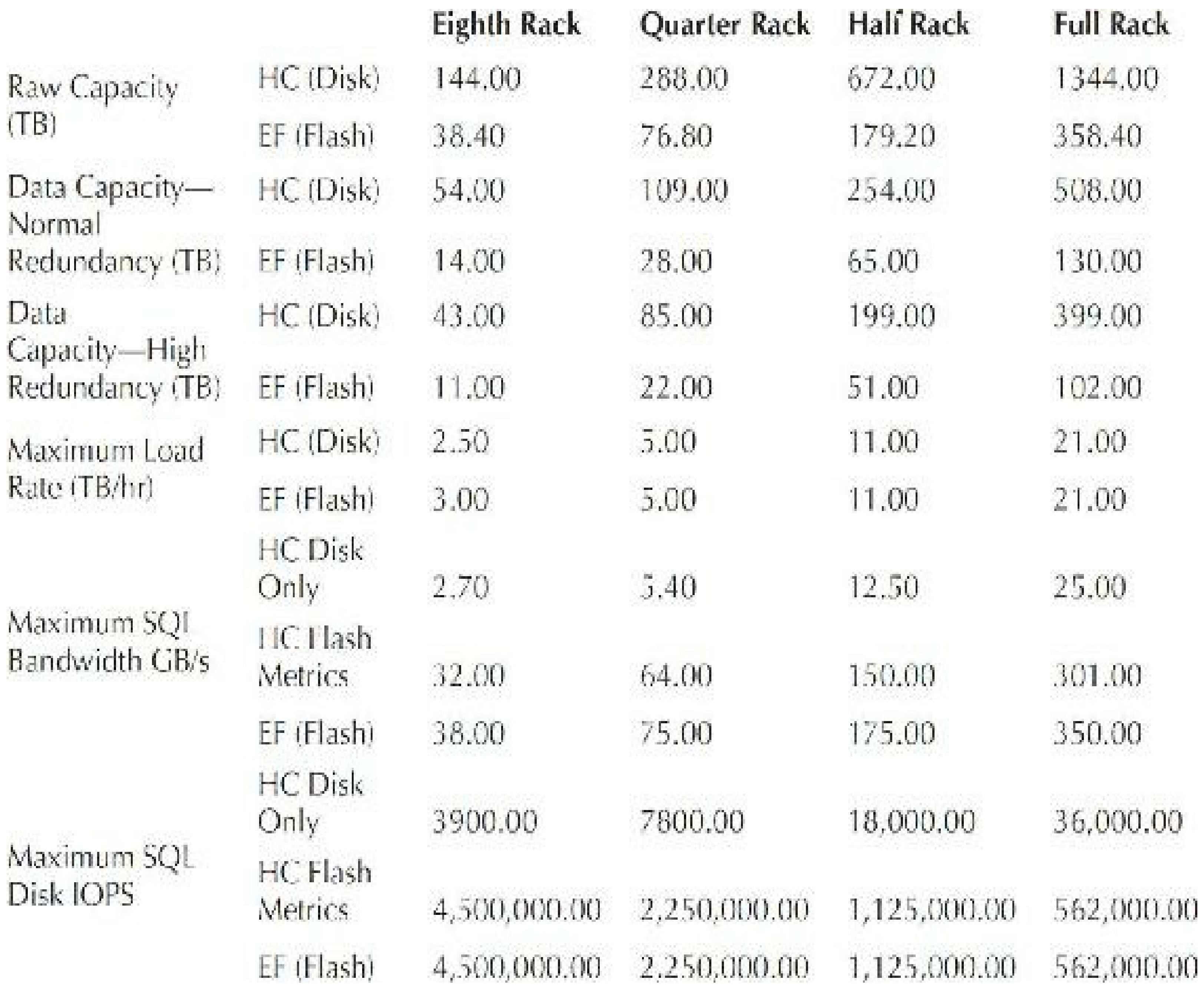
- 8 compute servers:
  - 8 servers × 2 CPU sockets × 22 cores = 356 cores
  - 8 servers × 4 disks × 600G (10K RPM) local storage
  - 8 servers × 768G DRAM = 6144G DRAM (standard is 2T with 256G per server)
- 3 InfiniBand switches (40 Gb/s) × 36 ports = 108 ports
- 14 storage servers:
  - 14 cells × 2 CPU sockets × 10 core/CPU = 280 cores
  - 14 cells × 128G = 1792G memory
- High Capacity Storage Option:
  - 14 × 12 × 8T 7200 RPM drives for 14 cells = 1344T raw storage (1.3P)
  - 14 × 4 × 3.2T NVMe PCIe flash cards = 179.2T of flash
- Extreme Flash Storage Option:
- 14 cells × 8 3.2T NVMe PCIe 3.0 flash drives = 358.4T flash

An X6-8 Exadata machine includes the same as the X6-2 in terms of storage and options. The difference is in the compute options:

- 2 compute servers option:
  - 2 servers × 8 CPU sockets × 18 cores = 288 cores
  - 2 servers × 2T DRAM = 4T DRAM
- 4 compute servers option:

- 4 servers × 8 CPU sockets × 18 cores = 576 cores
- 4 servers × 2T DRAM = 8T DRAM

The following table shows some actual storage-related statistics:



		Eighth Rack	Quarter Rack	Half Rack	Full Rack
Raw Capacity (TB)	HC (Disk)	144.00	288.00	672.00	1344.00
	EF (Flash)	38.40	76.80	179.20	358.40
Data Capacity—Normal Redundancy (TB)	HC (Disk)	54.00	109.00	254.00	508.00
	EF (Flash)	14.00	28.00	65.00	130.00
Data Capacity—High Redundancy (TB)	HC (Disk)	43.00	85.00	199.00	399.00
	EF (Flash)	11.00	22.00	51.00	102.00
Maximum Load Rate (TB/hr)	HC (Disk)	2.50	5.00	11.00	21.00
	EF (Flash)	3.00	5.00	11.00	21.00
Maximum SQL Bandwidth GB/s	HC Disk Only	2.70	5.40	12.50	25.00
	HC Flash Metrics	32.00	64.00	150.00	301.00
	EF (Flash)	38.00	75.00	175.00	350.00
Maximum SQL Disk IOPS	HC Disk Only	3900.00	7800.00	18,000.00	36,000.00
	HC Flash Metrics	4,500,000.00	2,250,000.00	1,125,000.00	562,000.00
	EF (Flash)	4,500,000.00	2,250,000.00	1,125,000.00	562,000.00

These are some important points to note about this table:

- HC = High Capacity; EF = Extreme Flash.
- The storage capacity does not take into account benefits of compression (HCC or Advanced Compression).
- Usable space is computed after taking into account ASM redundancy, DBFS and Flash Recovery Disk groups, ACFS disk, OS images/binaries, etc.
- The SQL metrics are based on 8K IOPS and take into account ASM redundancy, which issues multiple IOPS.

Exadata Storage Expansion Rack Briefly

As of July 2011, Oracle added an *Exadata Storage Expansion Rack* that allows you to grow storage capacity of the X6-2 and X6-8 by connecting to it via InfiniBand. This addition is great news for those who are looking to have petabytes (P) of information. It is also welcome news for those who would like to store more of their archived-to-tape data on disk. The Storage Expansion Rack can have up to 18 additional HC storage cells and 19 EF storage cells. Each cell has the exact same characteristics as the cells in the Exadata Database Machine racks.

- A single HC cells can add about 1.7 T/hr to the overall data load rate.
- A single EF cell can add about 2.0 T/hr to the data load rate.
- A fully loaded expansion rack with HC storage can add 690T of usable space with normal redundancy and 540T with high redundancy.
- A fully loaded expansion rack with EF storage can add 175T of usable space with normal redundancy and 140T with high redundancy.

Exadata Storage Server software uses the following features (covered in detail later in this chapter):

- Smart Scan technology
- Smart Flash Cache
- Storage indexes
- Hybrid Columnar Compression
- IORM/DBRM both available
- Smart Scans of data mining model scoring
- Automatic Storage Management (ASM)
- Backup with RMAN
- Restores using Flashback technologies
- Redundant power and InfiniBand switches

The Oracle database is capable of storing 8 exabytes (8E). Here's what's possible:

- In 2011, as noted in the prior edition of this book, it took 41,227 Storage Expansion Racks to get to the maximum 8E (exabytes of mirrored uncompressed storage) 11*g* Database. Compression gives you 80–500+ exabytes. At 10× compression, you would only need 4123 Storage Expansion Racks to get to 8E, and at 70× compression, you would only need 589 Storage Expansion Racks to get to 8E.
- In 2016, the X6-2 has 1.3P and it would take only 6154 Exadata X6-2s to get to the maximum 8E 12*c* Database. Compression gives you 80–500+ exabytes. At 10× compression, you would

only need 616 Storage Expansion Racks to get to 8E, and at 70× compression, you would only need 88 Storage Expansion Racks to get to 8E.

- The Facebook data warehouse has about 0.3E of stored data and is growing at 0.2E per year, so it will reach 8E in about 38 years (except it will be faster, I predict, since Facebook's growth will be faster in the future). Facebook would currently fit on 23 X6-2s with 10× compression or only *four* X6-2s with 70× compression (except, you need mirroring, standby, etc). That's a lot better than the warehouses that house Facebook's servers.
- 64 bit allows 16E to be in memory (18,446,744,073,709,551,616).

Smart Scans

Smart Scans are done internally by Oracle, and when they are used, you commonly realize a 10× savings in query time. Oracle filters data based on WHERE clause conditions (predicates), and it filters on row, column, and join conditions. Oracle also performs incremental backup filtering. Smart Scans work with uncommitted data, locked rows, chained rows, compressed data, and even encrypted data (since 11.2). You can *see* and monitor the benefits with Oracle Enterprise Manager Cloud Control.

Smart Scans leverage Bloom filters used for faster join filtering. Bloom filters are a quick way to search for matches. They save space and are transparent to the user. Bloom filters are basically hardware-level filters that test to see if the elements are in a set. Google BigTable uses Bloom filters to reduce disk lookups as well. Oracle's join filtering is a perfect application for Bloom filters. Following are some simple Smart Scan comparisons.

Without Smart Scan (push whole table via network):

- 5T table scan
- Network bandwidth (40 Gb/s)
- 40 Gb/s = 5 GB/s (e.g., with 14 storage cells, each cell has a data transfer rate of 0.357 GB/s)

16 minutes, 40 seconds (5T at 5 GB/s)—without Smart Scan

With Smart Scan (limit first at hardware level):

- 5T table scan
- Limit result *before* it hits the network
- Effectively scan 21 GB/s (1.5G/storage cell × 14 cells)

3 minutes, 58 seconds (5T at 21 GB/s)—with Smart Scan

Flash Cache

The Flash Cache is composed of solid-state disks (information stored on chips). It is between 20×–50× faster than disk (depending on the disks). The Flash Cache caches *hot* data (frequently used data). It does this as the *last* step (so it returns data to you *first* and then caches it for next time based on the settings you give it). It uses PCIe-based flash cards (PCIe is Peripheral Component Interconnect Express). It knows which objects *not* to cache, such as full table scans, but *you* can also specify exactly which data you want to cache using the STORAGE clause or you can specify it at the table/partition level with CREATE/ALTER:

- **STORAGE** CELL_FLASH_CACHE KEEP
- **Table/partition level** CREATE or ALTER

Flash Cache also has a write-through cache that you can use to accelerate reads. With this feature, data written to disk *might* also be written to cache (again, stored in the cache *after* the user gets it written to disk) for future reads.

The Flash Cache caches:

- Hot data/index blocks
- Control file reads/writes
- File header reads/writes

The Flash Cache does not cache:

- Mirror copies, backups, or Data Pump
- Tablespace formatting
- Table scans (or, at least, this is rare; for example, small tables are possibilities)

The Flash Cache LRU (least recently used) settings for caching include:

- **CELL_FLASH_CACHE storage clause** The possible values are:
  - **DEFAULT** Normal, large I/Os not cached.
  - **KEEP** Use Flash Cache more aggressively/it may not occupy > 80 percent of all cache.
  - **NONE** Flash Cache not used.
- **CACHE (NOCACHE) hint** I/O cached/not-cached in the Flash Cache.
  - SELECT /*+ CACHE */ …
- **EVICT hint** Data removed from the Flash Cache. ASM rebalance data is evicted from cache when done.

Large I/O (full table scans) on objects with CELL_FLASH_CACHE set to DEFAULT are not cached.

Setting the KEEP cache is accomplished as follows:

```
ALTER TABLE CUSTOMER
STORAGE (CELL_FLASH_CACHE KEEP);
Table Altered.
```

Use the following query to see if a table is currently set to cache or not:

```
SELECT     TABLE_NAME, TABLESPACE_NAME,
           CELL_FLASH_CACHE
FROM       USER_TABLES
WHERE      TABLE_NAME = 'CUSTOMER';

TABLE_NAME   TABLESPACE_NAME     CELL_FL
------------ ------------------- -------
CUSTOMER     R_TEST              KEEP
```

Here is how the Flash Cache works: A database request comes to CELLSRV (*cell storage server*). The CELLSRV (first time) gets data from disk and the data is cached based on settings, hints, and so on. The data that goes to WRITE may also be cached after being written if it is deemed that it may be needed again. The CELLSRV (next time) checks the Memory Hash Table that lists what is cached. If cached, the data goes to Flash Cache; if not cached, it may cache based on settings and so on. You can also query the hardware cells directly as listed here:

```
CELLCLI> list flashcache detail (allows you to monitor)
CELLCLI> list flachcachecontent where ObjectNumber=62340 detail
```

SQL*Plus Query—is it working?

```
SELECT      NAME, VALUE
FROM        V$SYSSTAT
WHERE       NAME IN ('physical read total IO requests',
            'physical read requests optimized');

Name                                         Value
------------------------------------------   --------
physical read total IO requests              36240
physical read requests optimized             23954
```

This second line times block size (*8192) is the bytes of Flash Cache used; it’s working!

It is working … 4G query:

```
SELECT      NAME, VALUE, VALUE*8192 VALUE2
FROM        V$SYSSTAT
WHERE       NAME IN ('physical read total IO requests',
            'physical read requests optimized');

NAME                                      VALUE          VALUE2
--------------------------------   ----------    -------------
physical read total IO requests    10,862,844   88,988,418,048
physical read requests optimized    2,805,003   22,978,584,576
```

run2...

```
physical read total IO requests   11,320,185     92,734,955,520
physical read requests optimized   3,203,224     26,240,811,008
```

run4...

```
physical read total IO requests  11,993,845      98,253,578,240
physical read requests optimized  3,793,000      31,072,256,000
```

It is working … V$SQL:

```
select      sql text, optimized phy read requests, physical read requests,
            io_cell_offload_eligible_bytes
from        v$sql
where       sql text like '%FIND YOUR SQL%'

SQL_TEXT     OPTIMIZED_PHY_READ_REQUESTS PHYSICAL_READ_REQUESTS
------------ --------------------------- ----------------------
IO_CELL_OFFLOAD_ELIGIBLE_BYTES
------------------------------
SELECT....   567790                      688309
4.2501E+10
Run 2.....
SELECT...    762747                      906729
4.9069E+10
run 4 ....
SELECT...    1352166                     1566537
6.8772E+10
```

NOTE
The Exadata PCIe card Smart Flash Cache (that is, the stored Exadata hardware PCIe Card Cache) is not the same as the Database Flash Cache (file stored) used with Oracle Enterprise Linux or Solaris only.

Finally, keep in mind that Flash Cache wears out faster than disks (see the specifications for more information; Flash Cache wears out faster in higher elevations). Oracle does give you uncounted "extra" space to make up for this, however.

Storage Indexes

A storage index utilizes minimum and maximum values for certain columns to help queries run faster by eliminating rows (similar to partitioning). A performance gain of 10× is common with storage indexes (could be higher/lower depending on the minimum/maximum and how many rows can be eliminated for a given query). These indexes primarily maintain summary information about the data (*like metadata in a way*). The memory structure resides in the cell level (storage). It groups data into min/max for various columns (based on usage patterns), and it eliminates I/Os where there is no match. A storage index is 100 percent transparent to the user. Indexing is performed at the hardware level, and one storage index is used for every 1M of disk. A storage index does *not* perform like a B-tree index, but more like partition elimination—where you skip data *not* meeting the query conditions. Oracle builds 100 percent of the storage indexes based on query patterns and data use; no additional coding is required. Consider the following queries to see if storage indexing is working on a two-node RAC cluster.

Is it working for me?

```
SELECT      NAME, VALUE
FROM        V$SYSSTAT
WHERE NAME LIKE ('%storage%');

NAME                                               VALUE
---------------------------------------------     --------
cell physical IO bytes saved by storage index     25604736
```

This is the actual savings from an Exadata-built storage index; it's working on this node!

Check both servers (only savings on one node during this test):

```
SELECT       NAME, VALUE
FROM         GV$SYSSTAT
WHERE        NAME LIKE ('%storage%');

NAME                                              VALUE
------------------------------------------ ----------
cell physical IO bytes saved by storage index 19693854720
cell physical IO bytes saved by storage index           0
```

This is the actual savings from the Exadata-built storage index; it's working!

Hybrid Columnar Compression

Hybrid Columnar Compression (HCC), also known as *Exadata Hybrid Columnar Compression (EHCC)*, is data that is organized by a hybrid of columns/rows and compressed versus data organized by basic row format. A performance gain anywhere from 10× to 30× is common. The tables are organized in compression units (CUs), which contain around 1000 rows (more or less depending on the amount of data in the rows). CUs span many blocks. HCC is very good for bulk-loaded data, but is not built for OLTP or single block read operations. It is primarily built for data warehouses and queried data, not for frequently updated data.

Using the old OLTP compression algorithm, you could get 2–3× compression or so. Yet, with HCC, 10× compression in a typical data warehouse is common. In limited tests, I got anywhere from 4–11×. HCC also allows archive compression (used for cold data), which gives you anywhere from 15× to 70× compression (I got approximately 32× compression in limited tests). The nice thing about HCC is that operations are faster because the query runs without decompression. The compressed version is processed in the Flash Cache, which results in lower I/O. The compressed version is also sent over InfiniBand; it is cloned compressed; and it is even backed up compressed! As a result, it scans *much* less (compressed) data!

Figure 11-16 is a logical representation of a CU. The image does not specifically show block headers and so on, but they are maintained for each block. The initial piece of a CU is a header that maintains the metadata associated with its contents. Among other things, it contains the starting point of each column within the CU.

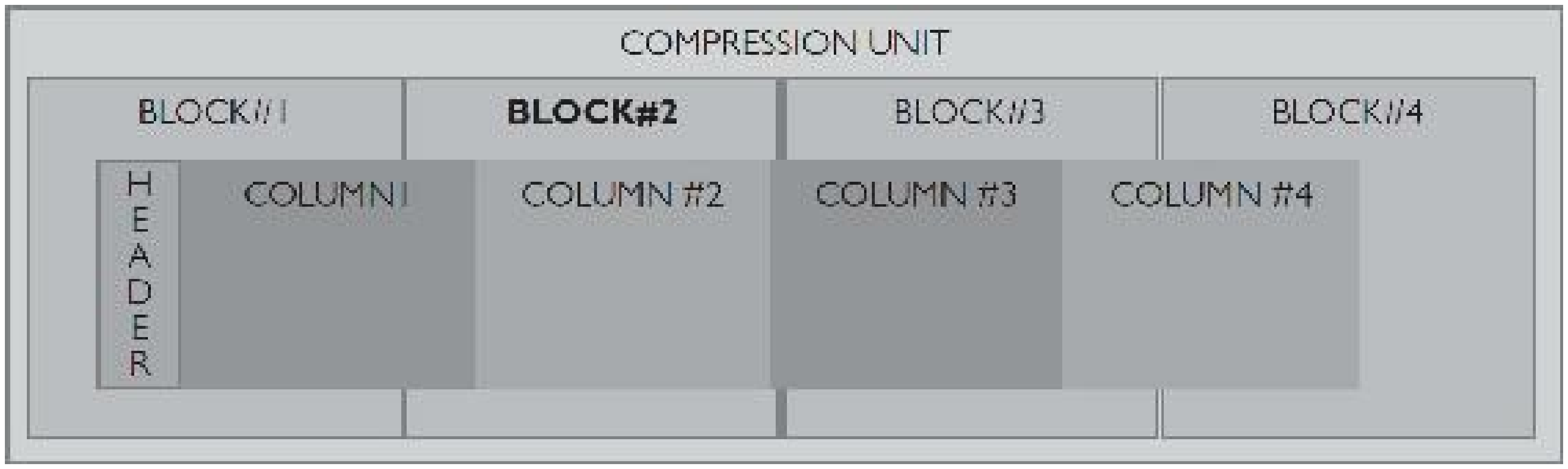


FIGURE 11-16. *Logical structure of a compression unit under HCC*

A given column's data can span over several blocks, and for that reason the CU header is structured similarly to chained rows within regular tables, with a pointer to the top of each column. Therefore, ROWID for an HCC-organized table must refer to the CU and not the block itself. For normal tables, the ROWID is composed of the following:

- FILE NUMBER or RELATIVE FILE NUMBER
- BLOCK NUMBER
- ROW NUMBER

In the case of HCC, the FILE NUMBER and BLOCK NUMBER actually relate to the CU itself. We can use DBMS_ROWID.ROWID_RELATIVE_FNO and DBMS_ROWID.ROWID_BLOCK_NUMBER to see how many rows are in each CU, an example of which can be seen in the following query. To see how many blocks were actually in use, not just allocated, we used the Oracle-provided PL/SQL package DBMS_SPACE.UNUSED_SPACE.

```
SELECT COUNT(*) FROM (
      SELECT DISTINCT DBMS_ROWID.ROWID_RELATIVE_FNO(ROWID),
      DBMS ROWID.ROWID BLOCK NUMBER(ROWID) FROM TABLE NAME);
```

HCC can be deployed in multiple flavors :

- **HCC Query Low or Query High** More suited for querying data. Lesser compression benefits but less costly to query. Query Low uses the LZO compression algorithm while Query High uses the ZLIB algorithm.
- **HCC Archive Low or Archive High** More suited for archiving data, thus higher compression but more costly to query. Archive logs use the ZLIB algorithm while Archive High uses the BZIP2 algorithm.

Tables 11-1 and 11-2 provide a comparison of the compression ratio and CU usage statistics, respectively, by type of HCC.

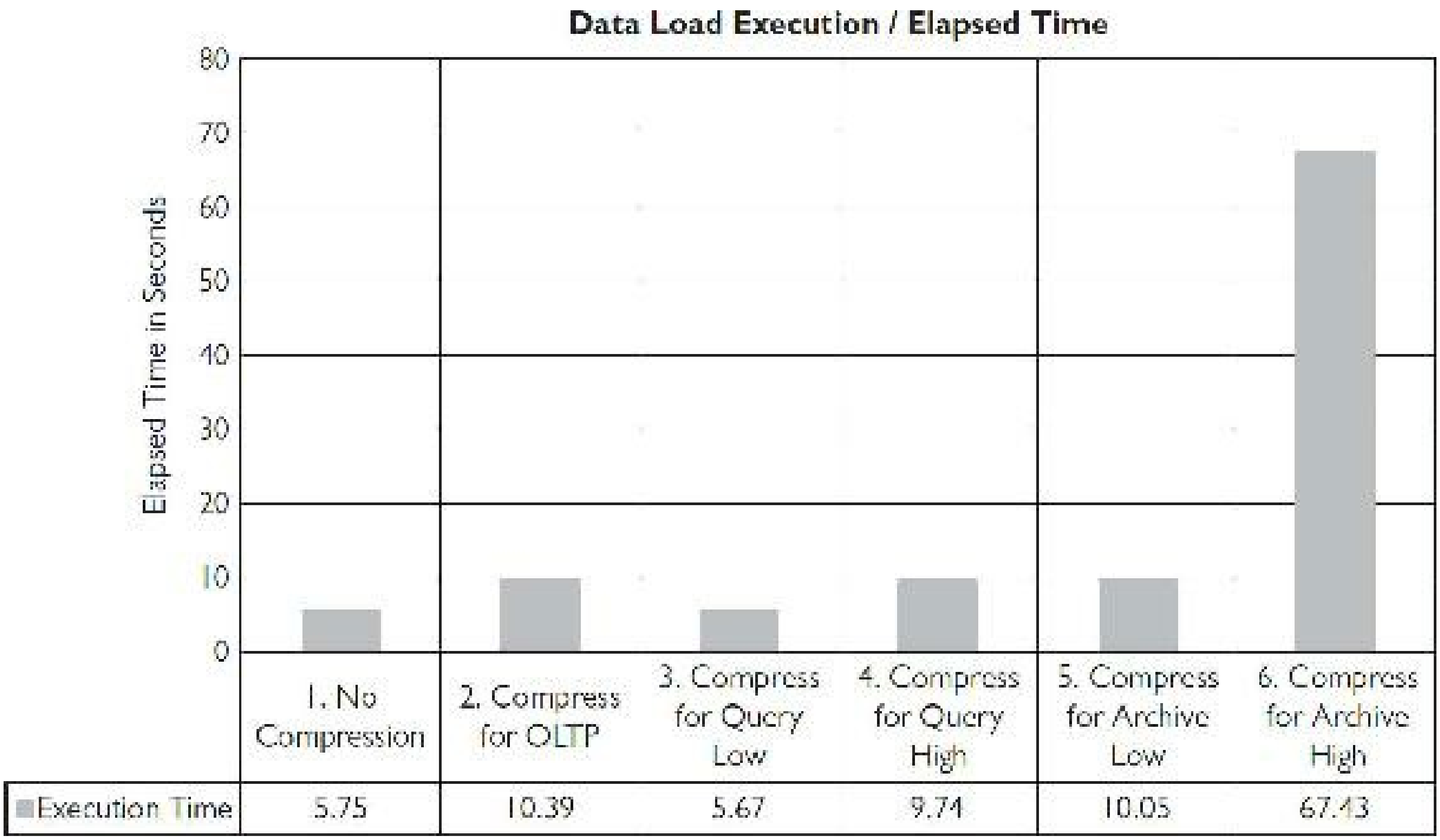
Compression Type	Size (MB)	Savings	Ratio
Uncompressed	232	0.0%	1.0
OLTP Compression	152	34.5%	1.5
HCC Query Low	61	73.7%	3.8
HCC Query High	25	89.2%	9.3
HCC Archive Low	25	89.2%	9.3
HCC Archive High	20	91.4%	11.6

TABLE 11-1. *Compression Ratio by Compression Type*

HCC Type	# of CUs	Blocks Used	Rows/CU	Blocks/CU
HCC Archive High	126	2413	29294.6	19.15
HCC Archive Low	656	3074	5626.7	4.69
HCC Query High	824	3094	4479.5	3.75
HCC Query Low	1926	7506	1916.5	3.90

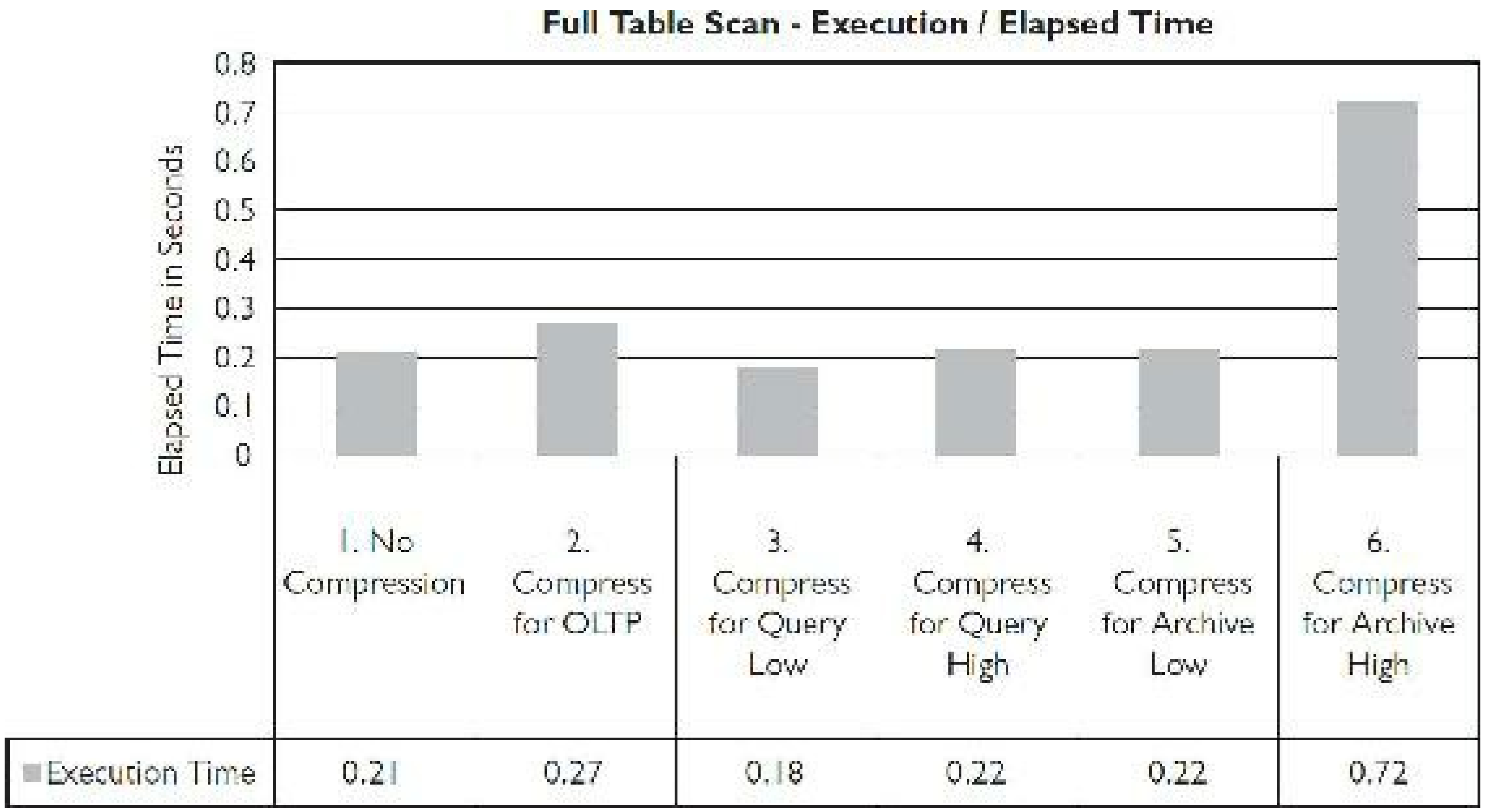
TABLE 11-2. *CU Usage Statistics by Compression Type*

Data load rates will depend upon the nature and type of data load. Bulk load operations are better suited for HCC than single row inserts. Similarly, full table scans are better suited for HCC. Either way, there is a penalty that comes with using HCC. Figures 11-17 and 11-18 show sample data to that effect.



	1. No Compression	2. Compress for OLTP	3. Compress for Query Low	4. Compress for Query High	5. Compress for Archive Low	6. Compress for Archive High
▨ Execution Time	5.75	10.39	5.67	9.74	10.05	67.43

FIGURE 11-17. *Data loads with compression*



	1. No Compression	2. Compress for OLTP	3. Compress for Query Low	4. Compress for Query High	5. Compress for Archive Low	6. Compress for Archive High
▨ Execution Time	0.21	0.27	0.18	0.22	0.22	0.72

FIGURE 11-18. *Effect of compression on full table scans*

Another important point to understand is the locking behavior in HCC during updates. Oracle traditionally has maintained row-level locking as the mantra and rule. This rule does not apply to HCC in the same way. When a table is created to take advantage of HCC, irrespective of the type, locking is now managed and maintained at the CU level. What this means is that if a session updates a row that is currently stored using HCC compression type, then the session lock is taken at the CU level. In other words, another session that tries to update a second row in the same CU will be blocked by the first session and will have to wait on an "enq: TX - row lock contention" wait event (see Chapter 14 for detail on locks/latches). It is important to note that though the lock is effectively on a CU, the wait event reported is still a row-level lock. Oracle asserts that performance of UPDATEs and INSERTs with CUs has been improved in 12*c*R2.

Note that you can still use standard table compression for OLTP, and a single block lookup is still generally *faster* than other columnar storage. The updated rows migrate to normal/lower-level compression. HCC fully supports:

- B-tree indexes
- Bitmap indexes
- Text indexes
- Materialized views
- Partitioning
- Parallel queries
- Data Guard physical standby

- Logical standby and Streams (in a future release)
- Smart Scans of HCC tables!

I/O Resource Management

Oracle's latest I/O Resource Management (IORM) tool can be used with Exadata to manage multiple workloads and set resources as you deem necessary. Although I don't cover this in detail here, please consider the following ways that you can set up three instances with different resources. Instance A gets 50 percent, instance B gets 30 percent, and instance C gets 20 percent. You can further break down the 50 percent that instance A gets into the various user- and task-related percentages.

Set I/O resources for different instance

- Instance A = 50%
- Instance B = 30%
- Instance C = 20%

Further set I/O based on users and tasks

- Instance A Interactive = 50%
- Instance A Reporting = 20%
- Instance A Batch = 15%
- Instance A ETL = 15%

You can also continue to use Database Resource Manager (DBRM) as in the past. DBRM has been enhanced for Exadata. It allows management of inter- and intra-database I/O. With inter-database I/O, you manage using IORM and Exadata storage software. For intra-database I/O, you manage using Consumer Groups. You can set limits for CPU, UNDO, degree of parallelism (DOP), active sessions, and much more. Please see the Oracle documentation for more details. This section is only a brief introduction so you can see what's possible.

Use All Oracle Security Advantages with Exadata

Oracle is known for its incredible security. Their first customer was the CIA (Central Intelligence Agency), so they've always been focused on security (for over 30+ years). Don't forget to investigate these security and recovery options that are available with Exadata:

- Audit Vault
- Total Recall/Flashback (recovery)

- Database Vault
- Label security
- Advanced security
- Secure encrypted backup (Please use!) (also available—incremental backup with change tracking file, which is much faster)
- Data masking
- Data Guard (recovery)
- Failure groups (automatic for storage cell failure)

Best Practices

There are many best practices that will help you get the most out of Exadata. I'll start with a list of *must haves* and *don't do's*. Note, however, that these can change at any time, so check Oracle's docs for the latest information.* Here is my list as of the writing of this chapter (late 2016):

- Must have Bundle Patch 5 (see Metalink Note 888828.1 for the latest).
- Must have ASM to use Exadata.
- Must have three floor tiles on a raised floor (must support 2219 lbs./964 kg) with holes (cooling) for a full rack (between 1560 CFM and 2200 CFM front to back—less for a half or quarter rack). You don't want to melt it! All of this is subject to change, so please check the latest specifications.
- Must have the correct power needs (it is not standard).
- Must use Oracle Linux and Oracle DB 11.2 or 12*c* (current).
- Must use RMAN for backups.
- Ensure InfiniBand is connected and MTU is set to 65520.
- Check disk group balance and notes on auto-extend.
- Capture performance baselines *early* in your implementation.
- Consider a ZFS appliance with connectivity over InfiniBand for database backups. If you do so, please make sure to configure the database with Oracle dNFS for maximum benefit.
- Alternatively, consider StorageTek tape backup (many positive reviews but it is pricey).
- Use an ASM allocation unit (AU) size of 4M (currently).
- Don't add any foreign hardware … or *no support!*
- Don't change BIOS/firmware … or *no support!*

Next, I'd like to list some Oracle stated best practices. Note that these can change at any time, as well, so please check your Oracle docs for the latest. Best practices include:

- CREATE ALL celldisk and griddisks.
- Use DCLI to run on *all* storage servers at once (helpful and saves time).
- Use IORM for resource management.
- Decide fast recovery area (FRA) and MAA needs before you install.
- Set log file size at 32G (whoa!).
- To optimize fast scan rates, ensure database extent sizes are at least 4M (locally managed tablespaces [LMTs] can have a uniform or auto-allocate extent policy).
- Move data with Data Pump (usually, but many other options are available).

Summary: Exadata = Paradigm Shift!

I've covered many Exadata topics in this section, including Exadata terminology and basics, Flash Cache, storage indexes, Smart Scans, Hybrid Columnar Compression, I/O Resource Manager, security, and best practices. To summarize, what makes Exadata fast is fast hardware, many CPUs, fast Flash Cache, lots of DRAM on database servers and storage, compression (saves 10×–70×), partition pruning (saves 10×–100×), storage indexes (saves 5×–10×), Smart Scan (saves 4×–10×), and other features not covered (see Oracle Docs for more information). Exadata is the best way to turn a 1T search into a 500M search or even a 50M search. I believe that Exadata is *The Real Deal* and will drive future accelerated hardware innovation by all major hardware vendors.

Oracle Database Appliance (ODA)

Exadata may be overkill for some customers. When Oracle introduced the Oracle Database Appliance, they were thinking about small- and medium-sized businesses (SMBs) and customers that needed departmental servers. The goal of ODA, however, is to have a quickly implemented, mid-sized server. Currently there are two different models where Oracle has one 10-core CPU in the X6-2S (128-384G RAM) and two 10-core CPUs in the X6-2M (256-768G RAM). Both systems come standard with 6.4T Flash (NVMe) that can be expanded to 12.8T and can run on Enterprise Edition (EE) or Standard Edition 2 (SE2) with licensing up to only two CPU cores (to save $$). The ODA X5-2 has two servers for a larger footprint. A database appliance can include:

- Oracle with ASM and RAC running on Oracle Linux
- High-availability fault tolerance—two nodes/dual server
- Cluster in a box (Oracle Clusterware comes installed)
- Oracle Appliance Manager (for quick patching and system management)
- Auto memory management, auto tuning, auto disk backup

The Oracle Database Appliance is now a little beefier since its introduction, but can be ready to go in a *couple of hours* (software and RAC is preloaded). It even has a phone-home capability; it calls for service and has one-button patching. Introducing the Oracle Database Appliance is just another way that Oracle is leveraging its Sun acquisition to create a full line of hardware that benefits its customers. While the hardware itself is inexpensive, the software license cost can certainly add up if you use the maximum CPU configuration, but it's still much lower priced than a quarter rack at the current time (a quarter rack is over 2× faster though). I'm confident that this will evolve over time, so please check with Oracle for the latest configuration and pricing.

SuperCluster Using the M7 SPARC Chip

On September 26, 2011, Oracle announced the new SPARC SuperCluster T4-4 and I thought, "How will they ever top a 1000+ threaded system?" In 2016, new SuperCluster using the M7 SPARC chip includes built-in hardware encryption (on the silicon with near zero overhead), protection from memory attacks (again at the silicon level), up to 512 CPU cores, and 8T of DRAM per rack. It also has HCC for 10–15×+ compression. It was engineered with the 12*c* database and Exadata storage (including those benefits described in the previous Exadata sections). SuperCluster runs the Solaris operating system (Solaris 11 or Solaris 10) with hardware using the new M7 multithreaded SPARC processor.

Oracle is primarily targeting their Solaris install base to migrate to SuperCluster. Oracle's goal is not only to make migrating easy for this install base, but also to give them the speed of Exadata and Exalogic in a single M7 SPARC-based machine. From reviewing the last few sections, you can see that Oracle is leveraging its Sun acquisition with the fastest hardware on earth for parallel database processing (rack(s) of Exadata), fastest middleware server or Internet eBusiness application server machine(s) (rack(s) of Exalogic), large company migration from Solaris to mix of Exadata/Exalogic speed systems (rack(s) of SuperCluster), small business or department server (Oracle Database Appliance(s)), and infinite storage (rack(s) of Exadata Storage Expansion Racks). I'm sure Oracle has already exceeded all of this, even as amazing as it sounded at the time I wrote this. My advice: *Teach your kids Oracle!*

Other Oracle Hardware to Consider

In this section, I cover some of the other hardware that you should at least consider as you implement your business solutions. All of these come from Oracle acquisitions.

Oracle Big Data Appliance X6-2

Oracle Big Data Appliance X6-2 is used to acquire, organize, analyze, and make sense of all the unstructured data in your company or on the Web. *Big data* is all the data associated with weblogs, social media, e-mail, sensors, photographs, videos, and all the other sources of big data that are coming. The Oracle Big Data Appliance is an engineered system that includes an open source version of Apache Hadoop, Oracle NoSQL Database (think of it as version 2 of Oracle, a highly scalable key-value database), Oracle Data Integrator Application Adapter for Hadoop (simplifies data integration in Hadoop), Big Data SQL to connect all data sources querying with SQL (query Hadoop or Hive directly from Oracle SQL), and an open source version of R (Oracle R Enterprise integrates with the open source statistical environment R to deliver advanced analytics). You can also integrate the Oracle Big Data Appliance with the Oracle Database, Exadata, or Exalytics. When you use Oracle's Big Data SQL to query Hadoop, you can apply security and access policies to Hadoop or other NoSQL (NoSQL = Not only SQL) sources. Exadata features such as Smart Scan and storage indexes coexist with Hadoop itself. It runs on Linux and includes Java, MySQL, Big Data Plug-in, Oracle R, Oracle NoSQL, Cloudera Impala, Apache HBase, Apache, Spark, Apache Kafka, Cloudera Hadoop (CDH), and Cloudera Manager. The hardware side includes up to 792 cores (36 × 22-core processors), 14T DRAM, and 1.7P of storage.

ZFS Storage Servers

Sun ZFS Storage ZS4-4 has 6.9P of raw storage capacity. This is a high-performance network attached storage (NAS) system with SAN storage capabilities. It supports an active-active cluster option, supports Oracle Database HCC, and has data compression and inline deduplication. It has 6.9P of raw storage capacity (and can be configured with 3T of read optimized cache) with eight 15-core processors.

With Oracle Database 12*c*, ZFS now uses the Oracle Intelligent Storage Protocol, which watches access patterns and tunes itself for optimal performance. It includes full PDB-level analytics (ZS Analytics) with 12*c*. It also includes Exadata storage features such as HCC. ZFS is an 128-bit file system that can address 16E more data than 64-bit can.

StorageTek Modular Library System

One of the largest companies I know of recently had to recover from tape. Most companies have online fast recovery areas (FRAs) for quick recoveries, as well as online backups located on slower 2T SATA disks. But there is still a place for an offsite tape backup, and StorageTek makes it fast and easy. Looking inside one of these machines is like watching a production assembly line where tapes are moved around as needed automatically. Another benefit of the Sun acquisition was getting this incredible company called StorageTek. It is no surprise that Oracle now archives more data than anyone else in the world.

The StorageTek SL8500, with a maximum configuration of ten libraries (there are many models/sizes to choose from if you need something smaller), includes the ability to back up 500P native or 2.1E (1 Exabyte = 1000P) with a 2.5:1 compression (at a speed of 553 TB/hr). To put this in perspective, a decade ago (around 2005), a business magazine estimated that the average Fortune 1000 company had an average size of 1P for *all* of their databases. That means all Fortune 1000 databases could have been backed up with this device (maximum ten-library configuration) with a 2:1 compression in 2005. You can connect up to 32 of these libraries for a maximum tape backup capacity of 67E. After reading these last few sections, you should start to see the future of Oracle accelerating at the speed of thought!

Parallel Databases

A *parallel clustered database* is a complex application that provides access to the same database (group of data tables, indexes, and other objects) from any server in the cluster concurrently without compromising data integrity. Parallel databases typically contain multiple instances of a database (located on many nodes/servers) accessing the same physical storage or data concurrently. In terms of storage access type, parallel systems are implemented in two ways: a shared-nothing model or a shared-disk model.

In a *shared-nothing* model, also termed a *data-partitioning model*, each system owns a portion of the database and each partition can only be read or modified by the owning system. Data partitioning enables each system to locally cache its portion of the database in processor memory without requiring cross-system communication to provide data access concurrency and coherency controls. Both IBM's and Microsoft's databases can operate this way and have in the past. Perhaps Oracle's adoption of the shared-disk model is what gave them a huge lead in grid computing and will help in the cloud.

In a *shared-disk* model, all the disks containing data are accessible by all nodes of the cluster. Disk sharing architecture requires suitable lock management techniques to control the update concurrency. Each of the nodes in the cluster has direct access to all disks on which shared data is placed. Each node has a local database buffer cache. Oracle's RAC database operates this way.

With due emphasis on high availability and high performance, Oracle has provided Oracle Parallel Server (OPS) for a long time. With Oracle9*i*, it drove into the next generation and rebuilt OPS as Real Application Clusters (RAC). RAC follows the shared-disk model and thus has access to all the shared disks as well as to an extensive mechanism to coordinate the resources across the nodes. Shared-disk technology has advanced rapidly over the past few years, giving RAC added advantages. Storage area network (SAN) technology hides much of the complexity of hardware units, controllers, disk drives, and interconnects from the servers and provides just *storage volumes*. In the same way, a group of servers together in a cluster provides a single system image and computing resource. Oracle's acquisition of Sun only strengthens an already-compelling RAC story.

Real Application Clusters (RAC)

High performance and high availability of information systems constitute key requirements for day-to-day business operations. As the dependence on stored information grew over the last couple of decades, large amounts of data are being accumulated and analyzed. There is an ever-increasing demand for high-performance databases, and at the same time, awareness of and requirements for keeping such databases online all the time has increased. Global operations and e-business growth depend very much on highly available stored data. With uneven and unpredictable loads on the database systems, it has become imperative for many business groups to search for high-performance systems and suitable parallel systems to support complex and large database systems. Scalability is another important feature. As the business grows, data accumulation and data interaction increase. More and more users and applications begin to use the database systems. The database systems should be able to support the increased demand for data without losing ground in performance and scope of availability.

Oracle9*i* introduced Real Application Clusters (RAC) to solve these issues. In Oracle 10*g*, Oracle started to perfect Grid Control for managing clusters of databases. In 11*g*, Oracle introduced *Oracle RAC One Node*. RAC One Node represents an Oracle RAC database that runs only one active Oracle database instance and can be managed using Server Control Utility (SVRCTL) as any Oracle RAC database. You can add nodes that can be used for failover, but you cannot add additional *instances* without first converting Oracle RAC One Node to Oracle RAC. You can convert from single instance to RAC One Node or RAC using Oracle's Database Configuration Assistant (DBCA) at any time. You can use Online Database Relocation with SVRCTL to perform a live migration of the database instance and connections to one of the failover nodes. This gives you the ability to move a database easily from an overworked server to a less-utilized server in the same cluster. RAC One Node helps you to consolidate many databases into one cluster with minimal overhead while also providing the high-availability benefits of client failover, online rolling patch application, and rolling upgrades for the operating system and Oracle Clusterware. Please see the documentation for full details and use. Oracle also enhanced Grid Control to make adding or subtracting nodes as well as managing the cluster infrastructure easier. Oracle 11*g* also adds zero-downtime patching and a 64-bit ASM cluster file system, eliminating the need for a third-party cluster file system. This section by no means covers all aspects of RAC functioning. It merely highlights some important concepts and some of RAC's inner workings. The scope of this book does not cover RAC specifically. You can switch from single-instance Oracle DB to RAC One Node or RAC at any time (if you have the appropriate licenses!). In 12*c* you can use In-Memory to replicate the IM column store on each node in a RAC cluster so that even memory used for analytics is fault-tolerant!

Oracle RAC Architecture

At a very high level, RAC is multiple Oracle instances (on separate nodes) accessing a single Oracle database. The database is a single physical database stored on a shared storage system. Each of the instances resides on a separate host (also called a node or server). All the nodes are clustered through a private interconnect, and all nodes have access to the shared storage. All the nodes concurrently execute transactions against the same database. The cluster manager software, usually supplied by the cluster vendor, provides a single system image, controls node membership, and monitors the node status. Broadly, the major components include:

- Nodes/servers
- High-speed private interconnect (connects the nodes together)
- Cluster Manager or OSD (operating system–dependent layer)
- Shared disk or storage
- Cluster file system or raw devices
- Volume manager
- Public network

- The database software

Cluster Interconnect

If a block of data has been changed in the cache memory on one node and the user asks for it on another node, Oracle uses Cache Fusion to pass one block through the interconnect (such as InfiniBand) to the cache on the other node. Parallel processing relies on passing messages among multiple processors. Processors running parallel programs call for data and instructions and then perform calculations. Each processor checks back periodically with the other nodes or a master node to plan its next move or to synchronize the delivery of results. These activities rely on message-passing software, such as the industry-standard Message Passing Interface (MPI).

In parallel databases, there is a great deal of message passing and data blocks, or pages, transferring to the local cache of another node. Much of the functionality and performance depends on the efficiency of the transport medium or methodology. The transport medium becomes very critical for the overall performance of the cluster and usage of the parallel application. Because parallel databases do not impose any constraints on the nodes to which users can connect and access, users have a choice to connect to any node in the cluster. Irrespective of the nature of the application, OLTP, or data warehousing databases, the movement of data blocks from one node to another using the interconnect is widely practiced. The role of the cluster interconnect to provide some kind of extended cache encompassing the cache from all the nodes is one of the most significant design features of the cluster. In general, the cluster interconnect is used for the following high-level functions:

- Health, status, and synchronization of messages
- Distributed lock manager (DLM) messages
- Accessing remote file systems
- Application-specific traffic
- Cluster alias routing

High performance, by distributing the computations across an array of nodes in the cluster, requires the cluster interconnect to provide a high data transfer rate and low-latency communication between nodes. Also, the interconnect needs to be capable of detecting and isolating faults, and using alternative paths. Some of the essential requirements for the interconnect are

- Low latency for short messages
- High speed and sustained data rates for large messages
- Low host-CPU utilization per message
- Flow control, error control, and heartbeat continuity monitoring
- Host interfaces that execute control programs to interact directly with host processes (OS bypass)
- Switch networks that scale well

Many of the cluster vendors have designed very competitive technology. Many of the interconnect products come close to the latency levels of a symmetric multiprocessing (SMP) bus.

Internal Workings of the Oracle RAC System

Oracle uses Global Cache Services to coordinate activity. A lock is treated as a held resource. RAC is a multi-instance database. Multiple instances access the same database concurrently. In terms of structure, the difference between a RAC instance and a stand-alone Oracle instance is miniscule. Besides all the usual Oracle background processes, many special processes are spawned to coordinate inter-instance communication and to facilitate resource sharing among nodes in a cluster. The Oracle documentation goes through all of the processes if you are interested in knowing more. Here is a brief description of some of the main ones:

- **ACMS** The Atomic Controlfile to Memory Service (ACMS) is an agent on a per-instance basis that helps to ensure a distributed SGA memory update is globally committed on success and globally aborted on failure.
- **LMON** The Global Enqueue Service Monitor (LMON) monitors the entire cluster to manage global enqueues and resources. LMON manages instance and process expirations and the associated recovery for the Global Cache Service.
- **LMD** The Global Enqueue Service Daemon (LMD) is the lock agent process that manages enqueue manager service requests for Global Enqueue Service enqueues to control access to global enqueues and resources. The LMD process also handles deadlock detection and remote enqueue requests.
- **LMSn** These Global Cache Service processes (LMSn) are processes for the Global Cache Service (GCS). RAC software provides for up to ten GCS processes. The number of LMSn processes varies depending on the amount of messaging traffic among nodes in the cluster. The LMSn processes do these things:
  - Handle blocking interrupts from the remote instance for Global Cache Service resources
  - Manage resource requests and cross-instance call operations for shared resources
  - Build a list of invalid lock elements and validate lock elements during recovery
  - Handle global lock deadlock detection and monitor lock conversion timeouts
- **LCK0 process** The Instance Enqueue Process manages global enqueue requests and cross-instance broadcast. Manages non–Cache Fusion and library/row cache requests.
- **RMSn** RAC management processes include tasks like the creation of resources as nodes are added.
- **RSMN** Remote Slave Monitor (RSMN) performs remote instance tasks for a coordinating process.
- **GTX0-j** The Global Transaction Process supports global XA transactions.

Global Cache Service (GCS) and Global Enqueue Service (GES)

GCS and GES (which are basically RAC components) play the key role in implementing Cache Fusion. GCS ensures a single system image of the data even though the data is accessed by multiple instances. GCS and GES are integrated components of Real Application Clusters that coordinate simultaneous access to the shared database and to shared resources within the database and database cache. GES and GCS together maintain a Global Resource Directory (GRD) to record information about resources and enqueues. The GRD remains in memory and is stored on all the instances. Each instance manages a portion of the directory. This distributed nature is a key point for fault tolerance of RAC.

The coordination of concurrent tasks within a shared cache server is called *synchronization***.** Synchronization uses the private interconnect and heavy message transfers. The following types of resources require synchronization: data blocks and enqueues. GCS maintains the modes for blocks in the global role and is responsible for block transfers between instances. LMS processes handle the GCS messages and do the bulk of the GCS processing.

An *enqueue* is a shared memory structure that serializes access to database resources. It can be local or global. Oracle uses enqueues in three modes: null (N) mode, shared (S) mode, and exclusive (X) mode. Blocks are the primary structures for reading and writing into and out of buffers. An enqueue is often the most requested resource.

GES maintains or handles the synchronization of the dictionary cache, library cache, transaction locks, and DDL locks. In other words, GES manages enqueues other than data blocks. To synchronize access to the data dictionary cache, latches are used in exclusive (X) mode and in single-node cluster databases. Global enqueues are used in cluster database mode.

Cache Fusion and Resource Coordination

Because each node in a Real Application Cluster has its own memory (cache) that is not shared with other nodes, RAC must coordinate the buffer caches of different nodes while minimizing additional disk I/O that could reduce performance. Cache Fusion is the technology that uses high-speed interconnects to provide cache-to-cache transfers of data blocks between instances in a cluster. Cache Fusion functionality allows direct memory writes of dirty blocks to alleviate the need to force a disk write and reread (or ping) of the committed blocks. This is not to say that disk writes do not occur; disk writes are still required for cache replacement and when a checkpoint occurs. Cache Fusion addresses the issues involved in concurrency between instances: concurrent reads on multiple nodes, concurrent reads and writes on different nodes, and concurrent writes on different nodes.

Oracle only reads data blocks from disk if they are not already present in the buffer caches of any instance. Because data block writes are deferred, they often contain modifications from multiple transactions. The modified data blocks are written to disk only when a checkpoint occurs. Before I go further, you need to be familiar with a couple of concepts introduced with RAC: resource modes and resource roles. Because the same data blocks can concurrently exist in multiple instances, there are two identifiers that help to coordinate these blocks:

- **Resource mode** The modes are null, shared, and exclusive. The block can be held in different modes, depending on whether a resource holder intends to modify data or merely read it.

- **Resource role** The roles are locally managed and globally managed.

The Global Resource Directory is *not* a database. It is a collection of internal structures and is used to find the current status of the data blocks. Whenever a block is transferred out of a local cache to another instance's cache, the GRD is updated. The following information about a resource is available in the GRD:

- Data Block Identifiers
- Location of most current versions
- Data block modes (N, S, X)
- Data block roles (local or global)

Past Image

To maintain data integrity, a new concept of past image was introduced in the 9*i* version of RAC. A *past image (PI)* of a block is kept in memory before the block is sent and serves as an indication of whether it is a dirty block. In the event of failure, GCS can reconstruct the current version of the block by reading PIs. This PI is different from a CR block, which is needed to reconstruct read-consistent images. The CR version of a block represents a consistent snapshot of the data at a point in time.

For example, Transaction-A of Instance-A has updated row-2 on block-5, and later another Transaction-B of Instance-B has updated row-6 on the same block-5. Block-5 has been transferred from Instance-A to Instance-B. At this time, the past image for block-5 is created on Instance-A.

SCN Processing

System change numbers (SCNs) uniquely identify a committed transaction and the changes it makes. An SCN is a logical timestamp that defines a committed version of a database at one point in time. Oracle assigns every committed transaction a unique SCN.

Within RAC, since you have multiple instances that perform commits, the SCN changes need to be maintained within an instance, but at the same time, they must also be synchronized across all instances with a cluster. Therefore, SCNs are handled by the Global Cache Service using the Lamport SCN generation scheme, or by using a hardware clock or dedicated SCN server. SCNs are recorded in the redo log so recovery operations can be synchronized in RAC.

Is RAC Unbreakable?

Can RAC be brought down? Sure it can. Any bad design or choice will bring it down. Besides the database itself, many components are involved in providing database service. RAC may be up and running, but clients may not be able to reach it. The intermediate network components involved between client machines and database servers may fail. Natural outages that destroy all of the hardware—fire, flood, and earthquake—will make the cluster and database inoperable.

Assuming that failures are localized or contained, however, RAC provides maximum protection and provides continuous database service. Even with the loss of many of the components, a RAC cluster can still function. But it calls for redundant design in terms of all the components involved. Design is the key word. Just setting up two or more nodes is not enough; dual interconnects, dual paths to storage units, dual storage units, dual power supplies, dual public network interfaces, and so on, will create a robust RAC cluster. For example, this table shows the effects of individual component failures:

Component	Effect of Failure	Result
CPU panic/crash	Node failed, other node still active.	Okay
Memory crash	Node failed, other node still active.	Okay
Interconnect	With dual interconnects.	Okay
OS failure/freeze	Node failed, other node still active.	Okay
Cluster Manager s/w	Cluster freezes, all nodes go down. (Chapter 4 details 12c ASM fixes.)	Down
DB instance crash	Instance running on other node provides database service.	Okay
Control file (corrupt/lost)	Multiplexed control file used.	Okay
Redo log file	Multiplexed REDO file.	Okay
Lost datafile	Requires media recovery. (Mirroring could solve this.)	Down
Human error	Depends on type of mistake; Flashback can get you back up and running quickly!	Down
Dropped object	DB is available, but applications stall; Flashback to get back up and running quickly (Flashback PDB in 12c)!	Down
DB software bug	DB may stall on all instances. Rolling patches can keep systems up while fixing this.	Down

As long as one of the Oracle instances is available in the cluster, client applications have data access and can execute their applications without any problems. Oracle Exadata makes many of these events of the past non-issues because Exadata machines are already designed for dual components and high availability.

Summary

This section by no means covers all aspects of RAC internal functioning. It merely highlights some important concepts and some of the inner workings of RAC (subject to change, of course).

Understanding special RAC requirements and implementation of the global shared cache helps you properly plan RAC implementation and its usage. An entire book is needed to cover RAC fully, but the next few sections should help you with tuning RAC.

RAC Performance Tuning Overview

Performance issues related to a RAC implementation should focus on the following areas *in the order listed:*

- Traditional database tuning and monitoring (most of this book)
- RAC cluster interconnect performance (this chapter and Chapter 5)
- Monitoring workload performance (most of this book, especially Chapter 5)
- Monitoring contention uniquely associated with RAC (this chapter)
- Prior to tuning RAC-specific operations, tuning each instance separately:
  - APPLICATION tuning
  - DATABASE tuning
  - OS tuning
- Begin tuning RAC

Normal or traditional database monitoring is covered in other areas of this book (especially Chapter 5). Aspects of database performance related to RAC are covered in this chapter. After tuning each instance individually, then focus on the processes that communicate through the cluster interconnect.

RAC Cluster Interconnect Performance

The most complex aspect of RAC tuning involves monitoring and the subsequent tuning of processes associated with the Global Resources Directory (GRD). The group of processes associated with the GRD is the Global Enqueue Service (GES) and the Global Cache Service (GCS). The GRD processes communicate through the cluster interconnects. If the cluster interconnects are not configured to process data packets efficiently, then the entire RAC implementation performs poorly. This is true regardless of performance-related tuning and configuration efforts in other areas.

Finding RAC Wait Events—Sessions Waiting

You can monitor sessions that wait on nonidle wait events that impact interconnect traffic with a query that lists GCS waits using the global dynamic performance view GV$SESSION_WAIT. You may also see these waits in a Statspack or AWR Report. The following are the major waits being monitored:

Wait	Wait Description
global cache busy	A wait event that occurs whenever a session has to wait for an ongoing operation on the resource to complete.
gc buffer busy	A wait event that is signaled when a process has to wait for a block to become available because another process is obtaining a resource for this block.
buffer busy global CR	A wait on a consistent read (block needed for reading) via the global cache.

To identify the sessions experiencing waits on the system, perform the following tasks:

1. Query GV$SESSION_WAIT to determine whether any sessions are experiencing RAC-related waits (at the current time).
2. Identify the objects that are causing contention for these sessions.
3. Try to modify the object or query to reduce contention.

For example, query GV$SESSION_WAIT (shown next) to determine whether any sessions are experiencing RAC cache–related waits. Note that the GV$ views are used much more to show statistics for the entire cluster, whereas the V$ views still show statistics from a single node. If you plan to use RAC, you must extend the V$ views and queries to the GV$ views for multiple nodes. This section is only an initial guide to help you see all of the components. The scope of this book does not cover RAC specifically, but some things that will help you tune RAC.

```
SELECT  inst_id, event, p1 FILE_NUMBER, p2 BLOCK_NUMBER, WAIT_TIME
FROM    gv$session_wait
WHERE   event IN ('buffer busy global cr', 'global cache busy',
        'buffer busy global cache');
```

The output from this query should look something like this:

```
INST_ID EVENT                               FILE_NUMBER BLOCK_NUMBER  WAIT_TIME
------- ----------------------------------- ----------- ------------ ----------
      1 global cache busy                             9          150         15
      2 global cache busy                             9          150         10
```

Run this query to identify objects that are causing contention for these sessions and the object that corresponds to the file and block for each FILE_NUMBER/BLOCK_NUMBER combination returned (this query is a bit slower):

```
SELECT owner, segment_name, segment_type
FROM   dba_extents
WHERE  file_id = 9
AND    150 BETWEEN block id AND block id+blocks-1;
```

The output is similar to

```
OWNER      SEGMENT_NAME                  SEGMENT_TYPE
---------- ----------------------------- ---------------
SYSTEM     MOD TEST IND                  INDEX
```

Modify the object to reduce the chances for application contention by doing the following:

- Reduce the number of rows per block.
- Adjust the block size to a smaller block size.
- Modify INITRANS and FREELISTS.

RAC Wait Events and Interconnect Statistics

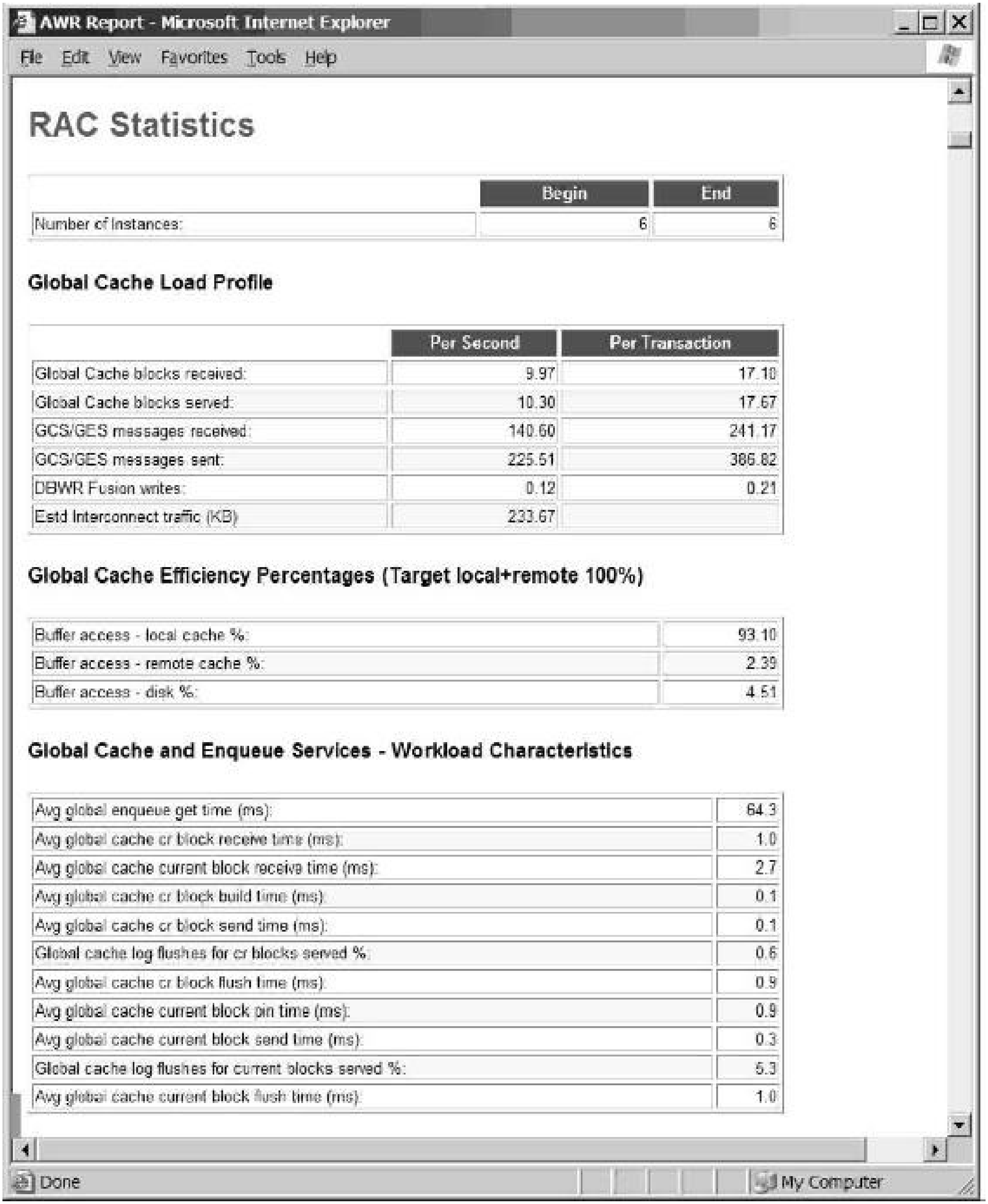
The RAC events are listed next in the Statspack or AWR Report if you are running RAC (multiple instances). As stated earlier, you need to run a Statspack or AWR Report for *each* instance that you have. For Statspack, you run the `statspack.snap` procedure and the `spreport.sql` script on each node you want to monitor to compare to other instances. One of the best methods for seeing if a node is operating efficiently is to compare the report from that node to one from another node that accesses the same database. I cover Cloud Control tuning in Chapter 5. Remember that single-instance tuning should be performed before attempting to tune the processes that communicate via the cluster interconnect—this is very important! In other words, tune the system in single instance before you move it to RAC.

Some of the top wait events that you may encounter are listed briefly next; wait events are covered in more detail in Chapter 14. The top global cache (gc) waits to look out for include:

- **gc current block busy** Happens when an instance requests a CURR (current version of a block) data block (wants to do some DML) and the block to be transferred is in use. A block cannot be shipped if Oracle hasn't written the REDO for the block changes to the log file.
- **gc buffer busy** A wait event that occurs whenever a session has to wait for an ongoing operation on the resource to complete because the block is in use. The process has to wait for a block to become available because another process is obtaining a resource for this block.
- **gc cr request/gc cr block busy** This happens when one instance is waiting for blocks from another instance's cache (sent via the interconnect). This wait says that the current instance

can't find a consistent read (CR) version of a block in the local cache. If the block is not in the remote cache, then a db file sequential read wait will also follow this one. Tune the SQL that is causing large amounts of reads that get moved from node to node. Try to put users who are using the same blocks on the same instance so blocks are not moved from instance to instance. Some non-Oracle application servers move the same process from node to node looking for the fastest node (unaware that they are moving the same blocks from node to node). Pin these long processes to the same node. Potentially increase the size of the local cache if slow I/O combined with a small cache is the problem. Monitor V$CR_BLOCK_SERVER to see if an issue like reading UNDO segments is occurring. Correlated to the waits, the values for P1,P2,P3 are file, block, lenum, respectively. For the value for P3, lenum, look in V$LOCK_ELEMENT for the row where LOCK_ELEMENT_ADDR has the same value as lenum. This happens when an instance requests a CR data block and the block to be transferred hasn't arrived at the requesting instance. This wait is the one I see the most, and it's usually because the SQL is poorly tuned and *many* index blocks are being moved back and forth between instances.

Figure 11-19 shows the AWR Report RAC Statistics section. You can see that there are six instances (nodes) in this cluster. You can also see things like the number of blocks sent and received as well as how many of the blocks are being accessed in the local cache (93.1 percent) versus the disk or another instance. As you would guess, accessing blocks in the local cache is faster, but accessing one of the remote caches on one of the other nodes is almost always faster (given a fast enough interconnect and no saturation of the interconnect) than going to disk.


AWR Report - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Done
My Computer

RAC Statistics

	Begin	End
Number of Instances:	6	6

Global Cache Load Profile

	Per Second	Per Transaction
Global Cache blocks received:	9.97	17.18
Global Cache blocks served:	10.30	17.67
GCS/GES messages received:	140.60	241.17
GCS/GES messages sent:	225.51	386.82
DBWR Fusion writes:	0.12	0.21
Estd Interconnect traffic (KB)	233.67	

Global Cache Efficiency Percentages (Target local+remote 100%)

Buffer access - local cache %:	93.10
Buffer access - remote cache %:	2.39
Buffer access - disk %:	4.51

Global Cache and Enqueue Services - Workload Characteristics

Avg global enqueue get time (ms):	64.3
Avg global cache cr block receive time (ms):	1.0
Avg global cache current block receive time (ms):	2.7
Avg global cache cr block build time (ms):	0.1
Avg global cache cr block send time (ms):	0.1
Global cache log flushes for cr blocks served %:	0.6
Avg global cache cr block flush time (ms):	0.9
Avg global cache current block pin time (ms):	0.9
Avg global cache current block send time (ms):	0.3
Global cache log flushes for current blocks served %:	5.3
Avg global cache current block flush time (ms):	1.0

FIGURE 11-19. *The AWR Report RAC Statistics section*

The following is another valuable query to derive session wait information. The INSTANCE_ID lists the instance where the waiting session resides. The SID is the unique identifier for the waiting session (GV$SESSION). The P1, P2, and P3 columns list event-specific information that may be useful for debugging. LAST_SQL lists the last SQL executed by the waiting session.

```
SET NUMWIDTH 10
COLUMN STATE FORMAT a7 tru
COLUMN EVENT FORMAT a25 tru
COLUMN LAST_SQL FORMAT a40 tru
SELECT sw.inst_id INSTANCE_ID, sw.sid SID, sw.state STATE, sw.event EVENT,
       sw.seconds_in_wait SECONDS_WAITING, sw.p1, sw.p2, sw.p3,
       sa.sql_text LAST_SQL
FROM   gv$session_wait sw, gv$session s, gv$sqlarea sa
WHERE  sw.event NOT IN ('rdbms ipc message','smon timer','pmon timer',
        'SQL*Net message from client','lock manager wait for remote message',
        'ges remote message', 'gcs remote message', 'gcs for action',
        'client message', 'pipe get', 'null event', 'PX Idle Wait',
        'single-task message', 'PX Deq: Execution Msg',
        'KXFQ: kxfqdeq - normal dequeue', 'listen endpoint status',
        'slave wait','wakeup time manager')
AND    sw.wait_time_micro > 0
AND    (sw.inst_id = s.inst_id and sw.sid = s.sid)
AND    (s.inst_id = sa.inst_id and s.sql_address = sa.address)
ORDER BY seconds_waiting DESC;
```

Here is a query that gives a description of the parameter names of the events seen in the last section:

```
COLUMN EVENT  FORMAT a30 tru
COLUMN p1text FORMAT a25 tru
COLUMN p2text FORMAT a25 tru
COLUMN p3text FORMAT a25 tru
SELECT DISTINCT event EVENT, p1text, p2text, p3text
FROM   gv$session_wait sw
WHERE sw.event NOT IN ('rdbms ipc message','smon timer','pmon timer',
      'SQL*Net message from client','lock manager wait for remote message',
      'ges remote message', 'gcs remote message', 'gcs for action',
      'client message','pipe get', 'null event', 'PX Idle Wait',
      'single-task message', 'PX Deq: Execution Msg',
      'KXFQ: kxfqdeq - normal dequeue','listen endpoint status',
      'slave wait','wakeup time manager')
AND   wait_time_micro > 0
ORDER BY event;
```

Some of the contents of the GV$SESSION_WAIT view are as follows:

Column	Data Type	Description
INST_ID	NUMBER	Number of the instance in the RAC configuration.
SID	NUMBER	Session identifier.
SEQ#	NUMBER	Sequence number that uniquely identifies this wait, incremented for each wait.

EVENT	VARCHAR2(64)	Resource or event for which the session is waiting.
P1TEXT	VARCHAR2(64)	Description of the first additional parameter.
P1	NUMBER	First additional parameter.
P1RAW	RAW(4)	First additional parameter.
P2TEXT	VARCHAR2(64)	Description of the second additional parameter.
P2	NUMBER	Second additional parameter.
P2RAW	RAW(4)	Second additional parameter.
P3TEXT	VARCHAR2(64)	Description of the third additional parameter.
P3	NUMBER	Third additional parameter.
P3RAW	RAW(4)	Third additional parameter.
WAIT_CLASS_ID	NUMBER	Identifier of the wait class.
WAIT_CLASS#	NUMBER	Number of the wait class.
WAIT_CLASS	VARCHAR2(64)	Name of the wait class.
WAIT_TIME	NUMBER	A nonzero value is the session's last wait time in hundredths of seconds. A zero value means the session is currently waiting; a negative 1 means it was less than a hundredth of a second (see WAIT_TIME_MICRO); a negative 2 means TIME_STATISTICS=FALSE.
SECONDS_IN_WAIT	NUMBER	If WAIT_TIME = 0, then SECONDS_IN_WAIT is the seconds spent in the current wait condition. If WAIT_TIME > 0, then SECONDS_IN_WAIT is the seconds since the start of the last wait, and SECONDS_IN_WAIT – WAIT_TIME/100 is the active seconds since the last wait ended. This column is being deprecated in favor of WAIT_TIME_MICRO.
STATE	VARCHAR2(19)	State.
WAIT_TIME_MICRO	NUMBER	Amount of time (microseconds) in current wait if waiting, and amount of time since the start of the last wait if not currently waiting. This column is replacing the SECONDS_IN_WAIT column, which is being deprecated.
TIME_REMAINING_MICRO	NUMBER	If NULL, session is not waiting. If > 0, it's the time remaining to wait for current wait to end. If = 0, process timed out. If negative 1, session may wait indefinitely.
TIME_SINCE_LAST_WAIT_TIME_MICRO	NUMBER	The value is 0 if session is currently waiting; otherwise, it's the time in microseconds since the last wait.

True proof of how much faster the database is in recent releases is evident with the move from waits being measured in seconds to waits being measured in microseconds.

TIP
Use V$SESSION_WAIT or GV$SESSION_WAIT, Statspack, or the AWR Report to find RAC wait events.

GES Lock Blockers and Waiters

Sessions that are holding global locks that persistently block others can be problematic to a RAC implementation and are, in many instances, associated with application design. Sessions waiting on a lock to release cannot proceed (hang) and are required to poll the blocked object to determine status. Large numbers of sessions holding global locks will create substantial interconnect traffic and inhibit performance. The following queries will help you find blocking sessions:

```
-- GES LOCK BLOCKERS:
--INSTANCE_ID    The instance on which a blocking session resides
--SID            Unique identifier for the session
--GRANT_LEVEL    Lists how GES lock is granted to user associated w/ blocking session
--REQUEST_LEVEL  Lists the status the session is attempting to obtain
--LOCK_STATE     Lists current status the lock has obtained
--SEC            Lists how long this session has waited

SET numwidth 10
COLUMN LOCK_STATE FORMAT a16 tru;
COLUMN EVENT FORMAT a30 tru;

SELECT dl.inst_id INSTANCE_ID, s.sid SID ,p.spid SPID,
   dl.resource_name1 RESOURCE_NAME,
   decode(substr(dl.grant_level,1,8),'KJUSERNL','Null','KJUSERCR','Row-S (SS)',
   'KJUSERCW','Row-X (SX)','KJUSERPR','Share','KJUSERPW','S/Row-X (SSX)',
   'KJUSEREX','Exclusive',request_level) AS GRANT_LEVEL,
   decode(substr(dl.request_level,1,8),'KJUSERNL','Null','KJUSERCR','Row-S (SS)',
   'KJUSERCW','Row-X (SX)','KJUSERPR','Share','KJUSERPW','S/Row-X (SSX)',
   'KJUSEREX','Exclusive',request_level) AS REQUEST_LEVEL,
   decode(substr(dl.state,1,8),'KJUSERGR','Granted','KJUSEROP','Opening',
   'KJUSERCA','Canceling','KJUSERCV','Converting') AS LOCK_STATE,
   s.sid, sw.event EVENT, sw.wait_time_micro SEC
FROM   gv$ges_enqueue dl, gv$process p, gv$session s, gv$session_wait sw
WHERE  blocker = 1
AND   (dl.inst_id = p.inst_id and dl.pid = p.spid)
AND   (p.inst_id = s.inst_id and p.addr = s.paddr)
AND   (s.inst_id = sw.inst_id and s.sid = sw.sid)
ORDER BY sw.wait_time_micro DESC;


GES LOCK WAITERS:
--INSTANCE_ID    The instance on which a blocking session resides
--SID            Unique identifier for the session
--GRANT_LEVEL    Lists how GES lock is granted to user associated w/ blocking session
```

```
--REQUEST_LEVEL  Lists the status the session is attempting to obtain
--LOCK_STATE     Lists current status the lock has obtained
--SEC            Lists how long this session has waited

SET numwidth 10
COLUMN LOCK_STATE FORMAT a16 tru;
COLUMN EVENT FORMAT a30 tru;

SELECT dl.inst_id INSTANCE_ID, s.sid SID, p.spid SPID,
   dl.resource_name1 RESOURCE_NAME,
   decode(substr(dl.grant_level,1,8),'KJUSERNL','Null','KJUSERCR','Row-S (SS)',
   'KJUSERCW','Row-X (SX)','KJUSERPR','Share','KJUSERPW','S/Row-X (SSX)',
   'KJUSEREX','Exclusive',request_level) AS GRANT_LEVEL,
   decode(substr(dl.request_level,1,8),'KJUSERNL','Null','KJUSERCR','Row-S (SS)',
   'KJUSERCW','Row-X (SX)','KJUSERPR','Share','KJUSERPW','S/Row-X (SSX)',
   'KJUSEREX','Exclusive',request_level) AS REQUEST_LEVEL,
   decode(substr(dl.state,1,8),'KJUSERGR','Granted','KJUSEROP','Opening',
   'KJUSERCA','Canceling','KJUSERCV','Converting') AS LOCK_STATE,
    s.sid,sw.event EVENT, sw.wait_time_micro SEC
FROM   gv$ges_enqueue dl, gv$process p,gv$session s,gv$session_wait sw
WHERE  blocked = 1
AND   (dl.inst_id = p.inst_id and dl.pid = p.spid)
AND   (p.inst_id = s.inst_id and p.addr = s.paddr)
AND   (s.inst_id = sw.inst_id and s.sid = sw.sid)
ORDER BY sw.wait_time_micro DESC;
```

Cache Fusion Reads and Writes

Cache Fusion reads occur when a user on one system queries a block and then a user on another system queries the same block. The block is passed over the high-speed interconnect (versus being read from disk). *Cache Fusion writes* occur when a block previously changed by another instance needs to be written to disk in response to a checkpoint or cache aging. When this occurs, Oracle sends a message to notify the other instance that a fusion write will be performed to move the data block to disk. Fusion writes do not require an additional write to disk and are a subset of all physical writes incurred by an instance. The ratio DBWR fusion writes to physical writes shows the proportion of writes that Oracle manages with fusion writes.

Here is a query to determine ratio of Cache Fusion writes:

```
SELECT A.inst_id "Instance",
       A.VALUE/B.VALUE "Cache Fusion Writes Ratio"
FROM   GV$SYSSTAT A, GV$SYSSTAT B
WHERE  A.name='DBWR fusion writes'
AND    B.name='physical writes'
AND    B.inst_id=a.inst_id
ORDER  BY A.INST_ID;
```

Here is some sample output:

```
Instance Cache Fusion Writes Ratio
--------- ------------------------
        1                .216290958
        2                .131862042
```

A larger than usual value for Cache Fusion writes ratio may indicate:

- Insufficiently large caches
- Insufficient checkpoints
- Large numbers of buffers written due to cache replacement or checkpointing

Cluster Interconnect Tuning—Hardware Tier

Cluster interconnect tuning is a very important piece of the clustered configuration. Oracle depends on the cluster interconnect for movement of data between the instances. Using a dedicated private network for the interconnect is extremely important.

The speed of the cluster interconnect solely depends on the hardware vendor and the layered operating system. Oracle, in its current version, depends on the operating system and the hardware for sending packets of information across the cluster interconnect. For example, one type of cluster interconnect supported between Sun Fire 4800s is the User Datagram Protocol (UDP). However, Solaris on this specific version of the interconnect protocol has an OS limitation of a 64K packet size used for data transfer. To transfer 256K worth of data across this interconnect protocol would take this configuration over four round trips. On a high-transaction system where you have a large amount of interconnect traffic, this could cause a serious performance issue.

After the initial hardware and operating system level tests to confirm the packet size across the interconnect, perform subsequent tests from the Oracle database to ensure that there is not any significant added latency using cache-to-cache data transfer or the Cache Fusion technology. The query that follows provides the average latency of a consistent block request on the system. The data in these views are a cumulative figure since the last time the Oracle instance was bounced. The data from these views do not reflect the true performance of the interconnect or give a true picture of the latency in transferring data. To get a more realistic picture of performance, bounce all the Oracle instances and test again. To obtain good performance, the latency across the cluster interconnect must be as low as possible. Latencies on the cluster interconnect could be caused by

- Large number of processes in the run queues waiting for CPU or scheduling delays
- Platform-specific OS parameter settings that affect IPC buffering or process scheduling
- Slow, busy, or faulty interconnects

Oracle recommends that the average latency of a consistent block request typically should not exceed 15 milliseconds, depending on the system configuration and volume. When you are sending many blocks across the interconnect, this figure is really too high (especially since going to disk is usually this fast). For a high-volume system, latency should be in the single-digit millisecond-to-microsecond range. The average latency of a consistent block request is the average latency of a consistent read request roundtrip from the requesting instance to the holding instance and back to the requesting instance.

```
set numwidth 20
column "AVG CR BLOCK RECEIVE TIME (ms)" format 9999999.9
select b1.inst id, b2.value "GCS CR BLOCKS RECEIVED",

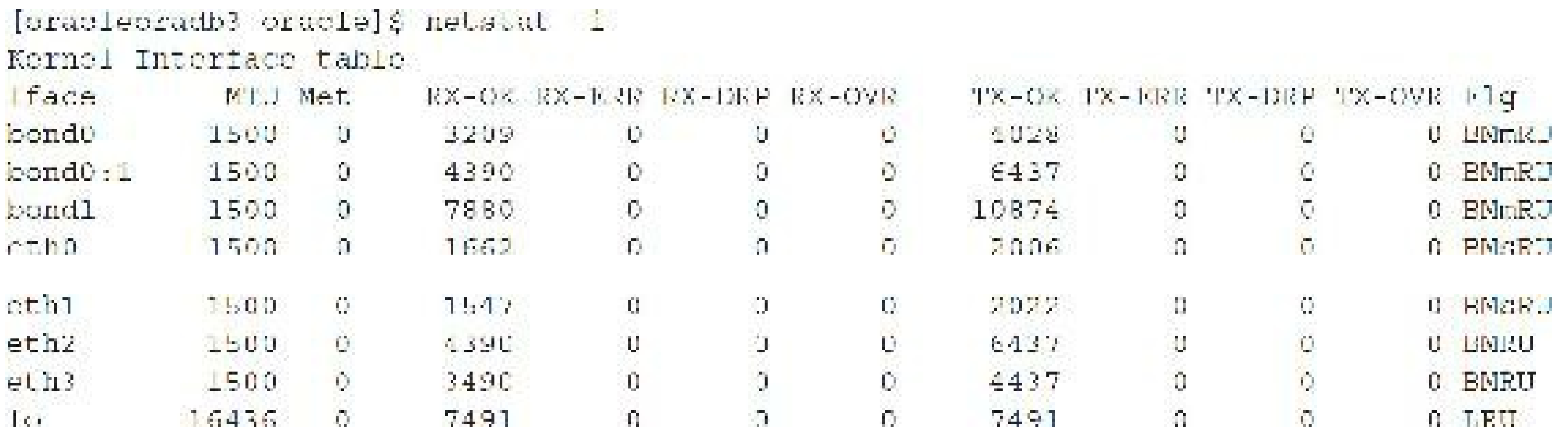
       b1.value "GCS CR BLOCK RECEIVE TIME",
       ((b1.value / b2.value) * 10) "AVG CR BLOCK RECEIVE TIME (ms)"
from   gv$sysstat b1, gv$sysstat b2
where  b1.name = 'gc cr block receive time'
and    b2.name = 'gc cr blocks received'
and    b1.inst id = b2.inst id
and    b2.value <> 0;

INST ID GCS CR BLOCKS RECEIVED GCS CR BLOCK RECEIVE TIME  AVG CR BLOCK RECEIVE TIME (ms)
------- ---------------------- ------------------------- ------------------------------
      1                   2758                    122394                         443.78
      2                   1346                      1457                           10.8

2 rows selected.
```

In the preceding output, notice that the AVG CR BLOCK RECEIVE TIME is 443.78 (ms); this is significantly high when the expected average latency, as recommended by Oracle, should not exceed 15 (ms). A high value is possible if the CPU has limited idle time and the system typically processes long-running queries. However, an average latency of less than one millisecond with user-mode IPC is possible. Latency can also be influenced by a high value for the DB_MULTI_BLOCK_READ_COUNT parameter. This is because a requesting process can issue more than one request for a block, depending on the setting of this parameter. Correspondingly, the requesting process may have to wait longer. This kind of high latency requires further investigation of the cluster interconnect configuration and that tests be performed at the operating system level. When such high latencies are experienced over the interconnect, another good test is to perform a test at the operating system level by checking the actual ping time. Checking the ping time helps to determine if there are any issues at the OS level. After all, the performance issue may not be from data transfers within the RAC environment.

Apart from the basic packet transfer tests that you can perform at the database level, you can undertake other checks and tests to ensure that the cluster interconnect has been configured correctly. There are redundant private high-speed interconnects between the nodes participating in the cluster. Implementing network interface card (NIC) bonding or pairing helps interconnect load balancing and failover when one of the interconnects fails. The user network connection does not interfere with the cluster interconnect traffic. That is, they are isolated from each other. At the operating system level, the `netstat` and `ifconfig` commands display network-related data structures. In 12*c*, Oracle has Redundant Interconnect Usage. Oracle Grid Infrastructure and Oracle RAC can now make use of redundant network interconnects, without using other network technology, to enhance optimal communication in the cluster. Redundant Interconnect Usage enables load-balancing and high availability across multiple (up to four) private networks (also known as *interconnects*). The output that follows, from `netstat-i`, indicates that four network adapters are configured and NIC pairing is implemented:



```
[oracle@oradb3 oracle]$ netstat -i
Kernel Interface table
Iface       MTU Met    RX-OK RX-ERR RX-DRP RX-OVR    TX-OK TX-ERR TX-DRP TX-OVR Flg
bond0      1500   0     3209      0      0      0     4028      0      0      0 BMmRU
bond0:1    1500   0     4390      0      0      0     6437      0      0      0 BMmRU
bond1      1500   0     7880      0      0      0    10874      0      0      0 BMmRU
eth0       1500   0     1662      0      0      0     2006      0      0      0 BMsRU

eth1       1500   0     1547      0      0      0     2022      0      0      0 BMsRU
eth2       1500   0     4390      0      0      0     6437      0      0      0 BMRU
eth3       1500   0     3490      0      0      0     4437      0      0      0 BMRU
lo        16436   0     7491      0      0      0     7491      0      0      0 LRU
```

The values in the IFACE column are defined as follows:

- **bond0** The public interconnect created using the bonding functionality (bonds Eth0 and Eth1).
- **bond0:1** The Virtual IP (VIP) assigned to bond0.
- **bond1** A private interconnect alias created using bonding functionality (bonds ETH2 and ETH3).
- **ETH0 and ETH1** The physical public interfaces that are bonded/paired together (bond0).
- **ETH2 and ETH3** The physical private interfaces that are bonded/paired together (bond1).
- **lo** This is the loopback; that is, the output also indicates that a loopback option is configured. Verify whether Oracle is using the loopback option using the ORADEBUG command, which is discussed later in this section. The use of the loopback IP depends on the integrity of the routing table defined on each of the nodes. Modifying the routing table can result in the inoperability of the interconnect.

Also found in the preceding `netstat` output is the maximum transmission unit (MTU), which is set at 1500 bytes (this is a standard setting for UDP). MTU definitions do not include the data-link header. However, packet-size computations include data-link headers. The maximum packet size displayed by the various tools is MTU plus the data-link header length. To get the maximum benefit from the interconnect, MTU should be configured to the highest possible value supported. For example, a setting as high as 9K using jumbo frames would improve interconnect bandwidth and data transmission.

Apart from the basic packet transfer tests that you could perform at the OS level, you can undertake other checks and tests to ensure that the cluster interconnect has been configured correctly. Perform checks from the Oracle instance to ensure proper configuration of the interconnect protocol. If the following commands are executed as user SYS, a trace file is generated in the user dump destination directory that contains certain diagnostic information pertaining to the UDP/IPC configurations. (See

Chapter 13 for more on the DEBUG functionality.) Please do not use this until you read the Oracle documentation on it.

```
SQL> ORADEBUG SETMYPID
      ORADEBUG IPC
```

The following is the extract from the trace file pertaining to the interconnect protocol. The output confirms that the cluster interconnect is being used for instance-to-instance message transfer:

```
SSKGXPT 0x3671e28 flags SSKGXPT_READPENDING     info for network 0
        socket no 9      IP 172.16.193.1        UDP 59084
        sflags SSKGXPT WRITESSKGXPT UP
        info for network 1
        socket no 0      IP 0.0.0.0      UDP 0

        sflags SSKGXPT_DOWN
context timestamp 0x4402d
        no ports
```

The preceding output is from a Sun Fire 4800 and indicates the IP address and that the protocol used is UDP. On certain operating systems such as Tru64 (now discontinued) the trace output does not reveal the cluster interconnect information. The following NDD Unix command at the operating system level confirms the actual UDP size definition. The following output is from a SUN environment:

```
oradb1:RAC1:oracle # ndd -get /dev/udp
name to get/set ? udp_xmit_hiwat
value ?
length ?
8192
name to get/set ? udp_recv_hiwat
value ?
length ?
8192
```

This output reveals that the UDP has been configured for an 8K packet size. Applying this finding to the data gathered from Oracle's views indicates that it would take 14,050 trips for all the blocks to be transferred across the cluster interconnect (112,394/8 =14,050). If this were set to be 64K, then the number of roundtrips would be significantly reduced (112,394/64 = 1756 trips).

Another parameter that affects the interconnect traffic is DB_FILE_MULTIBLOCK_READ_COUNT. This parameter helps read a certain number of blocks at a time from disk. When data needs to be transferred across the cluster interconnect, this parameter determines the size of the block that each instance would request from the other during read transfers.

Sizing this parameter should be based on the interconnect latency and the packet sizes as defined by the hardware vendor and after considering operating system limitations (for example, the Sun UDP max setting is only 64K). The following kernel parameters define the UDP parameter settings:

- UDP_RECV_HIWAT
- UDP_XMIT_HIWAT

Setting these parameters to 65536 each increases the UDP buffer size to 64K.

Another parameter, CLUSTER_INTERCONNECTS, provides Oracle information on the availability of additional cluster interconnects that you could use for Cache Fusion activity across the cluster interconnect. The parameter overrides the default interconnect settings at the operating system level with a preferred cluster traffic network. While this parameter does provide certain advantages on systems where high interconnect latency is noticed by helping reduce such latency, configuring this parameter could affect the interconnect high-availability feature. In other words, an interconnect failure that is normally unnoticeable could instead cause an Oracle cluster failure as Oracle still attempts to access the network interface. The parameter also overrides the network classifications stored by `OIFCFG` in the Oracle Cluster Registry (OCR).

Resource Availability

Resources available on any machine or node or to an Oracle instance are limited, meaning they are not available in abundance, and if a process on the system needs them, they may not be immediately available. A physical limit is imposed on the amount of resources available on any system. For example, the processor resources are limited by the number of CPUs available on the system, and the amount of memory or cache area is limited by the amount of physical memory available on the system. Now, for an Oracle process, this is further limited by the actual amount of memory allocated to the SGA. Within the SGA, the shared pool, the buffer cache, and so on, are again preallocated from the shared pool area. These memory allocations are used by a regular single-instance configuration.

In a RAC environment, there are no parameters to allocate any global-specific resources, for example, global cache size or global shared pool area. Oracle allocates a certain portion of the available resources from the SGA for global activity. The availability of global resources can be monitored using the view GV$RESOURCE_LIMIT.

Parallel Operations

Using parallel operations enables multiple processes (and potentially processors) to work together simultaneously to resolve a single SQL statement. This feature improves data-intensive operations, is dynamic (the execution path is determined at run time), and (when wisely implemented) makes use of all of your processors and disk drives. There are some overhead costs and administrative requirements, but using parallel operations can improve the performance of many queries.

Basic Concepts of Parallel Operations

Consider a full table scan. Rather than have a single process execute the table scan, Oracle can create multiple processes to scan the table in parallel. The number of processes used to perform the scan is called the *degree of parallelism (DOP)*. The degree can be set in a hint at the time of table creation or as a hint in the query. Figure 11-20 shows a full table scan of the EMP table broken into four separate parallel query server processes. (The degree of parallelism is four.) A fifth process, the query coordinator, is created to coordinate the four parallel query server processes.

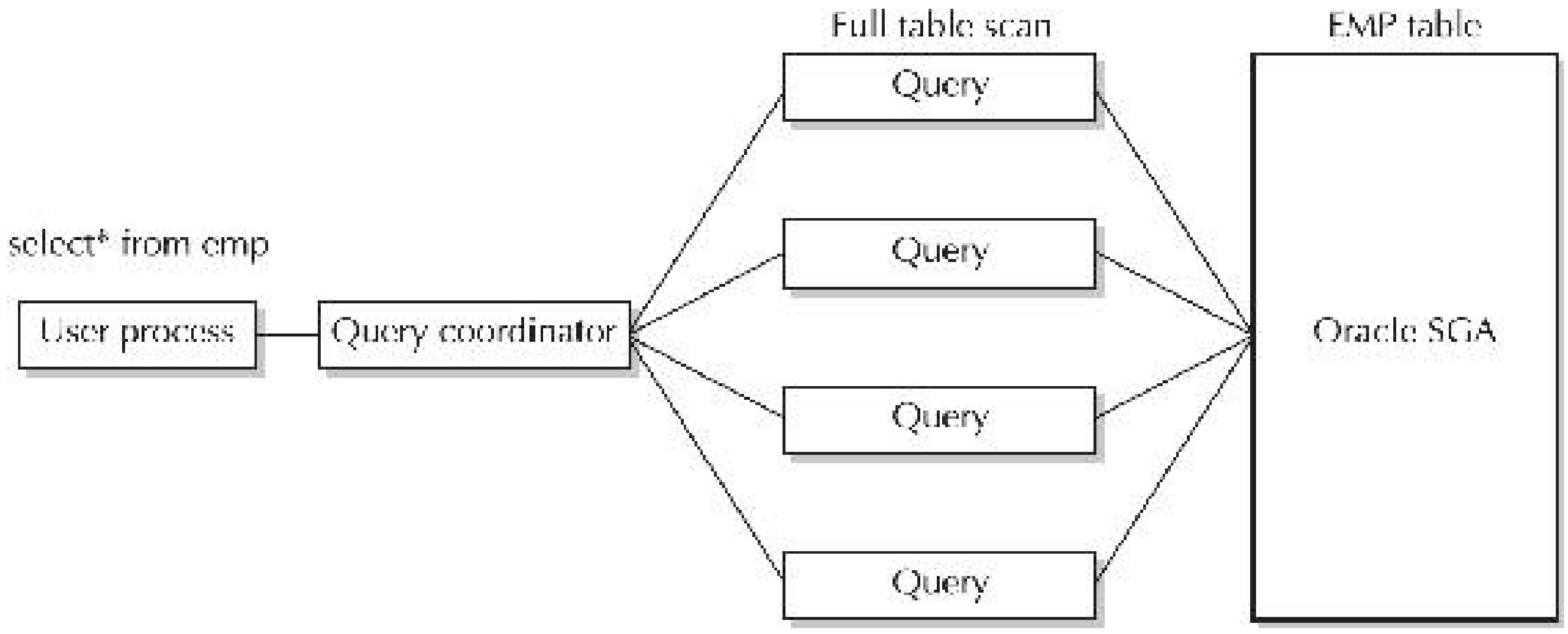


FIGURE 11-20. *A simple full table scan with parallel execution (disk access not shown)*

If the rows returned by the full table scan shown in Figure 11-20 also need to be sorted, the resulting operation will look like Figure 11-21 instead. Now Oracle may use one process to coordinate the query, four processes to run the query, and four processes to sort the query. The total is now nine processes, although the degree of parallelism is still 4. If you have nine processors (CPUs), your machine can use all nine processors for the operation (depending on your system setup and other operations that are being performed at the same time). If you have fewer than nine processors available, you may encounter some CPU bottleneck issues as Oracle manages the query.

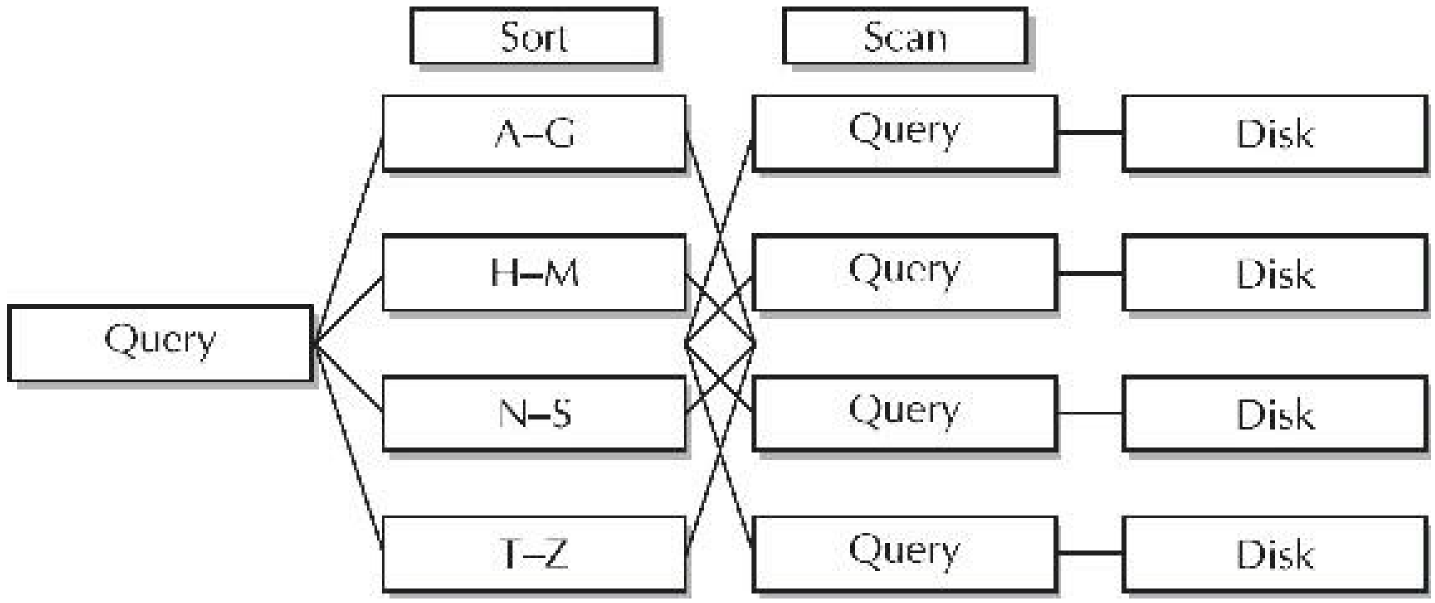


FIGURE 11-21. *Simple full table scan requiring a sort with parallel execution (SGA not shown)*

Because the query coordination parts of the operation take resources, fast-running queries are not usually enhanced (and may be degraded) with the use of parallel operations.

TIP
Using parallel operations on very small tables or very fast queries can also degrade performance because the query coordination may also cost performance resources. You should evaluate whether the parallel cost exceeds the nonparallelized cost.

Both queries in Figure 11-20 and Figure 11-21 require access to the physical disks to retrieve data, which is then brought into the SGA. Balancing data on those disks based on how the query is “broken up” makes a large I/O difference.

TIP
When the parallel degree is set to N, *it is possible to use (2*N) + 1 total processes for the parallel operation. Although parallel operations deal with processes and not processors, when a large number of processors are available, Oracle generally uses the additional processors to run parallel queries, often enhancing the performance of the query.*

Parallel DML and DDL Statements and Operations

Oracle supports parallelization of both DDL and DML operations. Oracle can parallelize the following operations on tables and indexes:

- SELECT
- UPDATE, INSERT, DELETE
- MERGE
- CREATE TABLE AS
- CREATE INDEX
- REBUILD INDEX
- MOVE/SPLIT/COALESCE PARTITION
- ENABLE CONSTRAINT

The following operations can also be parallelized within a statement:

- SELECT DISTINCT
- GROUP BY
- ORDER BY
- NOT IN
- UNION and UNION ALL
- CUBE and ROLLUP
- Aggregate functions such as SUM and MAX
- NESTED LOOPS joins
- SORT-MERGE joins
- Star transformations

Oracle uses the cost-based optimizer to determine whether to parallelize a statement and to determine the degree of parallelism applied. Most operations can be parallelized, including queries, DML, and DDL operations. Intrapartition parallelism is also supported; multiple parallel query server processes can execute against the same partition.

The degree of parallelism may be limited by a number of factors. Although the partitioning strategy does not play as significant a role for parallelism, you should still be aware of other limiting factors:

- The number of processors available on the server
- That you still need to have the partition option enabled, and UPDATE, DELETE, and MERGE are parallelized only for partitioned tables
- The number of parallel query server processes allowed for the instance, set via the PARALLEL_MAX_SERVERS initialization parameter
- The parallel degree limit supported for your user profile if you use the Database Resource

Manager

- The number of parallel query server processes used by other users in the instance
- The setting for the PARALLEL_ADAPTIVE_MULTI_USER parameter, which may limit your parallelism in order to support other users (if used; note that it is deprecated in 12*c*)

Monitoring your parallel operations in multiuser environments to guarantee they are allocated the resources that you planned for them to use is important. The Database Resource Manager can help allocate resources.

Managing Parallel Server Resources and Parallel Statement Queuing

If you use the Database Resource Manager to manage parallel server resources, and a consumer group uses up all its assigned resources, Oracle might be forced to downgrade the parallelism of the parallel statements issued by users assigned to that consumer group. You configure the allocation of parallel server resources for a consumer group with the PARALLEL_TARGET_PERCENTAGE directive. This directive specifies the maximum percentage of the parallel server pool that a particular consumer group can use.

In 12*c*, Oracle has parallel statement queuing, which offers the following features:

- When no more parallel servers are available, the parallel statement is queued. The parallel statement is dequeued and processed as parallel servers are freed up.
- A resource plan can be used to control the order of the parallel statement queue. When parallel servers are freed up, the resource plan is used to select a consumer group. The parallel query at the head of its queue is run.
- Parallel servers can be reserved for critical consumer groups.

This feature adds stability to the execution of SQL statements in parallel, but can introduce an additional wait time for parallel statements if the database server is running at full capacity. For a parallel statement to be queued, the following conditions must be met:

- The PARALLEL_DEGREE_POLICY initialization parameter is set to AUTO.
- The number of active parallel servers across all consumer groups exceeds the value of the PARALLEL_SERVERS_TARGET initialization parameter.
- The sum of the number of active parallel servers for the consumer group and the degree of parallelism of the parallel statement exceeds the target number of active parallel servers. In other words, (V$RSRC_CONSUMER_GROUP.CURRENT_PQ_SERVERS_ACTIVE + DOP of statement) > (PARALLEL_TARGET_PERCENTAGE/100 * PARALLEL_SERVERS_TARGET).

You can also use the NO_STATEMENT_QUEUING and STATEMENT_QUEUING hints in SQL statements to manage parallel statement queuing.

Parallelism and Partitions

Oracle's partitioning feature can have a significant impact on parallel operations. *Partitions* are logical divisions of table data and indexes, and partitions of the same table or index can reside in multiple tablespaces. Given this architecture, the following important distinctions exist with parallel operations on partitions:

- Operations are performed in parallel on partitioned objects *only* when more than one partition is accessed.
- If a table is partitioned into 12 logical divisions and a query executed against the table accesses only 6 of those partitions (because the dimension of the data dictates the partition in which the data is stored), a maximum of 6 parallel server processes can be allocated to satisfy the query. When partition granules are used to access a table or index, the maximum allowable DOP is the number of partitions (*block range granules* are the basic unit of *most* parallel operations, even on partitioned tables; *partition granules* are the basic unit of parallel index range scans, joins between two equipartitioned tables, parallel operations that modify multiple partitions of a partitioned object, and partitioned table/index creation).

Inter- and Intra-operation Parallelization

Due to the distribution of data, the processor allocated to each parallel server process, and the speed of devices servicing the parallel server data request, each parallel query server process may complete at a different time. As each server process completes, it passes its result set to the next lower operation in the statement hierarchy. Any single parallel server process may handle or service statement operation requests from any other parallel execution server at the next higher level in the statement hierarchy.

TIP
Any server process allocated for a statement may handle any request from a process within the same statement. Therefore, if some processes are faster than others, the ones that are faster can process the rows produced by the child set of parallel execution processes as soon as they are available instead of waiting for the ones that are slower (but only at the next higher statement hierarchy level).

The optimizer evaluates a statement and determines how many parallel query server processes to use during its execution. This intra-operation parallelization is different from interoperation parallelization. *Intra-operation parallelization* is dividing a single task within a SQL statement, such as reading a table, among parallel execution servers. When multiple parts of a SQL statement are performed in parallel, the results from one set of parallel execution servers are passed to another set of parallel execution servers. This is known as *interoperation parallelization***.**

The degree of parallelism is applied to each operation of a SQL statement that can be parallelized, including the sort operation of data required by an ORDER BY clause. As shown earlier in Figure 11-21, a query with a degree of parallelism of 4 may acquire up to nine processes.

Examples of Using Inter- and Intra-operations (PARALLEL and NO_PARALLEL Hints)

You can parallelize SQL statements via a SQL hint or with the object-level options declared for the table or index. The following listing illustrates a statement hint:

```
select      /*+ parallel (ORDER_LINE_ITEMS) */
            Invoice_Number, Invoice_Date
from        ORDER_LINE_ITEMS
order by    Invoice_Date;
```

The preceding statement does *not* specify a degree of parallelism. The default degree of parallelism dictated by the table definition or the initialization parameters will be used. When you create a table, you can specify the degree of parallelism to use for the table, as shown here:

```
create table ORDER_LINE_ITEMS
            (Invoice_Number  NUMBER(12) not null,
             Invoice_Date    DATE not null)
parallel 4;
```

When you execute queries against the ORDER_LINE_ITEMS table without specifying a degree of parallelism for the query, Oracle uses 4 as the default degree. To override the default, specify the new value within the PARALLEL hint, as shown in this next listing. Also shown in the listing is the PARALLEL_INDEX hint, whose only difference from the PARALLEL hint is that the index name is also specified.

```
select      /*+ parallel (ORDER_LINE_ITEMS, 6) */
            Invoice_Number, Invoice_Date
from        ORDER_LINE_ITEMS
order by    Invoice_Date;
select      /*+ parallel_index (ORDER_LINE_ITEMS, invoice_number_idx, 6) */
            Invoice_Number, Invoice_Date
from        ORDER_LINE_ITEMS
where       Invoice_Number = 777
order by    Invoice_Date;
```

This listing specifies a degree of parallelism of 6. As many as 13 parallel execution servers may be allocated or created to satisfy this query.

To simplify the hint syntax, use table aliases, as shown in the following listing. If you assign an alias to a table, you must use the alias, not the table name, in the hint.

```
select      /*+ parallel (oli, 4) */
            Invoice_Number, Invoice_Date
from        ORDER_LINE_ITEMS oli
order by    Invoice_Date;
```

TIP
Using the PARALLEL hint enables the use of parallel operations. If you use the PARALLEL hint but do not specify the degree of parallelism with the hint or set it at the table level, the query still executes in parallel, but the DOP is calculated from the initialization parameters.

You can also "turn off" the use of parallel operations in a given query on a table that has been specified to use parallel operations. The ORDER_LINE_ITEMS table has a default degree of parallelism of 4, but the query shown here overrides that setting via the NO_PARALLEL hint:

```
select      /*+ no_parallel (oli) */
            Invoice_Number, Invoice_Date
from        ORDER_LINE_ITEMS oli
order by    Invoice_Date;
```

TIP
The use of the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.

To change the default degree of parallelism for a table, use the PARALLEL clause of the ALTER TABLE command:

```
alter table order_line_items
parallel (degree 4);
```

To disable parallel operations for a table, use the NOPARALLEL clause of the ALTER TABLE command (notice that there is an underscore with the hint, but none with the clause below):

```
alter table order_line_items
noparallel;
```

The coordinator process evaluates the following in determining whether to parallelize the statement:

- Hints contained in the SQL statement
- Session values set via the ALTER SESSION FORCE PARALLEL command
- Tables/indexes defined as parallel as well as table/index statistics

You are advised to specify an explicit degree of parallelism either in the SQL statement itself or in the table definition. You can rely on default degrees of parallelism for many operations, but for performance management of time-sensitive operations, you should specify the degree of parallelism using a hint.

TIP
Specify the degree of parallelism using a hint instead of relying on the table definition to ensure that all operations are tuned for the given query.

Creating Table and Index Examples Using Parallel Operations

To further illustrate the application of parallel operations in SQL statements, consider the implementations of parallel operations for table and index creation shown in the following listings.

Using parallel operations for table creation

```
create table ORDER_LINE_ITEMS
tablespace tbsp1
storage (initial 75m next 75m pctincrease 0)
parallel (degree 4)
as
select      /*+ parallel (OLD_ORDER_LINE_ITEMS,4) */ *
from        OLD ORDER LINE ITEMS;
```

Using parallel operations for index creation

```
create index ORDER KEY on ORDER LINE ITEMS (Order Id, Item Id)
tablespace idx1
storage (initial 10m next 1m pctincrease 0)
parallel (degree 5) NOLOGGING;
```

The CREATE INDEX statement creates the ORDER_KEY index using parallel sort operations. The CREATE TABLE statement creates a new table ORDER_LINE_ITEMS with a degree of parallelism of 4 by selecting from an existing OLD_ORDER_LINE_ITEMS table using a parallel operation. In the preceding table creation listing, two separate operations within the CREATE TABLE command are taking advantage of parallelism: the query of the OLD_ORDER_LINE_ITEMS table is parallelized, and the insert into ORDER_LINE_ITEMS is parallelized.

NOTE
Although parallel queries increase the performance of operations that modify data, the redo log entries are written serially and could cause a bottleneck. By using the NOLOGGING option, you can avoid this bottleneck during table and index creation.

Because the writes to the redo log files are serial, redo log writes may effectively eliminate the parallelism you have defined for your statements. Using NOLOGGING forces the bulk operations to avoid logging, but individual INSERT commands are still written to the redo log files. If you use the NOLOGGING option, you must have a way to recover your data other than via the archived redo log files.

TIP
Use NOLOGGING to remove the I/O bottleneck caused by serial writes to the redo logs.

Up to this point, I have ignored the physical location of the data queried in the example SELECT statements. If a full-scanned table's data is all contained on a single disk, you may succeed only in creating a huge I/O bottleneck on the disk. An underlying principle of the performance gains that you can achieve using parallel operations is that the data is stored on different devices, all capable of being addressed independently of one another.

TIP
Make sure your data is properly distributed or the parallel query server processes may add to existing I/O bottleneck problems.

Not only that, but using the Parallel Execution Option (PEO) may make your system perform *worse*. If your system has processing power to spare but has an I/O bottleneck, using PEO will generate more I/O requests faster, creating a larger queue for the I/O system to manage. If you already have an I/O bottleneck, creating more processes against that same bottleneck will not improve your performance. You need to redesign your data distribution across your available I/O devices.

TIP
Parallel processes commonly involve disk accesses. If the data is not distributed across multiple disks, using the Parallel Execution Option (PEO) may lead to an I/O bottleneck.

Returning to the CREATE INDEX statement shown earlier in the "Using parallel operations for index creation" listing, consider the following tips:

- Index creation uses temporary tablespace if there is not enough memory available to perform the sort in memory (SORT_AREA_SIZE). Construct the temporary tablespace in such a way that the physical datafile are striped across at least as many disks as the degree of parallelism of the CREATE INDEX statement.
- When adding/enabling a primary or unique key for a table, you cannot create the associated index in parallel. Instead, create the index in parallel first and then use ALTER TABLE to add/enable the constraint and specify the USING INDEX clause. For this to work, the index must have the same name and columns as the constraint.

Monitoring Parallel Operations via the V$ Views

The V$ dynamic performance views are always a great place for instance monitoring and evaluating the current performance of the database; parallel operations are no exception. The key performance views for monitoring parallel execution at a system level are V$PQ_TQSTAT and V$PQ_SYSSTAT. In general, V$ views beginning with *V$PQ* give statistics and DBA information (mostly tuning information) whereas the *V$PX* views give details at the process level about parallel sessions and operations (mostly the mechanics). In the following sections, you will see examples of the most commonly used V$ views for monitoring parallel operations.

V$PQ_SYSSTAT

V$PQ_SYSSTAT provides parallel statistics for all parallelized statement operations within the instance. V$PQ_SYSSTAT is ideal for evaluating the number of servers executing currently high-water mark levels and the frequency of startup and shutdown of parallel servers. The following listing illustrates the statistics found on a freshly started instance and then a query run where there was a degree of parallelism of 4:

```
select      Statistic, Value
from        V$PQ_SYSSTAT;

STATISTIC                   VALUE
--------------------- -------
Servers Busy                    4
Servers Idle                    0
Servers Highwater               4
Server Sessions                 4
Servers Started                 0
Servers Shutdown                0
Servers Cleaned Up              0
...
```

As you can see, four parallel execution servers were used and no new processes were started.

Query V$PQ_SYSSTAT after a SELECT on a table defined with a hint specifying a parallel degree of 5. The following listing illustrates V$PQ_SYSSTAT output following the query. Note the values for Servers Busy and Servers Highwater.

```
select      Statistic, Value
from        V$PQ_SYSSTAT;

STATISTIC                    VALUE
---------------------- -------
Servers Busy                     5
Servers Idle                     0
Servers Highwater                8
Server Sessions                 20
Servers Started                  5
Servers Shutdown                 4
Servers Cleaned Up               0
Queries Queued                   0
Queries Initiated                1
Queries Initiated (IPQ)          0
DML Initiated                    2
DML Initiated (IPQ)              0
...
```

In this case, the hint has overridden the default degree of parallelism defined for the table, using five parallel query server processes.

TIP
A PARALLEL hint overrides the degree of parallelism defined for a table when determining the degree of parallelism for an operation.

V$PQ_SESSTAT

To provide the current session statistics, query the V$PQ_SESSTAT view. Use this view to see the number of queries executed within the current session, as well as the number of DML operations parallelized. Here's a sample output of a simple query from this view:

```
select Statistic, Last_Query, Session_Total
from   V$PQ SESSTAT;

STATISTIC                  LAST_QUERY  SESSION_TOTAL
-------------------------  ----------  -------------
Queries Parallelized                0              1
DML Parallelized                    1              2
DDL Parallelized                    0              0
DFO Trees                           1              3
Server Threads                      6              0
Allocation Height                   6              0
Allocation Width                    0              0
Local Msgs Sent                    27            171
Distr Msgs Sent                     0              0
Local Msgs Recv'd                  27            167
Distr Msgs Recv'd                   0              0
```

The output shown in V$PQ_SESSTAT refers only to the current session, so it is most useful when performing diagnostics during testing or problem resolution processes. Note that V$PX_SESSTAT has a similar name but a completely different set of columns. V$PX_SESSTAT joins session information from V$PX_SESSION with the V$SESSTAT table. V$PX_SESSION can also give information on the process requested degree (REQ_DEGREE) as compared to the actual degree (DEGREE) that ends up being used. A listing of V$ views related to parallel operations is given in the section "Other Parallel Notes" at the end of this chapter.

The next listing shows a simple example of querying V$PX_SESSTAT. In this example, if you tried to execute a parallel query where the specified degree of parallelism (12) is greater than PARALLEL_MAX_SERVERS (10), you might see the following:

```
Select      DISTINCT Req_Degree, Degree
from        V$PX_SESSTAT;

        REQ_DEGREE             DEGREE
------------------ ------------------
                12                 10
```

The V$PX_SESSTAT view is populated only while a parallel operation is executing; as soon as the parallel operation finishes, the contents of this view are cleared.

Using EXPLAIN PLAN and AUTOTRACE on Parallel Operations

You can use the EXPLAIN PLAN command to see tuned parallel statements. When you create a PLAN_TABLE for your database (via the `utlxplan.sql` script in the /rdbms/admin subdirectory under the Oracle software home directory), Oracle includes columns that allow you to see how parallelism affects the query's execution path. The information about the parallelization of the query is found in the OBJECT_NODE, OTHER_TAG, and OTHER columns in PLAN_TABLE.

TIP
New columns may be added to the PLAN_TABLE with each new release of Oracle. You should drop and re-create your PLAN_TABLE following each upgrade of the Oracle kernel. If you upgrade an existing database to a new version of Oracle, you should drop your old PLAN_TABLE and re-execute the `utlxplan.sql` *script to see all of the new PLAN_TABLE columns. You can also view the plan using Oracle Enterprise Manager in the SQL Details page.*

The OBJECT_NODE column is the name of the database link used to reference the object. The OTHER column provides information about the query server processes involved. The OTHER_TAG column describes the function of the OTHER column's entries. The OTHER column contains a derived SQL statement—either for a remote query or for parallel query operations.

Table 11-3 shows the possible values for OTHER_TAG and their associated OTHER values.

Value	Description
PARALLEL_COMBINED_WITH_CHILD	The parent of this operation performs the parent and child operations together; OTHER is NULL.
PARALLEL_COMBINED_WITH_PARENT	The child of this operation performs the parent and child operations together; OTHER is NULL.
PARALLEL_TO_PARALLEL	The SQL in the OTHER column is executed in parallel, and results are returned to a second set of query server processes.
PARALLEL_TO_SERIAL	The SQL in the OTHER column is executed in parallel, and the results are returned to a serial process (usually the query coordinator).
PARALLEL_FROM_SERIAL	The SQL operation consumes data from a serial operation and outputs it in parallel; OTHER is NULL.
SERIAL	The SQL statement is executed serially (the default); the OTHER column is NULL.
SERIAL_FROM_REMOTE	The SQL in the OTHER column is executed at a remote site.

TABLE 11-3. *Possible Values for PLAN_TABLE.OTHER_TAG for Parallel Operations*

When an operation is parallelized, it may be partitioned to multiple query server processes based on ranges of ROWID values; the ranges are based on contiguous blocks of data in the table. You can use the OTHER_TAG column to verify the parallelism within different query operations, and you can see the parallelized query in the OTHER column. For example, the query in this next listing forces a MERGE JOIN to occur between the CUSTOMERS and SALES tables; because a MERGE JOIN involves full table scans and sorts, multiple operations can be parallelized. You can use the OTHER_TAG column to show the relationships between the parallel operations.

```
Alter table sales parallel (degree 4);
Alter table customers parallel (degree 4);
select /*+ FULL(customers) FULL(sales) USE_MERGE(customers sales)*/
       customers.cust_last_Name, sales.amount_sold
  from customers, sales
 where customers.cust_ID = sales.cust_ID
   and sales.time_ID = to_date('18-AUG-01', 'DD-MON-YY');
```

Next, you can see the partial EXPLAIN PLAN for the MERGE JOIN query:

```
MERGE JOIN
   SORT JOIN
      PARTITION RANGE SINGLE
        TABLE ACCESS FULL SALES
    SORT JOIN
     TABLE ACCESS FULL CUSTOMERS
```

As shown in the plan, Oracle performs a full table scan (TABLE ACCESS FULL) on each table, sorts the results (using the SORT JOIN operations), and merges the result sets. The query of PLAN_TABLE in the next listing shows the OTHER_TAG for each operation. The query shown in the listing following the OTHER_TAG for each operation generates the EXPLAIN PLAN listings.

```
select
  LPAD(' ',2*Level)||Operation||' '||Options
                ||' '||Object_Name   Q_Plan, Other_Tag
from PLAN_TABLE
where Statement_ID = 'TEST'
connect by prior ID = Parent_ID and Statement_ID = 'TEST'
start with ID=1;
```

The result of the query for the MERGE JOIN example is shown here:

```
Q_PLAN                                    OTHER_TAG
----------------------------------------- ---------------------------------------
  PX COORDINATOR
    PX SEND QC (RANDOM) :TQ10001          PARALLEL_TO_SERIAL
      MERGE JOIN                          PARALLEL_COMBINED_WITH_PARENT
        SORT JOIN                         PARALLEL_COMBINED_WITH_PARENT
          PX RECEIVE                      PARALLEL_COMBINED_WITH_PARENT
            PX SEND BROADCAST :TQ10000    PARALLEL_TO_PARALLEL
              PX BLOCK ITERATOR           PARALLEL_COMBINED_WITH_CHILD
                TABLE ACCESS FULL SALES   PARALLEL_COMBINED_WITH_PARENT
        SORT JOIN                         PARALLEL_COMBINED_WITH_PARENT
          PX BLOCK ITERATOR               PARALLEL_COMBINED_WITH_CHILD
            TABLE ACCESS FULL CUSTOMERS   PARALLEL_COMBINED_WITH_PARENT
```

You can see (by their OTHER_TAG values) that each of the TABLE ACCESS FULL operations is parallelized and provides data to a parallel sorting operation. The SORT JOIN operations are PARALLEL_COMBINED_WITH_PARENT (their "parent" operation is the MERGE JOIN). The MERGE JOIN operation is PARALLEL_TO_SERIAL (the merge is performed in parallel; output is provided to the serial query coordinator process).

The OBJECT_NODE column values display information about the query server processes involved in performing an operation. The following listing shows the OBJECT_NODE column for the TABLE ACCESS FULL of CUSTOMERS operation performed for the MERGE JOIN query:

```
set long 1000
select Object_Node
  from PLAN_TABLE
 where Operation||' '||Options = 'TABLE ACCESS FULL'
   and Object_Name = 'CUSTOMERS';

OBJECT_NODE
-----------
:Q15000
```

As shown in this listing, the OBJECT_NODE column references a parallel query server process. (Q15000 is an internal identifier Oracle assigned to the process for this example.)

TIP
When using the EXPLAIN PLAN command for a parallelized query, you cannot rely on querying just the operations-related columns to see the parallelized operations within the EXPLAIN PLAN. At a minimum, you should query the OTHER_TAG column to see which operations are performed

in parallel.

Oracle provides a second script, `utlxplp.sql`, also located in the /rdbms/admin subdirectory under the Oracle software home directory. The `utlxplp.sql` script queries the PLAN_TABLE, with emphasis on the parallel query data within the table. You must create the PLAN_TABLE (via the `utlxplan.sql` script) and populate it (via the EXPLAIN PLAN command) prior to running the `utlxplp.sql` script.

TIP
When using EXPLAIN PLAN for parallel operations, use the `utlxplp.sql` *script to view the PLAN_TABLE.*

Using the SET AUTOTRACE ON/OFF Command

You can have the EXPLAIN PLAN automatically generated for every transaction you execute within SQL*Plus. The `set autotrace on` command causes each query, after being executed, to display both its execution path and high-level trace information about the processing involved in resolving the query.

To use the `set autotrace on` command, you must have first created the PLAN_TABLE table within your account. When using the `set autotrace on` command, you do not set a STATEMENT_ID, and you do not have to manage the records within the PLAN_TABLE. To disable the AUTOTRACE feature, use the `set autotrace off` command.

If you use the `set autotrace on` command, you will not see the EXPLAIN PLAN for your queries until *after* they complete—unless you specify TRACEONLY. The EXPLAIN PLAN command shows the execution paths without running the queries first. Therefore, if the performance of a query is unknown, use the EXPLAIN PLAN command before running it. If you are fairly certain that the performance of a query is acceptable, use `set autotrace on` to verify its execution path.

The next listing shows the effect of the `set autotrace on` command. When a MERGE JOIN query is executed, the data is returned from the query followed by the EXPLAIN PLAN. The EXPLAIN PLAN is in two parts: the first part shows the operations involved, and the second part shows the parallel-related actions. Here, you can see the first part of the AUTOTRACE output.

```
set autotrace on
select     /*+ parallel (ORDER_ITEMS) */
           order_id
from       order_items
order by   quantity;

            ORDER_ID
--------------------
                2454 (Partial listing…)
777 rows selected.

Execution Plan
----------------------------------------------------------
Plan hash value: 701983758
-----------------------------------------------------------------------------------------------
---------------------
| Id  | Operation              | Name          | Rows  | Bytes | Cost (%CPU)| Time
|    TQ  |IN-OUT| PQ Distrib |
-----------------------------------------------------------------------------------------------
---------------------
|   0 | SELECT STATEMENT       |               |   777 |  5320 |     3  (34)| 00:00:01
|        |      |            |
|   1 |  PX COORDINATOR        |               |       |       |            |          |
|        |      |
|   2 |   PX SEND QC (ORDER)   | :TQ10001      |   777 |  5320 |     3  (34)| 00:00:01 |  Q1,01
| P->S | QC (ORDER) |
|   3 |    SORT ORDER BY       |               |   777 |  5320 |     3  (34)| 00:00:01 |  Q1,01
| PCWP |      |
|   4 |     PX RECEIVE         |               |   777 |  5320 |     2   (0)| 00:00:01 |  Q1,01
| PCWP |      |
|   5 |      PX SEND RANGE     | :TQ10000      |   777 |  5320 |     2   (0)| 00:00:01 |  Q1,00
| P->P | RANGE      |
|   6 |       PX BLOCK ITERATOR |              |   777 |  5320 |     2   (0)| 00:00:01 |  Q1,00
| PCWC |      |
|   7 |        TABLE ACCESS FULL| ORDER_ITEMS  |   777 |  5320 |     2   (0)| 00:00:01 |  Q1,00
| PCWP |      |
-----------------------------------------------------------------------------------------------
---------------------
```

The AUTOTRACE output shows the operations and the objects on which they act. The information near the far right (*Q1* and so on) identifies the parallel query servers used during the query. The AUTOTRACE also shows the step ID values to describe the parallelism of the execution path's operations, as shown here (this one you can read from bottom to top).

Tuning Parallel Execution and the Initialization Parameters

Parameters related to physical memory are generally set much higher in a database that uses parallel operations than in a nonparallel environment. If you are using MEMORY_TARGET (sets memory for PGA/SGA), you should set it higher for a system using parallel operations. Many of the related parameters (detailed here) are set automatically, but you may want to set minimums. See Chapter 4 for information on setting MEMORY_TARGET and other initialization parameters. The settings shown in Table 11-4 are general parameter settings, but your settings must be based on your unique business environment. Also note that OPTIMIZER_PERCENT_PARALLEL and ENQUEUE_RESOURCES (deprecated in 10.2 and removed in 11*g*) are obsolete and thus not shown in this table.

Initialization Parameter	Meaning	Suggested Values
COMPATIBLE	Setting this parameter to the release level of the instance allows you to take advantage of all of the functionality built into the RDBMS engine. Oracle recommends backing up the database *before* changing this parameter!	Generally set to the default value for the database version. Standby databases must use a consistent setting for both the primary and standby.
DB_FILE_MULTIBLOCK_READ_COUNT*	Determines how many blocks are read at once during a full table scan. Improves the performance of parallel operations using table scans.	OS-dependent. On Windows and Linux this is 128.
PARALLEL_DEGREE_LIMIT	Sets the maximum DOP a statement can have when automatic DOP is used.	This is based on CPU threads and instances. Lower if DOP starts overloading system.
DML_LOCKS*	Sets the maximum number of DML locks acquired for the database. The default value assumes an average of four tables referenced per transaction.	Default value is 4*TRANSACTIONS. Increase to support parallel DML.

PARALLEL_ADAPTIVE_MULTI_USER	Reduces the degree of parallelism based on number of active parallel users and prevents overload.	Potentially set this to FALSE and control parallel resources with the Database Resource Manager instead if needed (deprecated in 12*c*).
PARALLEL_EXECUTION_MESSAGE_SIZE	Specifies the size of messages for all parallel operations to communicate among themselves. Larger values than the default will require a larger shared pool size or related memory setting.	OS-dependent; values range from 2148 to 65535. Setting this parameter to a larger value than the default leads to better throughput for parallel operations but uses more memory, which may cause performance problems for nonparallel operations or applications.
PARALLEL_MAX_SERVERS	Maximum number of parallel query server processes allowed to exist simultaneously.	Set higher for more parallel processes, but if you set it too high, shortages could occur.
PARALLEL_FORCE_LOCAL	Whether a parallel operation is restricted to a single instance in a RAC environment.	Default value is FALSE and recommended value is FALSE. Performance degradation could occur if this is set to TRUE at times, so be careful.
PARALLEL_MIN_PERCENT	If this percentage of the degree of parallelism (number of servers) required by the query is not available, statement will terminate with an error (ORA-12827). This is effective when a serial execution of the statement is undesired.	Default value is 0, range of values is 0–100. If 0, parallel operations will always execute in parallel. If 100, operations execute in parallel only if all servers can be acquired.
PARALLEL_MIN_SERVERS	Minimum number of servers created when instance originates. As servers idle out or terminate, the number of servers never falls below this number.	0 to OS limit. Realistically, start with 10–24 depending on resources. Consider changing if V$ views show too heavy use of parallel queries. *Set this parameter!*

PARALLEL_THREADS_PER_CPU	Specifies the default degree of parallelism for the instance, based on the number of parallel execution processes a CPU can support during parallel operations.	Any nonzero number; default is OS-dependent. This "number x CPUs" is the number of threads used in parallel operations.
RECOVERY_PARALLELISM	Number of recovery processes that will be devoted to instance or media recovery.	A value between 2 and PARALLEL_MAX_SERVERS. A value of 0 or 1 indicates that serial recovery will be performed.
TRANSACTIONS*	Specifies the number of concurrent transactions, which will increase if parallel DML is extensively used.	Default value is derived from SESSIONS setting. Increase to support parallel DML.

*Has an indirect effect on parallel options.

TABLE 11-4. *Oracle 12c Parallel Initialization Parameters*

NOTE
Table 11-4 is a limited list; see the Oracle docs for more settings.

TIP
Be sure your environment is properly configured to support the increase in processes, memory, and transactions generated by parallel operations.

The parameters in the initialization file define and shape the environment used by parallel operations. You enable parallel operations for your commands by using a PARALLEL hint on a SQL statement or using the PARALLEL clause during a CREATE/ALTER table command. When you are considering adjusting any initialization parameter (or removing deprecated parameters), fully investigate the *Oracle Database Administrator's Guide, 12*c, the *Oracle Database Upgrade Guide, 12*c, or the appropriate server installation guide for your system *prior* to experimenting with an Oracle database.

Parallel Loading

To use parallel data loading, start multiple SQL*Loader sessions using the PARALLEL keyword. Each session is an independent session requiring its own control file. This listing shows three separate direct path loads, all using the PARALLEL=TRUE parameter on the command line:

```
sqlldr USERID=SCOTT/PASS CONTROL=P1.CTL DIRECT=TRUE PARALLEL=TRUE
sqlldr USERID=SCOTT/PASS CONTROL=P2.CTL DIRECT=TRUE PARALLEL=TRUE
sqlldr USERID=SCOTT/PASS CONTROL=P3.CTL DIRECT=TRUE PARALLEL=TRUE
```

Each session creates its own log, bad, and discard files (`p1.log`, `p1.bad`, etc.) by default. You can have multiple sessions loading data into different tables, but the APPEND option is still required. APPEND is very fast because it fills only unused blocks. The SQL*Loader REPLACE, TRUNCATE, and INSERT options are not allowed for parallel data loading. If you need to delete the data using SQL commands, you must manually delete the data.

TIP
*If you use parallel data loading, indexes are not maintained by the SQL*Loader session unless you are loading a single table partition. Before starting a parallel loading process, you must drop all indexes on the table and disable all of its PRIMARY KEY and UNIQUE constraints. After the parallel loads completely, you need to re-create or rebuild the table's indexes. Inserting data using APPEND and UNRECOVERABLE is the fastest way to insert data into a table without an index. External tables may provide faster extract, transform, and load (ETL) operations.*

In parallel data loading, each load process creates temporary segments for loading the data; the temporary segments are later merged with the table. If a parallel data load process fails before the load completes, the temporary segments will not have been merged with the table. If the temporary segments have not been merged with the table being loaded, no data from the load will have been committed to the table.

You can use the SQL*Loader FILE parameter to direct each data loading session to a different datafile. By directing each loading session to its own database datafile, you can balance the I/O load of the loading processes. Data loading is very I/O-intensive and must be distributed across multiple disks for parallel loading to achieve significant performance improvements over serial loading.

TIP
Use the FILE parameter to direct the writes generated by parallel data loads.

After a parallel data load, each session may attempt to re-enable the table's constraints. As long as at least one load session is still under way, attempting to re-enable the constraints will fail. The final loading session to complete should attempt to re-enable the constraints, and it should succeed. You should check the status of your constraints after the load completes. If the table being loaded has PRIMARY KEY and UNIQUE constraints, you should first re-create or rebuild the associated indexes in parallel and then manually enable the constraints.

TIP
The PARALLEL option for data loading improves performance of loads, but it can also waste space when not properly used.

Optimizing Parallel Operations in RAC

The benefits of using parallel operations with an Oracle database have been well established, with the feature first being offered in version 7.1. Parallel execution of SQL statements on traditional Unix-based symmetric multiprocessor (SMP) architectures greatly increases utilization of the server and the speed of large resource-intensive operations. In a Real Application Clusters (RAC) architecture, the equivalent of a parallel SMP deployment is placed into effect and utilizes all the available servers (nodes) in the cluster. Use of parallel operations with RAC greatly enhances the scale-out cluster architecture.

Objectives of Parallel Operations

The objective of a parallel implementation is to use all available resources of the database platform architecture to increase overall processing potential. Resources included in this type of deployment are memory, processor, and I/O. Parallel operations that can be performed in any scale-up or single-system SMP image environment can also be performed in the scale-out RAC cluster environment. Operations that are included are as follows:

- Queries (based on full table scan)
- CREATE TABLE AS
- Index builds/rebuilds
- DML operations (INSERT, UPDATE, DELETE) on partitioned tables
- Data loads

You can perform the first four operations referenced in this list with the use of SQL hints or by setting the degree of parallelism at the object level. Configure node groups to restrict parallel operations to specific nodes. Therefore, when implementing a large RAC architecture (more than two servers), allocate named servers to named groups to restrict or enable parallel operations.

RAC Parallel Usage Models

Several usage models are available for parallel execution with RAC. Because splitting a query across multiple nodes can degrade performance as well, take care when using the parallel query with RAC! The models included are as follows:

- **Standard** Use of parallel query for large datasets. In this deployment, the degree of parallelism is usually defined to utilize all of the available resources in the cluster.
- **Restricted** This deployment restricts processing to specific nodes in the cluster. The referenced nodes can be logically grouped for specific types of operations.
- **Parallel index builds/rebuilds** In cases where large index builds are required, parallelism can be utilized to maximize the use of cluster node resources.

Parallel Initialization Parameters

Several standard parameters can be set to implement parallel processes at the server level as discussed earlier in the chapter. The two general parallel parameters to consider are as follows:

Parameter Name	Type	Description
PARALLEL_MAX_SERVERS	Integer	Maximum number of parallel processes per instance
PARALLEL_MIN_SERVERS	Integer	Minimum number of server processes per instance

V$ Views for Viewing Parallel Statistics

View Name	Description
GV$PQ_SYSSTAT	All parallel-related statistics for the entire RAC configuration
GV$PQ_SESSTAT	Session-specific parallel statistics by session ID

Several database views are used to obtain parallel operation statistics. The view names referenced here are prefaced with the GV$ identifier, which depicts the RAC-level statistics:

Create Table As

Using the CREATE TABLE AS (CTAS) feature within Oracle can be extremely useful for making copies of table objects. For large tables, the operation can be performed in parallel in the same manner as with the parallel query examples in the prior section. The SQL statement that follows is an example of using CTAS with the parallel option. Instance groups can also be used to restrict processing to specific nodes. Thus, based on the INSTANCE_GROUPS parameter, the query is executed only on the TEST1 node.

```
alter session set parallel_instance_group = 'TEST_20';

create table c_district_backup parallel (degree 3)
as
select *
from   c_district;
```

Parallel Index Builds

Performing index creates or rebuilds for large tables is another resource-intensive operation where performance can be greatly improved with parallel operations. The INDEX CREATE statement requests a parallel degree of 6 for the operation. Similar to the previous examples, this operation can also utilize the INSTANCE_GROUPS parameter to restrict the operation to specific nodes.

```
alter session set parallel_instance_group = 'TEST_20';

create unique index C_STOCK_I1 on C_STOCK (s_i_id, s_w_id)
tablespace stock_indx
parallel (degree 6);
```

Performance Considerations and Summary

The downside of parallel operations is the exhaustion of server resources. The easiest server resource to monitor is CPU utilization. If normal CPU utilization were relatively high, deploying a large number of parallel processes would not be advisable. Exceeding the total number of CPUs would cause performance degradation as well. Data layout is another immediate consideration. If I/O bottlenecks currently exist, use of parallel operations may exacerbate this condition. Ensure that datafiles for parallel target objects are spread across a reasonable number of disk spindles.

The use of parallel operations within a RAC deployment provides for the flexibility to utilize all server hardware included in the cluster architecture. Utilizing instance groups, database administrators can further control the allocation of these resources based on application requirements or service level agreements.

Other Parallel Notes

Planning (or reengineering) the physical location of datafiles is key to successful parallel data access. Determine an appropriate degree of parallelism for each parallelized SQL statement and parallelize the creation of your physical design. Don't let the initialization parameters dictate how the degree of parallelism is determined. Remember, you're usually trying to optimize a small number of slow queries, not every table access. Experiment with conservative parameters; use parallel operations for table or index creations and hint the degree of parallelism you identify as optimal. Use proper syntax for the parallel hints or they will be ignored. Other V$ views that may be helpful to you include V$PX_SESSION (session performing parallel operations), V$PX_SESSTAT (statistics for sessions performing parallel operations), V$PX_PROCESS (parallel processes), V$PX_PROCESS_SYSSTAT (statistics for parallel execution servers), V$SESSTAT (user session statistics), V$FILESTAT (file I/O statistics), V$PARAMETER (initialization parameters), and V$PQ_TQSTAT (workload statistics for parallel execution servers).

The parallel features offered in Oracle are incredibly powerful tools when used in a targeted fashion—most databases can be tuned to place indexes in the right quantity and location to deliver acceptable performance. Use parallel operations for those statements that cannot be written any other way but to scan an entire table or address a partitioned large table/index. Parallelized operations are powerful tools for managing data warehouses or performing periodic maintenance activities. Configure the database environment to take full advantage of the benefits parallelism offers.

Oracle Documentation Is Online

Don't forget that all of the Oracle documentation (multiple Oracle versions) for all of the products is online at http://docs.oracle.com.

Tips Review

- The cloud is here to stay. Ensure that you become educated on the Oracle Cloud so that you can discern which parts benefit your company and which parts require a wait-and-see approach.
- Get ready for the cloud by trying a simple DBaaS instance at http://cloud.oracle.com/tryit or http://cloud.oracle.com/database for free or by trying the new 12*c*R2 Oracle Database Exadata Express Cloud Service for $175/month.
- Exadata has been the next generation flagship hardware platform for relational database architecture. Get ready for it, it is constantly being updated.
- Use V$SESSION_WAIT or GV$SESSION_WAIT, Statspack, or the AWR Report to find RAC

wait events.

- Using parallel operations on very small tables or very fast queries can also degrade performance because the query coordination may also cost performance resources. You should evaluate whether the parallel cost exceeds the nonparallelized cost.
- When the parallel degree is set to *N*, it is possible to use (2**N*) + 1 total processes for the parallel operation. Although parallel operations deal with processes and *not* processors, when a large number of processors are available, Oracle generally uses the additional processors to run parallel queries, often enhancing the performance of the query.
- Any server process allocated for a statement may handle any request from a process within the same statement. Therefore, if some processes are faster than others, the ones that are faster can process the rows produced by the child set of parallel execution processes as soon as they are available instead of waiting for the ones that are slower (but only at the next higher statement hierarchy level).
- Using the PARALLEL hint enables the use of parallel operations. If you use the PARALLEL hint but do not specify the degree of parallelism with the hint or set it at the table level, the query still executes in parallel, but the DOP is calculated from the initialization parameters.
- The use of the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.
- Specify the degree of parallelism using a hint instead of relying on the table definition to ensure that all operations are tuned for the given query.
- Use NOLOGGING to remove the I/O bottleneck caused by serial writes to the redo logs.
- Make sure your data is properly distributed or the parallel query server processes may add to existing I/O bottleneck problems.
- Parallel processes commonly involve disk accesses. If the data is not distributed across multiple disks, using the Parallel Execution Option (PEO) may lead to an I/O bottleneck.
- A PARALLEL hint overrides the degree of parallelism defined for a table when determining the degree of parallelism for an operation.
- New columns may be added to the PLAN_TABLE with each new release of Oracle. You should drop and re-create your PLAN_TABLE following each upgrade of the Oracle kernel. If you upgrade an existing database to a new version of Oracle, you should drop your old PLAN_TABLE and re-execute the `utlxplan.sql` script to see all of the new PLAN_TABLE columns. You can also view the plan using Oracle Enterprise Manager in the SQL Details page.
- When using the EXPLAIN PLAN command for a parallelized query, you cannot rely on querying just the operations-related columns to see the parallelized operations within the EXPLAIN PLAN. At a minimum, you should query the OTHER_TAG column to see which operations are performed in parallel.
- When using EXPLAIN PLAN for parallel operations, use the `utlxplp.sql` script to view the PLAN_TABLE.

- Be sure your environment is properly configured to support the increase in processes, memory, and transactions generated by parallel operations.
- If you use parallel data loading, indexes are not maintained by the SQL*Loader session unless you are loading a single table partition. Before starting a parallel loading process, you must drop all indexes on the table and disable all of its PRIMARY KEY and UNIQUE constraints. After the parallel loads completely, you need to re-create or rebuild the table's indexes. Inserting data using APPEND and UNRECOVERABLE is the fastest way to insert data into a table without an index. External tables may provide faster extract, transform, and load (ETL) operations.
- Use the FILE parameter to direct the writes generated by parallel data loads.
- The PARALLEL option for data loading improves performance of loads, but it can also waste space when not properly used.
- Exadata, Exalogic, Exadata Storage Expansion Rack, Oracle Database Appliance, SPARC SuperCluster, Exalytics BI Machine, ZFS, Pillar Storage, and the latest StorageTek combines probably more hardware speed than the entire hardware industry put out prior to Oracle buying Sun. Hardware speeds *were* doubling every 18 months; enter Oracle and hardware speed is now accelerating exponentially with Oracle at the wheel (in the last two years Oracle has probably accelerated hardware/software performance 2,000–20,000 times if you know how to use it). The Terabytes database will soon be the Exabytes database. Teach your kids Oracle!

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Websites: www.tusc.com, www.oracle.com, https://code.facebook.com, and www.ioug.org.

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* This is an abbreviated list. Please see My Oracle Support Doc ID 757552.1 for the full document. Note 1274475.1 is the subsection for performance-specific information.

CHAPTER 12

The V$ Views (Developer and DBA)

Senior DBAs often tell junior DBAs that back in version 6 they used to know every V$ view by heart. Version 6 had only 23 V$ views, so the DBAs from the old days had it pretty easy. Oracle 10*g*R2 had 372 V$ views and 613 X$ tables. Oracle 11*g*R2 has 525 V$ views and 945 X$ tables. Oracle 12*c*R2 has 746 V$ views and 1312 X$ tables (the number of tables and views depends on the version, OS, and options that you use as well). There are new V$ views related to the In-Memory column store and pluggable databases (PDBs) in 12*c*. There is also an additional column on many V$ views for Container ID (CON_ID) with PDBs and container databases (CDBs).

Almost every great tuning or DBA product has one aspect in common. Most of them access the V$ views to get the insightful information that is retrieved about the database, individual queries, or an individual user. Accessing the V$ views has become quite prevalent due to the numerous presentations by Joe Trezzo and other V$ gurus. If you currently don't look at the V$ views, you don't know what you're missing. The V$ views look into the heart of the Oracle database. They are the link to moving from the average DBA to the expert DBA.

Chapter 13 more extensively explores the X$ tables, which are the underlying part of the V$ views. Appendixes B and C provide information about the V$ views and also the creation scripts from the X$ tables. Unfortunately, I can't show every great V$ script due to space limitations, and I'll try not to duplicate things that are covered in depth in other chapters. Please check my sessions on the Web for the latest V$ scripts available.

Topics covered in this chapter include the following:

- Creating V$ views and granting access to them in 12*c*
- Getting a listing of all V$ views in 12*c*
- Getting a listing of the X$ scripts that make up the V$ views in 12*c*
- Examining the underlying objects that make up the DBA_ and CDB_ views
- Querying V$DATABASE to get database creation time and archiving information
- Learning about the Automatic Workload Repository (AWR)
- Querying V$LICENSE to view licensing limits and warning settings
- Accessing V$OPTION to view all options that have been installed
- Querying V$SGA and using MEMORY_TARGET to allocate basic memory for 12*c*

- Querying V$SGA when setting INMEMORY_SIZE for the In-Memory column store
- Querying V$IM_SEGMENTS and V$IM_COLUMN_LEVEL for the In-Memory column store
- Querying V$SGASTAT to allocate detailed memory for Oracle
- Querying V$SGASTAT as the Root CDB user or PDB user
- Finding initialization parameter settings in V$PARAMETER
- Determining if an initialization parameter is modifiable at PDB level in V$PARAMETER
- Determining memory for data (V$SYSSTAT and V$SYSMETRIC)
- Determining memory for the data dictionary (V$ROWCACHE and V$SYSMETRIC)
- Determining memory for shared SQL and PL/SQL (V$LIBRARYCACHE and V$SYSMETRIC)
- Determining memory for the In-Memory column store (12.1.0.2+ only)
- Querying V$CONTAINERS for CDB and PDB information
- Querying for pluggable databases in V$PDBS at both PDB and CDB levels
- Using the Result Cache
- Deciding which objects need to be pinned and whether there is contiguous free memory (V$DB_OBJECT_CACHE)
- Finding the problem queries by accessing V$SESSION_LONGOPS, V$SQLAREA, V$SQLTEXT, V$SESSION, and V$SESS_IO
- Finding out what users are doing and which resources they are using
- Identifying locking problems and killing the corresponding session
- Finding users with multiple sessions
- Balancing I/O using V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES
- Checking privileges and roles
- Finding Waits with V$SESSION, V$SESSION_WAIT, V$SESSION_EVENT, V$SESSION_WAIT_CLASS, V$SESSION_WAIT_HISTORY, V$SYSTEM_EVENT, and V$SYSTEM_WAIT_CLASS

Creating and Granting Access to V$ Views

The V$ views are created by the `catalog.sql` script (in $ORACLE_HOME/rdbms/admin). As of Oracle 12*c*R2, there are approximately 746 V$ views. The actual number varies by version and platform. Here is the number of views from Oracle 6 to Oracle 12*c*R2:

Version	V$ Views	X$ Tables
6	23	(35?)
7.1	72 (+213% vs. V6)	126
8.0	132	200
8.1	185 (+157% vs. V7)	271 (+115% vs. V7)
9.0	227	352
9.2	259 (+29% vs. 8*i*)	394 (+45% vs. 8*i*)
10.1	340	543
10.2	372 (+44% vs. 9*i*)	613 (+56% vs. 9.2)
11.1	484	798
11.2	525 (+41% vs. 10.2)	945 (+54% vs. 10.2)
12.1	606	1062
12.2	746 (+42% vs. 11.2)	1312 (+39% vs. 11.2)

The views are all created with the prefix *V_$* and *GV_$*. Two of the views are created by the `catldr.sql` script, which is used for SQL*Loader direct load statistical information. The underlying view definitions (technically, these views are never created; their definitions are hard-coded into the binary) for each V$ and GV$ view can be seen in the V$ view named V$FIXED_VIEW_DEFINITION. The V$ views are created by selecting instance-specific information from GV$ views. For almost every V$ view, there is a corresponding GV$ view. GV$, or global V$, views contain the same information as the V$ views but across all instances of a RAC database (each instance is identified by its instance ID). The GV$ views are created by selecting from one or more X$ tables. A view is created for each V_$ and GV_$ view to allow users to access the view. Users cannot access the actual V$ views (they actually access the V_$ views; the V$ objects are only visible to SYS). In other words, this method provides access to these views via a view on a view. The view name changes the prefix of each view to V$. Lastly, a public synonym is created for each view because the SYS user owns the tables. The following listing shows an example of a V$ and GV$ view creation in the `cdfixed.sql` script called by the `catalog.sql` script:

```
create or replace view v_$datafile as
select *
from    v$datafile;
create or replace public synonym v$datafile for v_$datafile;

create or replace view gv_$datafile as
select *
from    gv$datafile;
create or replace public synonym gv$datafile for gv_$datafile;
```

The complete sequence of events is detailed in the following steps.

1. The GV$ view definitions are created from the X$ tables when the database is created (note that the CON_ID [Container ID] column was not present in the previous version):
```
create  or replace view gv$fixed_table as
select  inst_id,kqftanam, kqftaobj, 'TABLE', indx, con_id
from    x$kqfta
union all
select  inst_id,kqfvinam, kqfviobj, 'VIEW', 65537, con_id
from    x$kqfvi
union all
select  inst_id,kqfdtnam, kqfdtobj, 'TABLE', 65537, con_id
from    x$kqfdt;
```
2. The version-specific catalog script is executed as the following:
```
SQL> @catalog (this is in the $ORACLE_HOME/rdbms/admin directory)
```
3. A V_$ view is created from the V$ view when the CREATE database script executes the following:
```
create or replace view v_$fixed_table
as
select *
from   v$fixed_table;
```
4. A new V$ synonym is created on the V_$ view:
```
create or replace public synonym v$fixed_table for v_$fixed_table;
```
5. A new GV$ synonym is created on the GV_$ view:
```
create or replace public synonym gv$fixed_table for gv_$fixed_table;
```

TIP
The V$ views that are accessed by SYSTEM are actually synonyms that point to the V_$ views that are views of the original V$ views based on the X$ tables. (Better read that one again!)

The only operation that you can perform on these views is a SELECT. To provide access to the V$ views, you must grant access to the underlying V_$ view.

You cannot grant access to the V$ views (even as the SYS user), however:

```
connect sys/change_on_install as sysdba

Grant select on v$fixed_table to Richie;
ORA-02030: can only select from fixed tables/views.
```

Although the error message (following the preceding code) for attempting to grant access to V$FIXED_TABLE is erroneous, the GRANT is not allowed. You may, however, grant access to the underlying V_$ view that is behind the V$ view.

To connect to the SYS superuser, use the following:

```
Connect sys/change_on_install as sysdba
Connected.
```

To grant access to an underlying view to the desired user, use the following:

```
grant select on v_$fixed_table to Richie;
Grant succeeded.
```

To connect as the desired user, use this:

```
conn   Richie/Rich
Connected.
```

Access the V$FIXED_TABLE view via the synonym V$FIXED_TABLE, which is created for V_$FIXED_TABLE with the following:

```
select count(*)
from   v$fixed_table;

COUNT(*)
--------
    2769
```

You still *can't* access the V_$FIXED_TABLE even though that grant was made (SYS can access it, however):

```
select count(*)
from   v_$fixed_table;
ORA-00942: table or view does not exist.
```

You *can* access the V_$FIXED_VIEW if you preface it with SYS:

```
conn   Richie/Rich
select count(*)
from   SYS.v_$fixed_table;

COUNT(*)
--------
    2769
```

To avoid confusion, give access to the V_$ views and notify the DBA that he or she has access to the V$ views. Using this method, you may give access to the V$ view information without giving out the password for the SYS or SYSTEM accounts. The key is granting SELECT access to the original SYS owned V_$ view.

TIP

When other DBAs need access to the V$ view information, but not the SYS or SYSTEM passwords, grant the user access to the V_$ views. The user may then access the V$ views that have public synonyms to the V_$ views. However, scripts could always be written to query the SYS.V_$ views directly, to avoid the performance cost of dereferencing the public synonym, but this savings is small.

Please refer to Oracle documentation for guidelines and granting privileges to different levels of users. This is especially important when you have a very large number of users.

CAUTION

You should grant non-DBA users privileges to the V$ views only as needed, and use caution. Remember, performance costs come with querying the V$ views, and the larger your environment, the greater those costs.

Obtaining a Count and Listing of All V$ Views

To get a count of all V$ views for a given version of Oracle, query the V$FIXED_TABLE view. The number of V$ views continues to change even within the same version. The examples that follow display the V$ view queries for Oracle 12*c*R2. The frontier in the world of the V$ views continues to expand with each version of Oracle.

To get a count of V$ views, query as shown here:

```
select count(*)
from   v$fixed_table
where  name like 'V%';

COUNT(*)
--------
     746
```

Many of the V$ views continue to be undocumented. The methods of exploring information continue to expand in Oracle because the number of views continues to expand. In Oracle8 (now desupported), the GV$ views were introduced. The GV$ (global V$) views are the same as the V$ views with an additional column for the instance ID (for RAC). In 12*c*, we now see an additional column in many for the Container ID (CON_ID) used for pluggable databases. To get a list of GV$ views, query as shown here (this is a partial listing; you'll find a complete list of V$ views in Appendix B):

```
select   name
from     v$fixed_table
where    name like 'GV%'
order    by name
fetch    first 7 rows only;

NAME
---------------------------------
GV$ACCESS
GV$ACTIVE_INSTANCES
GV$ACTIVE_SERVICES
GV$ACTIVE_SESSION_HISTORY
GV$ACTIVE_SESS_POOL_MTH
GV$ADVISOR_CURRENT_SQLPLAN
GV$ADVISOR_PROGRESS

7 rows selected.
```

TIP
Query V$FIXED_TABLE to obtain a listing of all GV$ and V$ views in the database. The GV$ views are the exact same as the V$ views, except the instance ID contains an identifier, and the GV$ views contain data for all instances of an Oracle RAC database.

Getting a Listing for the X$ Scripts That Make Up the V$ Views

To understand where the V$ view information comes from, query the underlying X$ tables (see Chapter 13 for X$ table information). At times, querying the underlying X$ tables may be advantageous because the V$ views are often the join of several X$ tables. The X$ tables are very cryptic because they are similar to the underlying table constructs of the Oracle data dictionary. Oracle creates V$ views in the SGA to allow users to examine the information stored in the X$ tables in a more readable format. In fact, when SELECTs are performed against the V$ views, the SELECTs are actually retrieving information out of the SGA—and more specifically, out of the X$ tables, which are truly memory constructs that interface the software code constructs (which is why they are so cryptic).

With the knowledge of the V$ view underlying a given SELECT statement, you have the capability to create customized views; simply copy the existing V$ view underlying the SELECT statement and modify it or create a new customized SELECT on the X$ tables. This technique allows more selective and more optimized queries. The next listing is used to access the underlying query to the X$ tables. To get a listing of the X$ tables that make up the V$ views, you must access the V$FIXED_TABLE_DEFINITION view (output formatted for readability).

```
select   view_name, view_definition
from     v$fixed_view_definition
where    view_name = 'GV$FIXED_TABLE';
```

Output

```
VIEW_NAME        VIEW_DEFINITION
---------------  -------------------------------------------------------------
GV$FIXED_TABLE   select  inst_id,kqftanam, kqftaobj, 'TABLE', indx, con_id
                 from    x$kqfta
                 union all
                 select  inst_id,kqfvinam, kqfviobj, 'VIEW', 65537, con_id
                 from    x$kqfvi
                 union all
                 select  inst_id,kqfdtnam, kqfdtobj, 'TABLE', 65537, con_id
                 from    x$kqfdt
```

TIP
Access the V$FIXED_VIEW_DEFINITION view to get all information about the underlying X$ tables that make up a V$ view. CON_ID (Container ID) is a new column you'll see in 12c for pluggable databases.

Also note that, as of Oracle8, there are indexes on the underlying X$ tables to provide faster execution of queries performed on the V$ views (amazing that it took Oracle until version 8 to use indexes!). You can view the index information on the underlying X$ tables through the V$INDEXED_FIXED_COLUMN view (see Chapter 13 on X$ tables for more information).

Examining the Underlying Objects That Make Up the DBA_ Views

Some people think the DBA_ views also come from the X$ tables and/or the V$ views. They actually come from Oracle's underlying database tables (although some access the X$ tables as well). To look at the objects that make up the DBA_ views, access DBA_VIEWS, as shown in this listing (also note there is a CDB_ view for every corresponding DBA_ view):

NOTE
You may need to use `set long 2000000` *to see all of this output.*

```
select  text
from    dba_views
where   view_name='DBA_IND_PARTITIONS';

TEXT
--------------------------------------------------------------------------------
select u.name, io.name, 'NO', io.subname, 0, ip.hiboundval, ip.hiboundlen

SQL> set long 2000000
(RUN IT AGAIN)

select  text
from    dba_views
where   view_name='DBA_IND_PARTITIONS';

TEXT (this listing has been shortened by about 110 lines for brevity)
--------------------------------------------------------------------------------
select u.name, io.name, 'NO', io.subname, 0,
       ip.hiboundval, ip.hiboundlen, row_number() over (partition by u.name,
       io.name, order by ip.part#),
        decode(bitand(ip.flags, 1), 1, 'UNUSABLE', 'USABLE'), ts.name,
….. (much code deleted for space - about 86 lines)...
from   obj$ io, indpartv$ ip,  user$ u, ind$ i, indpart_param$ ipp, tab$ t,
where  io.obj# = ip.obj# and io.owner# = u.user# …
...(much code deleted for space - about 24 lines)...
```

Never modify the underlying objects; many DBAs have corrupted their database in this manner. Do *not* do the following, but note that it is possible:

```
Connect sys/change_on_install as sysdba
Connected.

DELETE FROM OBJ$;  -- Don't do this! If you commit, your database is over!
78239 rows deleted.

Rollback;
Rollback complete
```

Also consider the following CDB versus PDB example:

```
sqlplus / as sysdba (log on as CDB$ROOT user in Root CDB - Container DB)

select count(*) from cdb_tables;
  COUNT(*)
----------
      7059

select count(*) from dba_tables;
  COUNT(*)
----------
      2317

select count(*) from user_tables;
  COUNT(*)
----------
      1221

alter session set container=PDB1;
Session altered.

select count(*) from cdb_tables;
  COUNT(*)
----------
      2426

select count(*) from dba_tables;
  COUNT(*)
----------
      2426

select count(*) from user_tables;
  COUNT(*)
----------
      1235
```

Note the hierarchy: The main CDB contains information including the PDB, but the PDBs only hold their own information (but there may be multiple USERS in each PDB).

TIP
The DBA_ views are not derived from the X$ tables or V$ views. The fact that you can delete rows from OBJ$ and ruin your database is a great reason to never be the SYS superuser. There is a CDB_ view for every DBA_ view, and the Root CDB_ views also contain PDB information.

Using Helpful V$ Scripts

The rest of this chapter is dedicated to scripts that are helpful in analyzing different areas of the Oracle database. Many of these scripts are dynamic and provide valuable insight into areas of the database that you may need to analyze to determine resource contention at a point in time. Typically, the result is that the DBA performs some operation to eliminate the contention immediately by tuning a query or increasing an initialization parameter to reduce the resource contention in the future. Revoking access to a given ad hoc query user, or restricting his or her system resource use with profiles, could be an emergency option as well. The next four sections include scripts that retrieve the following:

- Basic database information
- Basic Automation Workload Repository (AWR) Information
- Basic licensing information
- Database options installed in your database

Basic Database Information

Getting the basic information about your instance is usually as easy as logging in to SQL*Plus because all of the information shows in the banner at that time. If you would like to see the full banner header, you can access the V$VERSION view to display the banner. The following listing shows a quick way to see the version you are using as well as other information:

Version Information:

```
select  banner
from    v$version;
```

Output from 12.2:

```
BANNER
--------------------------------------------------------------------------------
Oracle Database 12c Enterprise Edition Release 12.2.0.0.2 - 64bit Productio
PL/SQL Release 12.2.0.0.2 - Production
CORE    12.2.0.0.2      Production
TNS for Linux: Version 12.2.0.0.2 - Production
NLSRTL Version 12.2.0.0.2 - Production
```

Database Information:

```
select name, created, log_mode
from   v$database;

NAME      CREATED   LOG_MODE
--------- --------- ------------
ORCL      17-MAR-16 ARCHIVELOG
```

Accessing V$DATABASE gives you basic information concerning the database. The most important information in the output is to ensure that you are in the desired ARCHIVELOG mode. The output also gives you the exact date when the database was created, as you can see in the preceding listing.

Another way to view the archive log status for the database is to simply use the ARCHIVE LOG LIST command as the SYS user in SQL*Plus:

```
SQL> archive log list

Database log mode              Archive Mode
Automatic archival             Enabled
Archive destination            USE DB RECOVERY FILE DEST
Oldest online log sequence     418
Current log sequence           418
```

TIP
Query V$VERSION and V$DATABASE to view basic database information such as the version, to find out when your database was created, and to find out basic archiving information.

Basic Automatic Workload Repository (AWR) Information

With the advent of the Automatic Workload Repository (AWR), you now have many areas to watch. By default, the repository is populated every hour with a retention period of seven days. Here are some queries that are worth knowing for the AWR (the MMON background process is used to flush AWR data from memory to disk). See Chapter 5 for detailed information on AWR, licensing related to the V$ views based on the AWR, and using information from the AWR for tuning purposes.

How much space is the AWR using?

```
select occupant_name, occupant_desc, space_usage_kbytes
from   v$sysaux_occupants
where  occupant_name like '%AWR%';

OCCUPANT_NAME OCCUPANT_DESC                                          SPACE_USAGE_KBYTES

SM/AWR        Server Manageability - Automatic Workload Repository               345024
```

What's the oldest AWR information on the system?

```
select dbms_stats.get_stats_history_availability
from   dual;

GET_STATS_HISTORY_AVAILABILITY
---------------------------------------------------------------------------
18-MAY-16 10.46.48.800339000 PM -04:00
```

What's the retention period for AWR information?

```
select dbms_stats.get_stats_history_retention
from   dual;

GET_STATS_HISTORY_RETENTION
---------------------------
                         31
```

To change the retention period for AWR information to 15 days:

```
EXEC dbms_stats.alter_stats_history_retention(15);


select dbms_stats.get_stats_history_retention
from   dual;

GET_STATS_HISTORY_RETENTION
---------------------------
                         15
```

TIP
Query V$SYSAUX_OCCUPANTS to ensure that the Automatic Workload Repository (AWR) isn't taking up too much space. Use DBMS_STATS to check history and retention.

Basic Licensing Information

The V$LICENSE view allows a DBA to monitor system activity in terms of overall database licensing, warnings, and current use at any time. It provides a DBA with a log of the maximum number of concurrent sessions at any time, which allows a company to ensure it is licensed properly. The current number of sessions is displayed along with the session warning level and session maximum level (as shown next).

As a DBA, execute the script periodically to find out the actual number of sessions on the system throughout the day. In this next listing, there is no limit on the number of users if the value is set to 0:

```
select sessions_max sess_max, sessions_warning sess_warning,
       sessions_current sess_current, users_max
from   v$license;

SESS MAX   SESS WARNING   SESS CURRENT   SESS HIGHWATER   USERS MAX
--------   ------------   ------------   --------------   ---------
     110            100             44              105           0
```

Database Options Installed in Your Database

The script shown next describes what options are installed on your database and are available for use. If you have purchased a product that does not show up in this list, you may have incorrectly installed it. Query the V$OPTION view to check for installed products or log on to SQL*Plus to see the products that are installed (does your open source database do all this?).

```
select *
from   v$option
order  by parameter;
(selected rows displayed below - this returned 86 rows for my system)
```

Output

```
PARAMETER                                  VALUE                 CON_ID
----------------------------------------   ----------------------
ASM Proxy Instance                         FALSE                      0
Active Data Guard                          TRUE                       0
Adaptive Execution Plans                   TRUE                       0
Advanced Analytics                         TRUE                       0
Advanced Compression                       TRUE                       0
Basic Compression                          TRUE                       0
Cache Fusion Lock Accelerator              TRUE                       0
Flashback Database                         TRUE                       0
Flashback Table                            TRUE                       0
Heat Map                                   TRUE                       0
In-Memory Aggregation                      TRUE                       0
In-Memory Column Store                     TRUE                       0
Java                                       TRUE                       0
Join index                                 TRUE                       0
Managed Standby                            TRUE                       0
Online Index Build                         TRUE                       0
Online Redefinition                         TRUE                     0
Oracle Data Guard                           TRUE                     0
Oracle Database Vault                       FALSE                    0
Oracle Label Security                       FALSE                    0
Parallel backup and recovery                TRUE                     0
Parallel execution                          TRUE                     0
Parallel load                               TRUE                     0
Partitioning                                TRUE                     0
Plan Stability                              TRUE                     0
Real Application Clusters                   FALSE                    0
Real Application Testing                    TRUE                     0
Result Cache                                TRUE                     0
SQL Plan Management                         TRUE                     0
SecureFiles Encryption                      TRUE                     0
Server Flash Cache                          TRUE                     0
Transparent Data Encryption                 TRUE                     0
Unused Block Compression                    TRUE                     0
XStream                                     TRUE                     0
Zone Maps                                   TRUE                     0

86 rows selected (only selected rows are listed above)
```

The previous listing shows that the database has the PARTITIONING option installed (TRUE), but it does not have Real Application Clusters (RAC) installed (FALSE). Also note that Automatic Storage Management (ASM) is FALSE because this is a test environment; however, ASM would almost always be used on most production systems.

TIP
Query the V$OPTION view to retrieve the Oracle options you have installed. The V$VERSION view gives you the versions of the installed base options.

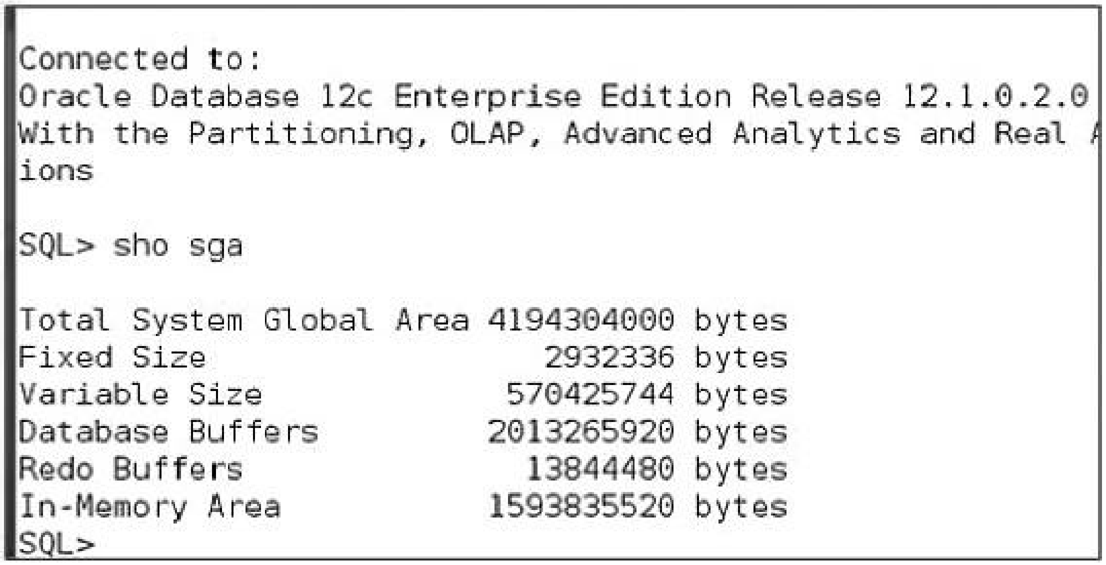
Summary of Memory Allocated (V$SGA)

V$SGA gives the summary information for the System Global Area (SGA) memory structures of your system, as shown in the next listing. The "Database Buffers" is the number of bytes allocated to memory for data. It comes from the `init.ora` parameter DB_CACHE_SIZE, if set. The "Redo Buffers" comes primarily from the value of the `init.ora` parameter LOG_BUFFER, which is used to buffer changed records and flushed to the REDO logs whenever a COMMIT is issued.

Consider this smaller SGA output listed using the SHO SGA command:

```
SQL> SHO SGA

Total System Global Area 1073741824 bytes
Fixed Size                  4429320 bytes
Variable Size             281020920 bytes
Database Buffers          784334848 bytes
Redo Buffers                3956736 bytes
```



```
Connected to:
Oracle Database 12c Enterprise Edition Release 12.1.0.2.0
With the Partitioning, OLAP, Advanced Analytics and Real A
ions

SQL> sho sga

Total System Global Area 4194304000 bytes
Fixed Size                  2932336 bytes
Variable Size             570425744 bytes
Database Buffers         2013265920 bytes
Redo Buffers               13844480 bytes
In-Memory Area           1593835520 bytes
SQL>
```

FIGURE 12-1. *The SGA listens when the In-Memory column store is used.*

Consider the same query, but now a query to V$SGA (if I go to an individual PDB, I will get the exact same output—there is no "local" information):

```
COL VALUE FORMAT 999,999,999,999
COMPUTE SUM OF VALUE ON REPORT
BREAK ON REPORT
select *
from   v$sga;

NAME                             VALUE  CON_ID
---------------------      ---------- ------
Fixed Size                   4,429,320       0
Variable Size              281,020,920       0
Database Buffers           784,334,848       0
Redo Buffers                 3,956,736       0
                         -------------
sum                      1,073,741,824
```

Set the following initialization parameters to turn on the In-Memory column store (also referred to as IM or INMEMORY or In-Memory):

```
inmemory_size=1520M
inmemory_query-enabled
sga target=25G     --(must increase this if I add IM)
```

Querying V$IM_SEGMENTS After Setting the INMEMORY_SIZE

After setting the INMEMORY_SIZE, which is included in the SGA (as seen in the previous section), you can check In-Memory (IM) segments. The V$IM_SEGMENTS view and the In-Memory column store are only available in 12.1.0.2 or later of the database. This view shows the memory allocated for all segments in the IM column store.

The following example shows how to create a one-column EMP7 table and put it into the IM:

```
CREATE TABLE emp7 (EMPNO number) INMEMORY;
Table created.
```

You can also alter it INMEMORY after it's created:

```
alter table emp7 inmemory;
Table altered.
```

Check the EMP7 table in the V$IM_SEGMENTS view:

```
select segment_name, bytes
from   v$im_segments
where  segment_name='EMP7';

SEGMENT_NAME                          BYTES
--------------------------- ---------
EMP7                              4194304
```

Check the EMP7 table in the V$IM_COLUMN_LEVEL view:

```
select table_name, column_name, inmemory_compression
from   v$im_column_level
where  table_name = 'EMP7';

TABLE_NAME          COLUMN_NAME  INMEMORY_COMPRESSION
------------------- ----------- ----------------------
EMP7                EMPNO       FOR QUERY LOW
```

Please see Chapter 4 for detailed information about the In-Memory (IM) column store. The following are a few other helpful commands as you use IM.

Place the entire tablespace (puts tables/partitions/mv) into IM:

```
SQL> ALTER TABLESPACE tbcsp1 INMEMORY;
```

Instantly remove the EMP table from the IM column store:

```
SQL> ALTER TABLE emp NO INMEMORY;
```

Instantly remove D1 Partition(dept) from the IM column store:

```
SQL> ALTER TABLE dept MODIFY PARTITION d1 NO INMEMORY;
```

Exclude some columns from going into the IM (by default all columns go into the IM):

```
SQL> ALTER TABLE emp INMEMORY NO INMEMORY (ename, job, mgr, hiredate, deptno, sal, comm);
```

The main views to view IM information include V$IM_SEGMENTS, V$IM_USER_SEGMENTS, V$IM_COLUMN_LEVEL, USER_TABLES, and (the deep dive) V$KEY_VECTOR.

TIP
Query the V$IM_SEGMENTS and V$IM_COLUMN_LEVEL views to retrieve detailed information about specific objects that are stored in the In-Memory column store (only available in 12.1.0.2+).

Automatic Memory Management and

MEMORY_TARGET

Oracle simplified PGA memory management by introducing a PGA_AGGREGATE_TARGET parameter. In 12*c*, Oracle introduced the PGA_AGGREGATE_LIMIT parameter to ensure there is a cap on the PGA. Oracle also simplified SGA memory management by providing Automatic Shared Memory Management (ASMM) and by providing the SGA_TARGET parameter. Oracle offers Automatic Memory Management (AMM) that unifies both PGA memory and SGA memory in a single parameter setting, the MEMORY_TARGET parameter (see Chapter 4 for more information on all initialization parameters). As a result, Oracle provides a data dictionary table called V$MEMORY_DYNAMIC_COMPONENTS. Here is a query that shows the dynamic components using AMM parameters:

```
select component,current_size,min_size,max_size
from   v$memory_dynamic_components
where  current_size !=0;

COMPONENT                       CURRENT_SIZE   MIN_SIZE   MAX_SIZE
------------------------------ ------------ ---------- ----------
shared pool                       184549376  184549376  184549376
large pool                          4194304    4194304    4194304
java pool                          12582912   12582912   12582912
SGA Target                        536870912  536870912  536870912
DEFAULT buffer cache              327155712  327155712  327155712
Shared IO Pool                     50331648          0   50331648
PGA Target                        318767104  318767104  318767104

7 rows selected.
```

The V$MEMORY_TARGET_ADVICE view provides tuning advice for setting the MEMORY_TARGET parameter. Issue the following query to obtain advice on the effects of increasing or shrinking the MEMORY_TARGET parameter:

```
select   *
from     v$memory_target_advice
order by memory_size;

MEMORY_SIZE MEMORY_SIZE_FACTOR ESTD_DB_TIME ESTD_DB_TIME_FACTOR    VERSION
----------- ------------------ ------------ ------------------- ----------
        204                .25          382                   1          0
        408                 .5          382                   1          0
        612                .75          382                   1          0
        816                  1          382                   1          0
       1020               1.25          382                   1          0
       1224                1.5          382                   1          0
       1428               1.75          382                   1          0
       1632                  2          382                   1          0

8 rows selected.
```

When MEMORY_TARGET is set, SGA_TARGET and PGA_AGGREGATE_TARGET initially have zero values (automatically set) unless you set minimum values (a maximum value for PGA can be set with PGA_AGGREGATE_LIMIT as of 12*c*). To use ASMM, set SGA_TARGET to a nonzero value.

Consider a larger SGA in this example and a different way to show it:

```
COLUMN value FORMAT 999,999,999,999

select *
from   v$sga;

NAME                            VALUE
-------------------- ----------------
Fixed Size                  2,188,768
Variable Size           4,513,073,696
Database Buffers        2,315,255,808
Redo Buffers               17,420,288
```

If SGA_TARGET is used, it dynamically resizes internally:

```
select (
   (select sum(value) from v$sga) -
   (select current_size from v$sga_dynamic_free_memory)
   ) "SGA_TARGET"
from dual;

SGA TARGET
----------
4448796672
```

This output indicates a relatively large SGA (over 4.5G) with a buffer cache that includes DB_CACHE_SIZE, DB_KEEP_CACHE_SIZE, and DB_RECYCLE_CACHE_SIZE of over 2.5G. As discussed in Chapters 1 and 4, I could have just set the SGA_TARGET to something like 4.5G and set the other parameters to enforce minimum sizes only. The predominant part of the Variable Size category is the buffer cache and shared pool. (The shared pool for this SGA is 1G.) This SGA is over 4.5G of the actual physical system memory in the preceding listing. This information is also given in the AWR or Statspack Report (still available in 12*c*R2; see Chapter 14) and can also be displayed by issuing a SHOW SGA command as the SYS superuser.

TIP
Access the V$SGA view to get a baseline idea of the system's physical memory allocated for data, shared pool, large pool, Java pool, and log buffering of Oracle.

Detailed Memory Allocated (V$SGASTAT)

A V$ view to query and retrieve more detailed information about memory allocation for the SGA is the V$SGASTAT view (most records are related to the shared pool). This view provides dynamic information about SGA and memory resources. It changes as the database is accessed. This statement describes the SGA sizes at a detailed level. The records FIXED_SGA, BUFFER_CACHE, and LOG_BUFFER are the same values for both V$SGA and V$SGASTAT. The remaining records in V$SGASTAT make up the only other V$SGA record (the Variable Size or Shared Pool record).

```
Fixed Size (V$SGA)          = FIXED_SGA (V$SGASTAT)
Database Buffers (V$SGA)    = BUFFER_CACHE (V$SGASTAT)
Redo Buffers (V$SGA)        = LOG_BUFFER (V$SGASTAT)
Variable Size (V$SGA)       = many other records (V$SGASTAT)
```

In Oracle 9.2, V$SGASTAT had only 43 total records; in 12*c*R2, it has 1312 records, as shown here (partial listing only; varies based on database use):

```
select *
from   v$sgastat;

POOL          NAME                            BYTES CON_ID
------------ -------------------------- ---------- ------
              fixed_sga                     4429320      0
              buffer_cache                734003200      0
              log_buffer                    3956736      0
              shared_io_pool               50331648      0
shared pool   KGX                            172152      0
shared pool   pid                             56976      0
shared pool   sot                               280      0
shared pool   KGLA                           612952      0
shared pool   KGLS                          2764080      0
etc…
1312 rows selected
```

Some of this information is also given in the AWR or Statspack Report (see Chapter 14), along with the starting and ending values over the duration of the Statspack Report.

TIP
Querying V$SGASTAT provides a detailed breakdown for the Oracle SGA and details all aggregated buckets of shared pool allocation.

Detailed Memory Allocated (V$SGASTAT) for a PDB vs. Root CDB

When I go to an individual PDB and query a view, only the information for that PDB is displayed. As stated earlier, querying V$SGA is the same at the PDB level or CDB level. If I query V$SGASTAT, there are many more records at the CDB level (which includes the CDB and all PDBs) than at the PDB level:

```
alter session set container=CDB$ROOT;
Session altered.
select count(*)
from   v$sgastat;
```

```
  COUNT(*)
----------
      1130
alter session set container=PDB1;
Session altered.

select count(*)
from v$sgastat;
  COUNT(*)
----------
        47
```

We can see that for the CDB, there are 1130 records and in the PDB only 47 records. One important note is that there *are* some CON_ID=0 records in the PDB (such as free memory that will be used by the PDB), but the used SGA items show as CON_ID=3 (or specific to this PDB).

Finding spfile.ora/init.ora Settings in V$PARAMETER

The script in the next listing displays the initialization parameters for your system. It also provides information on each parameter that identifies whether the current value is the default value (ISDEFAULT=TRUE). It further shows whether the parameter is modifiable with the ALTER SESSION command and with the ALTER SYSTEM command (ISSYS_MODIFIABLE=IMMEDIATE). You can modify these with the ALTER SESSION and ALTER SYSTEM commands instead of modifying the `init.ora` file and shutting down and restarting the instance. The example in this listing displays some of the initialization parameters that you can modify with one of the ALTER commands. (IMMEDIATE means it can be modified and it will take effect immediately.) Note that you can use an ALTER command, but for some parameters, such as O7_DICTIONARY_ACCESSIBILITY, you can only use an ALTER SYSTEM … SCOPE=SPFILE command to modify it, and *then* you have to bounce the database for it to take effect. The query here shows the parameter values in effect for the instance (not what is necessarily in the parameter file):

```
select      name, value, isdefault, isses_modifiable, issys_modifiable
from        v$parameter
where       con_id = 0
order by    name;
```

Query of V$PARAMETER:

```
NAME                            VALUE     ISDEFAULT ISSES ISSYS_MOD
------------------------------- --------- --------- ----- ---------
O7 DICTIONARY ACCESSIBILITY     FALSE     TRUE      FALSE FALSE
active instance count                     TRUE      FALSE FALSE
aq_tm_processes                 0         TRUE      FALSE IMMEDIATE
archive lag target              0         TRUE      FALSE IMMEDIATE
asm diskgroups                            TRUE      FALSE IMMEDIATE
asm_diskstring                            TRUE      FALSE IMMEDIATE
asm_power_limit                 1         TRUE      TRUE  IMMEDIATE
...partial output listing)
```

Version-dependent columns are also available.

TIP

Query V$PARAMETER to get the current values for the initialization parameters. V$PARAMETER also shows which initialization parameters have been changed from their original defaults: ISDEFAULT=FALSE. It also shows which parameters may be changed only for a given session if ISSES_MODIFIABLE=TRUE. Lastly, it shows which parameters may be changed without shutting down and restarting the database for ISSYS_MODIFIABLE=IMMEDIATE as well as ISSYS_MODIFIABLE=DEFERRED for a parameter that is enforced for all new logins but not currently logged-on sessions. If the parameter ISSYS_MODIFIABLE=FALSE, then the instance must be shut down and restarted for the parameter to take effect. See Chapter 4 for more information on the initialization parameters.

Modifying an Initialization Parameter at PDB Level

You can gain some insight into which initialization parameters are modifiable at the PDB level (or just the CDB level) by using the following query (pluggable databases are covered in detail in Chapter 3):

```
select   name
from     v$parameter
where    ispdb_modifiable = 'TRUE'
and      name like 'optim%';
(At the PDB level, can set 150 parameters out of 412 in R12.2)
NAME                                        VALUE
------------------------------------------------------------
optimizer_adaptive_features                 TRUE
optimizer_adaptive_reporting_only           FALSE
optimizer_capture_sql_plan_baselines        FALSE
optimizer_dynamic_sampling                  2
optimizer_features_enable                   12.2.0.1
optimizer_index_caching                     0
optimizer index cost adj                    100
optimizer_inmemory_aware                    TRUE
optimizer_mode                              ALL_ROWS
optimizer_secure_view_merging               TRUE
optimizer_use_invisible_indexes             MANUAL
optimizer_use_pending_statistics            FALSE
optimizer_use_sql_plan_baselines            TRUE
13 rows selected.
```

The following key initialization parameters are reported as modifiable: cursor_sharing, open_cursors, result_cache_mode, sort_area_size, db_cache_size, shared_pool_size, pga_aggregate_target, inmemory_size.

The key initialization parameter that is reported as *not* modifiable is memory_target.

Determining If Data Is in Memory (V$SYSSTAT and V$SYSMETRIC)

Query V$SYSSTAT (as shown in the next listing) to see how often your data is being read from memory. V$SYSSTAT gives the hit ratio for the setting of the database block buffers. This information can help you identify when your system needs more data buffers (DB_CACHE_SIZE) or when a system is not tuned very well. (Both lead to low hit ratios.) Generally, you should ensure the read hit ratio is greater than 95 percent (95 percent of data is accessed from memory). Increasing the hit ratio on your system from 98 percent to 99 percent could mean performance that is 100+ percent faster (depending on what is causing the disk reads).

```
select 1-(sum(decode(name, 'physical reads', value,0))/
         (sum(decode(name, 'db block gets', value,0)) +
         (sum(decode(name, 'consistent gets', value,0)))))
         "Read Hit Ratio"
from      v$sysstat;

Read Hit Ratio
--------------
    .996558641
```

In 12*c*, you can also go directly to AWR information in V$SYSMETRIC. The V$SYSMETRIC view displays the system metric values captured for the most current time interval. It does this for a 60-second interval (INTSIZE_CSEC column = 6017) and another for a 15-second duration (INTSIZE_CSEC column = 1504); both are displayed in hundredths of a second. The following query displays the two rows:

```
select metric_name, to_char(begin_time,'DD-MON-YY HH24MISS') BEGIN_TIME,
       to_char(end_time, 'DD-MON-YY HH24MISS') END_TIME, value
from   v$sysmetric
where  metric_name like 'Buffer Cache Hit Ratio';

METRIC_NAME               BEGIN_TIME       END_TIME              VALUE
------------------------- ---------------- ---------------- ----------
Buffer Cache Hit Ratio    19-JUN-16 101614 19-JUN-16 101714 73.85
Buffer Cache Hit Ratio    19-JUN-16 101729 19-JUN-16 101744 100.00
```

In addition to the V$SYSMETRIC view, V$SYSMETRIC_SUMMARY displays a summary of system metric values for the long-duration system metrics (the 60-second ones) along with minimum, maximum, and average values over a 60-second duration. V$SYSMETRIC_HISTORY displays the last 90 minutes of 60-second duration metric values.

The hit ratio in this listing is very good, but that does not mean the system is perfectly tuned. A high hit ratio could mean that overly indexed queries are being used. If this hit ratio is well below 95 percent, you may need to increase the instance parameter, DB_CACHE_SIZE, or tune some of the queries that are causing disk reads (if possible and efficient to do so). One exception to this (many others are covered in Chapter 4) is when the distribution of data within the individual blocks is greatly skewed. Despite this possibility, hit ratios less than 90 percent almost always involve systems that are poorly tuned—other than those that are built in a Petri dish by someone who has built an extremely rare balance of data within each block (see Chapter 4 for additional information on data hit ratios).

You can also use the new V$DB_CACHE_ADVICE view to help you resize the data cache if you feel it is necessary. The next listing creates a list of values that shows you the effects of larger and smaller data caches and the resulting effect on physical reads (as buffers are increased, the value in the "Estd Phys Reads" column goes down):

```
column buffers_for_estimate format 999,999,999 heading 'Buffers'
column estd_physical_read_factor format 999.90 heading 'Estd Phys|Read Fact'
column estd_physical_reads format 999,999,999 heading 'Estd Phys| Reads'
SELECT   size_for_estimate, buffers_for_estimate,
         estd_physical_read_factor, estd_physical_reads
FROM     V$DB_CACHE_ADVICE
WHERE    name = 'DEFAULT'
AND      block_size =
             (SELECT value
              FROM   V$PARAMETER
              WHERE  name = 'db_block_size')
AND      advice_status = 'ON';

                                      Estd Phys    Estd Phys
SIZE_FOR_ESTIMATE        Buffers Read Fact        Reads
----------------- ------------ --------- ------------
                4          501     63.59  243,243,371
                8        1,002     45.65  174,614,755
               12        1,503      2.61    9,965,760
               16        2,004      1.00    3,824,900
               20        2,505       .76    2,909,026
               24        3,006       .57    2,165,817
               28        3,507       .41    1,555,860
               32        4,008       .33    1,253,696
```

Determining Memory for the Data Dictionary (V$ROWCACHE)

You use the V$ROWCACHE view (as in this next listing) to find how often the data dictionary calls are effectively hitting the memory cache allocated by the SHARED_POOL_SIZE instance parameter. Chapter 4 discusses this in detail. The only goal here is to review the V$ view access. If the dictionary hit ratio is not adequate, the overall system performance suffers greatly.

```
select     sum(gets), sum(getmisses),(1 - (sum(getmisses) / (sum(gets)
           + sum(getmisses)))) * 100 HitRate
from       v$rowcache;

SUM(GETS)   SUM(GETMISSES)      HITRATE
--------    -------------    ----------
  110673              670    99.9982558
```

You can also go directly to AWR information in V$SYSMETRIC:

```
select metric_name, value
from   v$sysmetric
where  metric_name = 'Row Cache Hit Ratio';

METRIC_NAME                                                            VALUE
---------------------------------------------------------------- ----------
Row Cache Hit Ratio                                                    99.99
```

The recommended hit ratio is 95 percent or greater (see Chapter 4 for some qualifications to this). If the hit ratio falls below this percentage, it indicates that the SHARED_POOL_SIZE parameter *may* need to be increased. But remember, you saw in the V$SGASTAT view that the shared pool is made up of many pieces, of which this is only one.

NOTE
Environments that make heavy use of public synonyms may struggle to get their dictionary cache hit rate higher than 75 percent even if the shared pool is huge. This is because Oracle must often check for the existence of nonexistent objects.

Determining Memory for the Shared SQL and PL/SQL (V$LIBRARYCACHE)

Accessing the V$LIBRARYCACHE view shows how well the actual statements (SQL and PL/SQL) are accessing memory. If the SHARED_POOL_SIZE parameter is too small, enough room may not be available to store all of the statements into memory. If the shared pool becomes extremely fragmented, large PL/SQL routines may not fit into the shared pool. If statements are not reused effectively, an enlarged shared pool may cause more harm than good (see Chapter 4 for additional details).

There is an execution ratio (pinhitratio) and a reload hit ratio. The recommended hit ratio for pin hits is 95+ percent, and the reload hit ratio should be 99+ percent (less than 1 percent reloads). Reloads occur when a statement has been parsed previously, but the shared pool is usually not large enough to keep in memory as other statements are parsed. The body of the statement is pushed out of memory (the head is still there); when the statement is again needed, a reload is recorded to reload the body. A reload could also occur if the execution plan for the statement changes. If either of the hit ratios falls below these percentages, it indicates that you should investigate the shared pool in greater detail. The following listing shows how to query for all of the information discussed (specifically, query V$LIBRARYCACHE to see if SQL is being reused):

```
select   sum(pins) "Executions", sum(pinhits) "Hits",
         ((sum(pinhits) / sum(pins)) * 100) "PinHitRatio",
         sum(reloads) "Misses", ((sum(pins) / (sum(pins)
         + sum(reloads))) * 100)  "RelHitRatio"
from     v$librarycache;

Executions       Hits PinHitRatio     Misses RelHitRatio
---------- ---------- ----------- ---------- -----------
   7002504    6996247  99.9106462        327  99.9953305
```

The V$SYSMETRIC view also displays the Library Cache system metric values captured for the most current time interval for 60-second and 15-second durations. The following query displays two rows, one for the last 60-second intervals and one for the last 15-second intervals:

```
select metric name, to char(begin time,'DD-MON-YY HH24MISS') BEGIN TIME,
       to_char(end_time, 'DD MON YY HH24MISS') END_TIME, value
from   v$sysmetric
where  metric name like 'Library Cache Hit Ratio';

METRIC_NAME              BEGIN_TIME      _END_TIME              VALUE
------------------------ ---------------- ---------------- ----------
Library Cache Hit Ratio 19-JUN-16 140251 19-JUN-16 140351      99.97
Library Cache Hit Ratio 19-JUN-16 140351 19-JUN-16 140406      99.82
```

Query V$SQL_BIND_CAPTURE to see if binds per SQL statement are greater than 20 (issue):

```
select sql_id, count(*) bind_count
from   v$sql_bind_capture
where  child_number = 0
group  by sql_id
having count(*) > 20
order  by count(*);

SQL_ID        BIND_COUNT
------------- ----------
9qgtwh66xg6nz         21
```

Find the problem SQL to fix:

```
select  sql_text, users_executing, executions, users_opening, buffer_gets
from    v$sqlarea
where   sql_id =  '9qgtwh66xg6nz'
order   by buffer_gets;

SQL TEXT
--------------------------------------------------------------------------------
USERS_EXECUTING EXECUTIONS USERS_OPENING BUFFER_GETS
--------------- ---------- ------------- -----------
update seg$ set type#=:4,blocks=:5,extents=:6,minexts=:7,maxexts=:8,extsize=:9,e
xtpct=:10,user#=:11,iniexts=:12,lists=decode(:13, 65535, NULL, :13),groups=decod
e(:14, 65535, NULL, :14), cachehint=:15, hwmincr=:16, spare1=DECODE(:17,0,NULL,:
17),scanhint=:18 where ts#=:1 and file#=:2 and block#=:3
              0         88             0         698
```

Query V$SQL_BIND_CAPTURE to see if average binds are greater than 15 (issue):

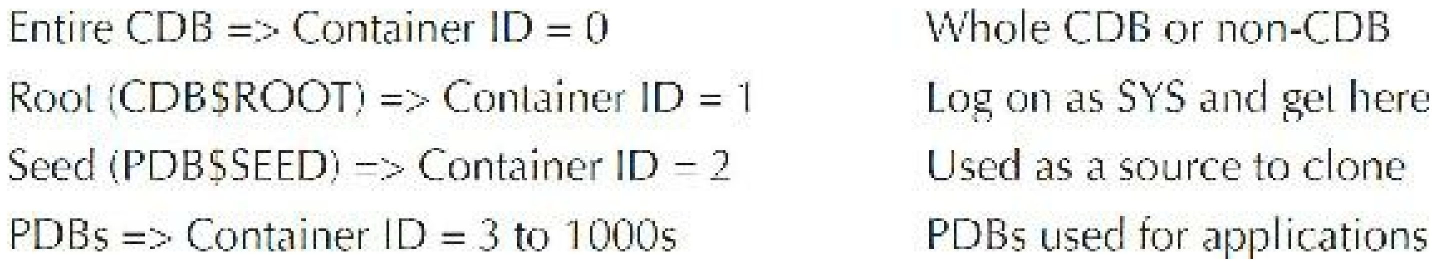
```
select avg(bind_count) AVG_NUM_BINDS from
      (select sql_id, count(*) bind_count
       from   v$sql_bind_capture
       where  child_number = 0
       group  by sql_id);

AVG_NUM_BINDS
-------------
   3.35471698
```

Querying V$CONTAINERS and V$PDBS for Container Information

Pluggable databases (PDBs) are covered in detail in Chapter 3. This chapter will serve to cover the V$ views aspect of CDBs and PDBs only. In 12*c* you can have a container database (CDB) containing multiple PDBs. Pluggable databases are also known as *multitenant databases* because each "tenant" can reside in their own PDB. "Pluggable" databases can be unplugged from one container and plugged into another container easily, therefore making a database portable between environments and allowing upgrade of a database by unplugging from one environment at one version and plugging into a new environment at a higher version. You can also unplug from on-premises and plug into the cloud (or vice versa). This feature also allows a single pluggable database to be independently recovered (you can flashback a PDB in 12*c*R2).

As mentioned in Chapter 3, in 12*c*R2, the number of containers went from 254 in 12*c*R1 to 1000+. Oracle supports 252 PDBs in 12*c*R1 and 4096 PDBs in 12*c*R2. Here is what is in each container:



Entire CDB => Container ID = 0	Whole CDB or non-CDB
Root (CDB$ROOT) => Container ID = 1	Log on as SYS and get here
Seed (PDB$SEED) => Container ID = 2	Used as a source to clone
PDBs => Container ID = 3 to 1000s	PDBs used for applications

Querying V$CONTAINERS When Using Pluggable Databases

You can query the container information by accessing V$CONTAINERS. As an example, first I'll log into the Root CDB which has two different tenants (PDB1 and PDB2), and then log into PDB1 and query V$CONTAINERS.:

```
$sqplus / as sysdba --(you are in CON ID=1 as SYS)
```

Or

```
alter session set container=cdb$root; --(you are in CON_ID=1 as SYS)
Session altered.
```

Next, I'll query V$CONTAINERS (I'm in the Root CDB which shows four containers, 1–4):

```
select con_id, name
from   v$containers;

CON_ID NAME
------ ------------------------------
     1 CDB$ROOT
     2 PDB$SEED
     3 PDB1
     4 PDB2
```

Finally, I'll go into PDB1 and query V$CONTAINERS (now only one container appears, CON_ID=3):

```
alter session set container=PDB1;
Session altered.

select con_id, name
from   v$containers;

CON_ID NAME
------ ------------------------------
     3 PDB1
```

In the next section, we'll look into the corresponding PDB names (accessing V$PDBS) for each of the containers.

Querying V$PDBS for Pluggable Database Information

You can query the pluggable database information by accessing V$PDBS. Again, first I'll log into the Root CDB (showing two different methods of doing so) and then connect to PDB1:

```
$sqplus / as sysdba --(you are in CON ID=1 as SYS)
```

Or

```
alter session set container=cdb$root;  --(you are in CON_ID=1 as SYS)
Session altered.
```

Next I query V$PDBS (which displays three PDBs, PDB$SEED, PDB1, and PDB_SS):

```
select name, open_mode, open_time
from v$pdbs;

NAME            OPEN_MODE  OPEN_TIME
--------------- ---------- -------------------------
PDB$SEED        READ ONLY  23-FEB-13 05.29.19.861 AM
PDB1            READ WRITE 23-FEB-13 05.29.25.846 AM
PDB_SS          READ WRITE 23-FEB-13 05.29.37.587 AM
3 rows selected.
```

Here is a different CDB (with three PDBs, PDB$SEED, PDB1, and PDB2):

```
select con_id, name, open_time
from v$pdbs;

    CON_ID NAME           OPEN_TIME
---------- -------------- -------------------------
         2 PDB$SEED       15-JUL-16 03.44.23.369 PM
         3 PDB1           15-JUL-16 03.44.25.710 PM
         4 PDB2           15-JUL-16 03.44.27.510 PM
3 rows selected.
```

Finally, I query V$PDBS while in PDB1 (now only one PDB appears, PDB1):

```
alter session set container=PDB1;  (I am now in CON_ID=3)
Session altered.

    CON_ID NAME           OPEN_TIME
---------- -------------- -------------------------
        3 PDB1           15-JUL-16 03.44.25.710 PM
1 row selected.
```

While logged into the Root CDB (CON_ID=1), all PDBs are listed in V$PDBs. While logged into an individual PDB (CON_ID=3 or PDB1 in the previous example), only information about that PDB is shown. There is also a V$PDB_INCARNATION view that is used to access information about a PDB incarnation (when a PDB is open with the RESETLOGS option).

TIP
Query V$CONTAINERS and V$PDBS to get detailed information on both containers and pluggable databases. When connected to the PDB, you only see information related to that specific PDB.

Using the Result Cache

Up to version 10*g*, the SHARED_POOL_SIZE consisted of the Library Cache and Dictionary Cache. You can obtain hit ratios for these caches by querying V$ROWCACHE and V$LIBRARYCACHE data dictionary views. Oracle 12*c* (and also 11*g*) provides an additional area of memory called *Result Cache Memory* (set with the RESULT_CACHE_MAX_SIZE parameter). This memory (also part of the shared pool) stores the results of SQL and PL/SQL functions in memory. The RESULT_CACHE_MODE initialization parameter controls the behavior of this memory. When RESULT_CACHE_MODE is set to MANUAL, queries need to employ a RESULT_CACHE hint to use this memory. When RESULT_CACHE_MODE is set to FORCE, all queries use this memory, if possible. The following shows an example of a query using the RESULT_CACHE hint, resulting in the use of the Result Cache Memory:

```
select      /*+ result_cache */ deptno, avg(sal)
from        emp
group by    deptno;
```

The following query displays the objects that are cached along with other attributes:

```
column cache_id format A30

select  type,status,name,cache_id,cache_key
from    v$result_cache_objects;

Type         Status    Cache Name          CACHE_ID            CACHE_KEY
------------ --------- ------------------- ------------------- ---------------------------
Dependency   Published SCOTT.EMP           SCOTT.EMP           SCOTT.EMP
Result       Published select /*+ result_ca 1bhc1ku7h4yxm07dd0z1 21ny1f0hxsxck0k98249?x1x28
                       che */ deptno, avg(s pv4zzu
                       al) from scott.emp g
                       roup by deptno

2 Rows selected.
```

The following query displays all the memory blocks and corresponding statistics:

```
col chunk            for 9999999  HEADING       'Chunk#'
col offset           for 9999999  HEADING       'Offset#'
col free             for A5       HEADING       'Free?'
col position         for 9999999  HEADING       'Position'

select  chunk, offset, free, position
from    v$result_cache_memory;

  Chunk#  Offset# Free? Position
-------- -------- ----- --------
       0        0 NO           0
       0        1 NO           0
       0        2 NO           0
       0        3 YES          0
       0        4 YES          0
       0        5 YES          0
       0        6 YES          0
       0        7 YES          0
       0        8 YES          0
       0        9 YES          0
...
```

The following query monitors Result Cache Memory usage. For a system that makes good use of Result Cache Memory, you should see a low value for Create Count Failures and a high value for Find Count.

```
column name format a20
select name, value from v$result_cache_statistics;

Cache Name                VALUE
-------------------- ----------
Block Size (Bytes)         1024
Block Count Maximum        3072
Block Count Current          32
Result Size Maximum          30
Create Count Success          1
Create Count Failure          0
Find Count                  774
Invalidation Count            0
Delete Count Invalid          0
Delete Count Valid            0
Hash Chain Length             1
Find Copy Count             774
Latch (Share)                 0

13 rows selected.
```

TIP
Query V$LIBRARYCACHE to see how often your SQL and PL/SQL are being read from memory. The pinhitratio should generally be 95 percent or greater, and the number of reloads should not be greater than 1 percent. Query V$SQL_BIND_CAPTURE to see if binds per SQL are too high and CURSOR_SHARING is needed. Use the Result Cache to force results from a query to remain in the Result Cache Memory portion of the shared pool.

Identifying PL/SQL Objects That Need to Be Kept (Pinned)

Fragmentation resulting in several small pieces being available in the shared pool and not enough large contiguous pieces is a common occurrence in the shared pool. The key to eliminating shared pool errors (see Chapters 4 and 13 for more information) is to understand which objects can cause problems. Once you know the potential problem PL/SQL objects, you can then pin this code when the database is started (and the shared pool is completely contiguous). You can query the V$DB_OBJECT_CACHE view to determine PL/SQL that is both large and currently not marked *kept*.

This query shows only the current statements in the cache. The example in this listing searches for those objects requiring greater than 100K.

```
select name, sharable_mem
from   v$db_object_cache
where  sharable_mem > 100000
and    type in ('PACKAGE', 'PACKAGE BODY',
       'FUNCTION', 'PROCEDURE')
and    kept = 'NO';

NAME                                  SHARABLE_MEM
------------------------------------- ------------
STANDARD                                    653872
DBMS_SQLTUNE                                507936
DBMS_SQLTUNE_INTERNAL                       540112
DBMS_RCVMAN                                 678488
DBMS_SCHEDULER                              238176
DBMS_BACKUP_RESTORE                         256480
DBMS_STATS                                 1222768
...
```

TIP
Query the V$DB_OBJECT_CACHE view to find objects that are not pinned and are also potentially large enough to cause fragmentation problems in the shared pool.

Finding Problem Queries by Monitoring V$SESSION_LONGOPS

If you want to track long-running SQL queries, Oracle provides a data dictionary table called V$SESSION_LONGOPS. Run the following query to get the SID, serial number, and message for long-running queries:

```
select sid, serial#, message
from   v$session_longops;

       SID    SERIAL# MESSAGE
---------- ---------- ---------------------------------------
       292       3211 Table Scan:  SYSTEM.STATSSUSER_LOG: 2477
                      7 out of 24777 Blocks done
       375      64234 Table Scan:  SYSTEM.STATSSUSER_LOG: 2477
                      7 out of 24777 Blocks done
        68      29783 Table Scan:  SYSTEM.STATSSUSER_LOG: 2477
                     7 out of 24777 Blocks done
```

You can monitor the performance of SQL statements while they are being executed. Oracle provides two data dictionary views to monitor the performance of long-running statements: V$SQL_MONITOR and V$SQL_PLAN_MONITOR (additional columns you can add in 12*c* are IS_ADAPTIVE_PLAN and IS_FINAL_PLAN as well as CON_ID when accessing this view).

```
 select   key, sql_id, sql_exec_id,
          to_char(max(sql_exec_start) ,'DD/MM/YYYY HH24:Mi:SS')
          sql_exec_start,
          sql_child_address child_address
from      v$sql_monitor
group by  key, sql_id, sql_exec_id, sql_child_address
order by  sql_exec_start;

       KEY SQL_ID        SQL_EXEC_ID SQL_EXEC_START      CHILD_AD
---------- ------------- ----------- ------------------- --------
3.6078E+11 ahvccymgw92jw    16777217 18/06/2016 12:59:08 28172AC0
3.3930E+11 ahvccymgw92jw    16777220 18/06/2016 12:59:11 28172AC0
1.6321E+11 ahvccymgw92jw    16777221 18/06/2016 12:59:12 28172AC0
2.7917E+11 ahvccymgw92jw    16777224 18/06/2016 12:59:14 28172AC0
2.3193E+11 ahvccymgw92jw    16777223 19/06/2016 12:59:14 28172AC0
...

col id format 999
col operation format a25
col object format a6
set colsep '|'
set lines 100
```

```
select   p.id,
         rpad(' ',p.depth*2, ' ')||p.operation operation,
         p.object_name object,
         p.cardinality card,
         p.cost cost,
         substr(m.status,1,4) status,
         m.output_rows
from     v$sql_plan p, v$sql_plan_monitor m
where    p.sql_id=m.sql_id
and      p.child_address=m.sql_child_address
and      p.plan_hash_value=m.sql_plan_hash_value
and      p.id=m.plan_line_id
and      m.sql_id=' ahvccymgw32jw'
and      m.sql_exec_id=16777217
and      m.sql_exec_start=to_date('20/11/2016 12:59:08 ','DD/MM/YYYY HH24:MI:SS')
order by p.id;

  ID|OPERATION                    |OBJECT|        CARD|        COST|STAT|OUTPUT_ROWS
----|-----------------------------|------|------------|------------|----|-----------
   0|SELECT STATEMENT             |      |            |     4941833|DONE|          0
   1|  RESULT CACHE               |2k8xzg|            |            |DONE|          0
    |                             |unm7z5|            |            |    |
    |                             |0c8ssc|            |            |    |
    |                             |mhy1t6|            |            |    |
    |                             |ph    |            |            |    |
   2|    SORT                     |      |           1|            |DONE|          1
   3|      NESTED LOOPS           |      |   289220332|     4941833|DONE|  616317649
   4|        TABLE ACCESS         |EMP   |       74130|          63|DONE|     150000
   5|        TABLE ACCESS         |EMP   |        3902|          67|DONE|  616317649

6 rows selected.
```

The STAT column displays EXEC when the query is still running. This status shows which step is being executed at a point in time. In the V$SESSION_LONGOPS view, you can query the TIME_REMAINING and SOFAR columns, but using these to estimate how long something will take is tough. Oracle considers operations to be linearly running, so later operations may take longer than earlier ones (and vice versa). Lastly, not every long-running query shows up in this view. The following criteria must be met (note that it is not the scans that must meet the minimum block threshold, but the objects being scanned):

- Must be running over 6 seconds of actual time AND
- Be a full table scan of a table that occupies over 10,000 blocks OR
- Be a full index scan of an index that occupies over 1000 blocks OR
- Be a hash join (as few as 20 blocks reported to show up)

This changes from version to version; do your own testing to make sure.

Finding Problem Queries by Querying V$SQLAREA

V$SQLAREA provides a means of identifying the *potential* problem SQL statements or SQL statements that need to be optimized to improve overall database optimization by reducing disk access. The DISK_READS column displays the volume of disk reads being performed on the system. This, combined with the EXECUTIONS column (DISK_READS/EXECUTIONS), returns the SQL statements that have the most disk hits per statement execution. The DISK_READS value is set to 100000, but it could be set much higher or lower on production systems (depending on the database) to reveal only the top problem statements on your system. Once identified, review and optimize the top statements to improve overall performance. Typically, a statement with very large disk reads is not using an index or the execution path is forcing the statement to not use the proper indexes.

One potentially misleading part of the query in the following listing is the RDS_EXEC_RATIO column. RDS_EXEC_RATIO contains the number of disk reads divided by the executions. In reality, a statement may be read once using 100 disk reads and then forced out of memory (if memory is insufficient). If it is read again, then it will read 100 disk reads again and the RDS_EXEC_RATIO will be 100 (or 100 + 100 reads divided by 2 executions). But if the statement happens to be in memory the second time (memory is sufficient), the disk reads will be 0 (the second time) and the RDS_EXEC_RATIO will be only 50 (or 100 + 0 divided by 2 executions). Any statement that makes the top of this list is a problem and needs to be tuned—period!

NOTE
The following code was formatted for ease of reading.

```
select      b.username username, a.disk_reads reads,
            a.executions exec, a.disk_reads /decode
            (a.executions, 0, 1,a.executions) rds_exec_ratio,
            a.sql_text Statement
from        v$sqlarea a, dba_users b
where       a.parsing_user_id = b.user_id
and         a.disk_reads        > 100000
order by    a.disk_reads desc;

USERNAME  READS      EXEC  RDS_EXEC_RATIO   STATEMENT
--------  -------    ----  --------------   ---------------------------------
ADHOC1    7281934       1         7281934   select  custno, ordno
                                            from    cust, orders
ADHOC5    4230044       4         1057511   select  ordno
                                            from    orders
                                            where   trunc(ordno)  = 721305
ADHOC1     801715       2          499858   select  custno, ordno
                                            from    cust
                                           where   decode(custno,1,6)  = 314159
```

The DISK_READS column in the preceding statement can be replaced with the BUFFER_GETS column to provide information on SQL statements that may not possess the large disk hits (although they usually do) but possess a large number of memory hits (higher than normally desired). These statements are using a large amount of memory that is allocated for the data (DB_CACHE_SIZE). The problem is not that the statement is being executed in memory (which is good), but that the statement is hogging a lot of the memory. Many times, this problem is attributable to a SQL statement using an index when it should be doing a full table scan or a join. These types of SQL statements can also involve a join operation that is forcing the path to use a different index than desired, or using multiple indexes and forcing index merging or volumes of data merging. Remember, the bulk of system performance problems are attributable to poorly written SQL and PL/SQL statements.

TIP
Query the V$SQLAREA to find problem queries (and users).

Finding Out What Users Are Doing and Which Resources They Are Using

Joining V$SESSION and V$SQLTEXT displays the SQL statement that is currently being executed by each session, as shown here. This query is extremely useful when a DBA is trying to determine what is happening in the system at a given point in time.

```
select   a.sid, a.username, s.sql_text
from     v$session a, v$sqltext s
where    a.sql_address   = s.address
and      a.sql_hash_value = s.hash_value
order by a.username, a.sid, s.piece;

SID  USERNAME     SQL_TEXT
---  ----------   ------------------------------------
 11  PLSQL USER   update s employee set salary = 10000
  9  SYS          select a.sid, a.username, s.sql_text
  9  SYS          from v$session a, v$sqltext
  9  SYS          where a.sql_address  = s.address
  9  SYS          and a.sql hash value  = s.hash value
  9  SYS          order by a.username, a.sid, s.piece
(...partial output listing)
```

The SQL_TEXT column displays the entire SQL statement, but the statement is stored in the V$SQLTEXT view as a VARCHAR2(64) data type and, therefore, spans multiple records. The PIECE column is used to order the statement. To view the resources being used by each of the users, simply use the query in the next listing. The goal of this statement is to highlight the physical disk and memory hits for each session. Recognizing users who are performing a large number of physical disk or memory reads is very easy.

```
select    a.username, b.block_gets, b.consistent_gets,
          b.physical_reads, b.block_changes, b.consistent_changes
from      v$session a, v$sess_io b
where     a.sid = b.sid
order by  a.username;

USERNAME   BLOCK GETS  CONSISTENT GETS  PHYSICAL READS  BLOCK CHANGES  CONSISTENT CHANGES
---------- ----------  ---------------  --------------  -------------  ------------------
PLSQL USER         39               72              11             53                   1
SCOTT              11               53              12              0                   0
SYS                14              409              26              0                   0
SYSTEM           8340            10197             291           3558                 419
```

TIP
Query V$SESSION, V$SQLTEXT, and V$SESS_IO to find the problem users and what they are executing at a given point in time.

Finding Out Which Objects a User Is Accessing

Querying V$ACCESS can point you to potential problem objects (potentially missing indexes) once you have found the problem user or query on your system. It can also be helpful when you want to modify a particular object and need to know who is using it at a given point in time, as shown here:

```
select a.sid, a.username, b.owner, b.object, b.type
from   v$session a, v$access b
where  a.sid = b.sid;
```

```
SID  USERNAME   OWNER   OBJECT                  TYPE
---  --------   -----   ---------------------   -------
  8  SCOTT      SYS     DBMS_APPLICATION_INFO   PACKAGE
  9  SYS        SYS     DBMS_APPLICATION_INFO   PACKAGE
  9  SYS        SYS     X$BH                    TABLE
 10  SYSTEM     PUBLIC  V$ACCESS                SYNONYM
 10  SYSTEM     PUBLIC  V$SESSION               SYNONYM
 10  SYSTEM     SYS     DBMS_APPLICATION_INFO   PACKAGE
 10  SYSTEM     SYS     V$ACCESS                VIEW
 10  SYSTEM     SYS     V$SESSION               VIEW
 10  SYSTEM     SYS     V $ACCESS               VIEW
```

This script displays all objects being accessed, including synonyms, views, and stored source code.

TIP
Query V$ACCESS to find all objects that are being accessed by a user at a given time. This can help to pinpoint problem objects, while also being helpful when modifying a particular object (find out who is accessing it). However, this operation would be very expensive on a system with a large shared pool and hundreds of users.

Getting Detailed User Information

A method for analyzing user statistics is extremely valuable when testing a new or updated application module to determine overhead. This method also provides a window to a user who is having performance problems because it provides statistics on a variety of areas for each user. In addition, it can serve as a guideline for setting profiles to limit a particular user. The script in this next listing limits the statistics only to areas that have a value (b.value != 0).

```
select    a.username, c.name, sum(b.value) value
from      v$session a, v$sesstat b, v$statname c
where     a.sid          = b.sid
and       b.statistic#   = c.statistic#
and       b.value       != 0
group by  name, username;

USERNAME                       NAME                                    VALUE
------------------------------ ----------------------------------- ----------
SYS                            DB time                                   3690
                               redo size                              2143640
SYS                            redo size                                98008
                               user calls                                  28
SYS                            user calls                                 337
                               IMU Flushes                                  1
SYS                            IMU Flushes                                  2
                               IMU commits                                 19
SYS                            IMU commits                                  1
                               redo writes                               4443
                               redo entries                              8728
...etc.
```

Using Indexes

The V$OBJECT_USAGE view indicates whether the index is used but not how often it is used. You need to turn monitoring ON and OFF individually for indexes that you want to monitor. You initiate monitoring with the ALTER INDEX command, and index use is then tracked by querying the V$OBJECT_USAGE view. Here is a description of the V$OBJECT_USAGE view:

```
SQL> desc v$object_usage

Name                      Null?    Type
------------------------- -------- ----------------------------
INDEX_NAME                NOT NULL VARCHAR2(30)
TABLE_NAME                NOT NULL VARCHAR2(30)
MONITORING                         VARCHAR2(3)
USED                               VARCHAR2(3)
START_MONITORING                   VARCHAR2(19)
END_MONITORING                     VARCHAR2(19)
```

Before any index is monitored, the view has no records:

```
select   *
from     v$object_usage;

no rows selected
```

You start monitoring on four indexes (connect to user schema-owning indexes):

```
alter index HRDT_INDEX1 monitoring usage;
alter index HRDT_INDEX2 monitoring usage;
alter index HRDT_INDEX3 monitoring usage;
alter index HRDT_INDEX4 monitoring usage;
```

The view now shows the four indexes with a start time but no use yet:

```
select index_name, table_name, monitoring, used,
       start_monitoring, end_monitoring
from   v$object usage;

INDEX_NAME  TABLE_NAME MON USE START_MONITORING    END_MONITORING
----------- ---------- --- --- ------------------- -------------------
HRDT_INDEX1 HRS_DETAIL YES NO  10/13/2016 03:11:34
HRDT INDEX2 HRS DETAIL YES NO  10/13/2016 03:11:38
HRDT INDEX3 HRS DETAIL YES NO  10/13/2016 03:11:46
HRDT INDEX4 HRS DETAIL YES NO  10/13/2016 03:11:52
```

If you query using HRDT_INDEX1, the view now shows that this index has been used:

```
select index_name, table_name, monitoring, used,
       start monitoring, end monitoring
from   v$object_usage;

INDEX_NAME  TABLE_NAME MON USE START_MONITORING    END_MONITORING
----------- ---------- --- --- ------------------- -------------------
HRDT_INDEX1 HRS_DETAIL YES YES 10/13/2016 03:11:34
HRDT INDEX2 HRS DETAIL YES NO  10/13/2016 03:11:38
HRDT_INDEX3 HRS_DETAIL YES NO  10/13/2016 03:11:46
HRDT INDEX4 HRS DETAIL YES NO  10/13/2016 03:11:52
```

You end the monitoring on HRDT_INDEX4, and the view now shows an end monitoring time:

```
alter index HRDT_INDEX4 nomonitoring usage;
select index_name, table_name, monitoring, used,
       start_monitoring, end_monitoring
from   v$object_usage;

INDEX NAME  TABLE NAME MON USE START MONITORING    END MONITORING
----------- ---------- --- --- ------------------- -------------------
HRDT_INDEX1 HRS_DETAIL YES YES 10/13/2016 03:11:34
HRDT_INDEX2 HRS_DETAIL YES NO  10/13/2016 03:11:38
HRDT_INDEX3 HRS_DETAIL YES NO  10/13/2016 03:11:46
HRDT_INDEX4 HRS_DETAIL NO  NO  10/13/2016 03:11:52 10/13/2011 03:16:01
```

TIP
Use the V$OBJECT_USAGE view to find out if indexes are being used. Perhaps some indexes are not needed.

Identifying Locking Issues

Identifying locking issues is instrumental in locating the user who is waiting for someone or something else. You can use this strategy to identify users who are currently being locked in the system and to determine whether an Oracle-related process is truly locked or just running slowly. You can also identify the current statement that the locked user is currently executing. The next listing provides an example of identifying locking issues.

NOTE
These statements were not tuned in the early version of the book. (Now that's embarrassing!)

```
select     /*+ ordered */ b.username, b.serial#, d.id1, a.sql_text
from       v$lock d, v$session b, v$sqltext a
where      b.lockwait    = d.kaddr
and        a.address     = b.sql_address
and        a.hash_value  = b.sql_hash_value;

USERNAME      SERIAL#          ID1    SQL_TEXT
--------   ----------  -----------    ------------------------------
AUTHUSER           53       393242    update emp set salary = 5000
```

You also need to identify the user in the system *who* is causing the problem of locking the previous user, as shown in this listing. (Usually this is the user/developer who presses ctrl-alt-del as you approach his or her desk.)

```
select    /*+ ordered */ a.serial#, a.sid, a.username, b.id1, c.sql_text
from      v$lock b, v$session a, v$sqltext c
where     b.id1 in
          (select   /*+ ordered */ distinct e.id1
           from     v$lock e, v$session d
           where    d.lockwait   = e.kaddr)
and       a.sid          = b.sid
and       c.hash_value = a.sql_hash_value
and       b.request      = 0;

SERIAL#   SID   USERNAME      ID1       SQL_TEXT
-------   ---   --------   -------      -----------------------------------
     18    11    JOHNSON    393242      update authuser.emp set salary=90000
```

JOHNSON will make everyone happy by forgetting a crucial WHERE clause. Unfortunately, JOHNSON has locked the authorized user of this table.

You can also look at locking in more detail to see exactly what's running and blocking. In Chapter 9, I discuss block-level tuning; there I describe some of these columns and also how to perform queries to V$TRANSACTION (which shows all DML [UPDATE/INSERT/DELETE] transactions currently running). In the following listing, you can see four transactions all running at the same time to the same block of information. There is no blocking because the initrans is set to handle (at least set to 4 ITL slots—max of 24 slots) all four changes within the same block at the same time. If there was a problem, the LMODE would have been 0 and the REQUEST would have been 6 (TX6), as in the third query that follows.

Four users are updating different rows in the same block:

```
select /*+ ordered */ username, v$lock.sid, trunc(id1/power(2,16)) rbs,
       bitand(id1,to_number('ffff','xxxx'))+0 slot,
       id2 seq, lmode, request
from   v$lock, v$session
where  v$lock.type = 'TX'
and    v$lock.sid = v$session.sid;

USERNAME          SID        RBS       SLOT        SEQ      LMODE    REQUEST
---------- ---------- ---------- ---------- ---------- ---------- ----------
SCOTT             146          6         32         85          6          0
SCOTT             150          4         39      21557          6          0
SCOTT             151          5         34       1510          6          0
SCOTT             161          7         24         44          6          0

select xid, xidusn, xidslot, xidsqn, status, start_scn
from   v$transaction
order by start_scn;

XID                  XIDUSN    XIDSLOT     XIDSQN STATUS            START_SCN
---------------- ---------- ---------- ---------- ---------------- ----------
0600200055000000          6         32         85 ACTIVE             16573480
0400270035540000          4         39      21557 ACTIVE             16573506
05002200E6050000          5         34       1510 ACTIVE             16573545
070018002C000000          7         24         44 ACTIVE             16574420
```

Here three users are trying to update the exact same row:

```
select /*+ ordered */ username, v$lock.sid, trunc(id1/power(2,16)) rbs,
       bitand(id1,to_number('ffff','xxxx'))+0 slot,
       id2 seq, lmode, request
from   v$lock, v$session
where  v$lock.type = 'TX'
and    v$lock.sid = v$session.sid;

USERNAME          SID        RBS       SLOT        SEQ      LMODE    REQUEST
---------- ---------- ---------- ---------- ---------- ---------- ----------
SCOTT             146          4         47      21557          0          6
SCOTT             150          4         47      21557          6          0
SCOTT             161          4         47      21557          0          6

select xid, xidusn, xidslot, xidsqn, status, start_scn
from   v$transaction
order by start_scn;

XID                  XIDUSN    XIDSLOT     XIDSQN STATUS            START_SCN
---------------- ---------- ---------- ---------- ---------------- ----------
04002F0035540000          4         47      21557 ACTIVE             16575501
```

Here two users are blocked:

```
SELECT sid, blocking_session, username, blocking_session_status
FROM   v$session
WHERE  username='SCOTT'
ORDER BY blocking_session;

       SID BLOCKING_SESSION USERNAME   BLOCKING_SESSION_STATUS
---------- ---------------- ---------- -----------------------
       146              150 SCOTT      VALID
       161              150 SCOTT      VALID
       150                  SCOTT      NO HOLDER
```

Killing the Problem Session

A user may have run something that he or she really didn't want to run, or a problem query may need to be eliminated during business hours and rerun at night. If the operation in the preceding section needs to be aborted, you could execute the statements in the next listing (to find and then kill the session):

```
select username, sid, serial#, program, terminal
from   v$session;
```

You can also do this in a single statement using

```
select /*+ ordered */ username, v$lock.sid, trunc(id1/power(2,16)) rbs,
       bitand(id1,to_number('ffff','xxxx'))+0 slot,
       id2 seq, lmode, request
from   v$lock, v$session
where  v$lock.type = 'TX'
and    v$lock.sid = v$session.sid;

alter system kill session '150,47752';
System altered.
```

You can't kill your own session though:

```
alter system kill session '146,54327';
*
ERROR at line 1:
ORA-00027: cannot kill current session
```

The order of parameters is SID and then SERIAL# (`alter system kill session 'sid,serial#';`). Make sure you describe V$SESSION (DESC V$SESSION) because many of its columns are helpful. In previous versions of Oracle, you could kill the current user session. Thankfully, you can no longer kill your own session accidentally, as just shown in the preceding listing.

TIP
Identify users who are locking others and kill their session (if necessary).

Finding Users with Multiple Sessions

At times, users enjoy opening multiple sessions to accomplish several tasks at once, and this can be a problem. The problem may also be a developer who has built a poor application that begins spawning multiple processes. Either of these could degrade the system's overall performance. In the following output, the usernames that are NULL are background processes. The query to the V$SESSION view in this listing displays these types of issues:

```
select    username, count(*)
from      v$session
group by  username;

USERNAME      COUNT(*)
-----------   --------
PLSQL_USER           1
SCOTT                1
JOHNSON              9
DBSNMP               3
SYS                  4
SYSTEM               1
                    39
```

On certain OS platforms, if a user starts a session and reboots his or her PC, oftentimes the process continues in the background on the server as the user starts another session. If the user is running multiple reports on multiple terminals or PCs, this could also affect the system's overall performance.

NOTE
The rows in V$SESSION that have NULL values for username are the Oracle background processes.

TIP
Identify users who are running multiple sessions and determine whether the problem is administrative (the user is using multiple terminals) or system related (sessions are not being cleaned or are spawning runaway processes).

Querying for Current Profiles

Profiles are limits on a given schema (user). The Oracle STIG (Security Technical Implementation Guide) Profile is provided in Oracle 12*c*. This is much stronger security than the DEFAULT profile. To view the profiles for your system, execute the query shown here:

```
select    substr(profile,1,10) Profile,
          substr(resource_name,1,30) "Resource Name",
          substr(limit,1,10) Limit
from      dba_profiles
group by  substr(profile,1,10), substr(resource_name,1,30),
          substr(limit,1,10);

PROFILE         Resource Name                  LIMIT
--------------- ------------------------------ ----------
DEFAULT         CONNECT_TIME                   UNLIMITED
DEFAULT         CPU_PER_CALL                   UNLIMITED
DEFAULT         COMPOSITE_LIMIT                UNLIMITED
DEFAULT         CPU_PER_SESSION                UNLIMITED
DEFAULT         FAILED_LOGIN_ATTEMPTS          10
DEFAULT         IDLE_TIME                      UNLIMITED
DEFAULT         INACTIVE_ACCOUNT_TIME          UNLIMITED
DEFAULT         LOGICAL_READS_PER_CALL         UNLIMITED
DEFAULT         LOGICAL_READS_PER_SESSION      UNLIMITED
DEFAULT         PASSWORD_LIFE_TIME             180
DEFAULT         PASSWORD_LOCK_TIME             1
DEFAULT         PASSWORD_REUSE_MAX             UNLIMITED
DEFAULT         PASSWORD_GRACE_TIME            7
DEFAULT         PASSWORD_REUSE_TIME            UNLIMITED
DEFAULT         PASSWORD_VERIFY_FUNCTION       NULL
DEFAULT         PRIVATE_SGA                    UNLIMITED
DEFAULT         SESSIONS_PER_USER              UNLIMITED
ORA_STIG_PRFILE IDLE_TIME                      15
ORA_STIG_PRFILE PRIVATE_SGA                    DEFAULT
ORA_STIG_PRFILE CONNECT_TIME                   DEFAULT
ORA_STIG_PRFILE CPU_PER_CALL                   DEFAULT
ORA_STIG_PRFILE COMPOSITE_LIMIT                DEFAULT
ORA_STIG_PRFILE CPU_PER_SESSION                DEFAULT
ORA_STIG_PRFILE FAILED_LOGIN_ATTEMPTS          3
ORA_STIG_PRFILE INACTIVE_ACCOUT_TIME           30
ORA_STIG_PRFILE LOGICAL_READS_PER_CALL         DEFAULT
ORA_STIG_PRFILE LOGICAL_READS_PER_SESSION      DEFAULT
ORA_STIG_PRFILE PASSWORD_LIFE_TIME             60
ORA_STIG_PRFILE PASSWORD_LOCK_TIME             UNLIMITED
ORA_STIG_PRFILE PASSWORD_REUSE_MAX             10
ORA_STIG_PRFILE PASSWORD_GRACE_TIME            5
ORA_STIG_PRFILE PASSWORD_REUSE_TIME            365
ORA_STIG_PRFILE PASSWORD_VERIFY_FUNCTION       ORA12C_STRONG_VERIFY_FUNCTION
ORA_STIG_PRFILE SESSIONS_PER_USER              DEFAULT

34 rows selected.
```

Finding Disk I/O Issues

The views V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES provide file I/O activity across all database datafiles and disks. Ideally, the physical reads and writes should be distributed equally. If the system is not configured properly, overall performance suffers. The script in this next listing identifies the actual distribution and makes identifying where an imbalance exists easy. Chapter 3 looks at this topic in great detail; this section just shows the quick-hit query to get a baseline.

```
select     a.file#, a.name, a.status, a.bytes,
           b.phyrds, b.phywrts
from       v$datafile a, v$filestat b
where      a.file# = b.file#;
```

The queries in the following listings provide an improved formatted report for file and data distribution issues. The first listing gets the datafile I/O:

```
Set TrimSpool On
Set Line     142
Set Pages     57
Set NewPage    0
Set FeedBack Off
Set Verify   Off
Set Term     On
TTitle       Off
BTitle       Off
Clear Breaks
Break On Tablespace_Name
Column TableSpace_Name For A12     Head "Tablespace"
Column Name     For A45            Head "File Name"
Column Total    For 999,999,990    Head "Total"
Column Phyrds   For 999,999,990    Head "Physical|Reads  "
Column Phywrts  For 999,999,990    Head "Physical| Writes "
Column Phyblkrd For 999,999,990    Head "Physical  |Block Reads"
Column Phyblkwrt For 999,999,990   Head "Physical  |Block Writes"
Column Avg_Rd_Time  For 90.9999999 Head "Average |Read Time|Per Block"
Column Avg_Wrt_Time For 90.9999999 Head "Average |Write Time|Per Block"
Column Instance         New_Value _Instance   NoPrint
Column Today            New_Value _Date       NoPrint
select   Global_Name Instance, To_Char(SysDate, 'FXDay, Month DD, YYYY HH:MI') Today
from     Global_Name;
TTitle On
TTitle Left 'Date Run: ' _Date Skip 1-
Center 'Data File I/O' Skip 1 -
       Center 'Instance Name: ' _Instance Skip 1
select     C.TableSpace_Name, B.Name, A.Phyblkrd +
           A.Phyblkwrt Total, A.Phyrds, A.Phywrts,
           A.Phyblkrd, A.Phyblkwrt
from       V$FileStat A, V$DataFile B, Sys.DBA_Data_Files C
where      B.File# = A.File#
and        B.File# = C.File_Id
order by  TableSpace_Name, A.File#
/
```

```
select object_name, statistic_name, value
from v$segment_statistics

where value > 100000
order by value;
```

```
OBJECT_NAME  STATISTIC_NAME     VALUE
-----------  -----------------  ------
ORDERS       space allocated    96551
ORDERS       space allocated    134181
ORDERS       logical reads      140976
ORDER_LINES  db block changes   183600
```

This second listing gets the disk I/O:

```
Column TableSpace_Name For A12      Head "Tablespace"
Column Total      For 9,999,999,990 Head "Total"
Column Phyrds     For 9,999,999,990 Head "Physical|Reads  "
Column Phywrts    For 9,999,999,990 Head "Physical| Writes "
Column Phyblkrd   For 9,999,999,990 Head "Physical  |Block Reads"
Column Phyblkwrt  For 9,999,999,990 Head "Physical  |Block Writes"
Column Avg_Rd_Time   For 9,999,990.9999   Head "Average |Read Time|Per Block"
Column Avg_Wrt_Time  For 9,999,990.9999   Head "Average |Write Time|Per Block"
Clear Breaks
Break on Disk Skip 1
Compute Sum Of Total On Disk
Compute Sum Of Phyrds On Disk
Compute Sum Of Phywrts On Disk
Compute Sum Of Phyblkrd On Disk
Compute Sum Of Phyblkwrt On Disk
TTitle Left 'Date Run: ' _Date Skip 1-
       Center 'Disk I/O' Skip 1 -
       Center 'Instance Name: ' _Instance Skip 2
select      SubStr(B.Name, 1, 13) Disk, C.TableSpace_Name,
            A.Phyblkrd + A.Phyblkwrt Total, A.Phyrds, A.Phywrts,
            A.Phyblkrd, A.Phyblkwrt, ((A.ReadTim /
            Decode(A.Phyrds,0,1,A.Phyblkrd))/100) Avg_Rd_Time,
            ((A.WriteTim / Decode(A.PhyWrts,0,1,A.PhyblkWrt)) /
            100) Avg_Wrt_Time
from        V$FileStat A, V$DataFile B, Sys.DBA_Data_Files C
where       B.File# = A.File#
and         B.File# = C.File_Id
order by    Disk,C.Tablespace_Name, A.File#
/
Set FeedBack On
Set Verify   On
Set Term     On
Ttitle       Off
Btitle       Off
```

TIP
The views V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES provide file I/O activity across all database datafiles and disks. Ensure that both datafiles and disks are properly balanced for optimal performance.

The query in this listing shows the waits on the entire system as a whole:

```
Set TrimSpool On
Set NewPage    0
Set Pages     57
Set Line     132
Set FeedBack Off
Set Verify   Off
Set Term     On
TTitle       Off
BTitle       Off
Clear Breaks
Column Event       For A40 Heading "Wait Event"
Column Total_Waits For 999,999,990 Head "Total Number| Of Waits  "
Column Total_Timeouts For 999,999,990 Head "Total Number|Of TimeOuts"
Column Tot_Time    For 999,999,990 Head "Total Time|Waited  "
Column Avg_Time    For  99,990.999 Head "Average Time|Per Wait  "
Column Instance New_value _Instance    NoPrint
Column Today    New_Value _Date        NoPrint

select    Global_Name Instance, To_Char(SysDate,
          'FXDay DD, YYYY HH:MI') Today
from      Global_Name;

TTitle On
TTitle Left 'Date Run: ' _Date Skip 1-
       Center 'System Wide Wait Events' Skip 1 -
       Center 'Instance Name: ' _Instance Skip 2

select    event, total_waits, total_timeouts,
          (time_waited / 100)  tot_time, (average_wait / 100)
          Avg_time
from      v$system_event
order by  total_waits desc
/


Date Run: Friday    01, 2006 09:24
                                                         System Wide Wait Events
                                                           Instance Name: ORCL

                                          Total Number Total Number   Total Time Average
Time
Wait Event                                  Of Waits    Of TimeOuts     Waited       Per Wait
---------------------------------------- ------------ ------------ ------------ ------------
db file sequential read                      2,376,513            0       30,776        0.010
db file scattered read                         136,602            0        6,069        0.040
rdbms ipc message                              103,301       99,481      276,659        2.680
latch: redo writing                             57,488            0            0        0.000...
```

Checking for Privileges and Roles

This section contains several V$ scripts that show various security privileges. The title of each script preceding each of the following listings gives you a quick idea of what it retrieves for you. The output can be very large, depending on your system, so run with caution!

Object-level privileges that have been granted by username

```
select b.owner || '.' || b.table_name obj,
       b.privilege what_granted, b.grantable,
       a.username
from   sys.dba_users a, sys.dba_tab_privs b
where  a.username = b.grantee
order by 1,2,3;
```

Object-level privileges that have been granted by grantee

```
Select   owner || '.' || table_name obj,
         privilege what_granted, grantable, grantee
from     sys.dba_tab_privs
where    not exists
        (select  'x'
         from sys.dba_users
         where  username = grantee)
order by 1,2,3;
```

System-level grants by username

```
select    b.privilege what_granted,
          b.admin_option, a.username
from      sys.dba_users a, sys.dba_sys_privs b
where     a.username = b.grantee
order by  1,2;
```

System-level grants by grantee

```
select   privilege what_granted,
         admin_option, grantee
from     sys.dba_sys_privs
where    not exists
          (select  'x' from sys.dba_users
           where username = grantee)
order by 1,2;
```

Roles granted by username

```
select    b.granted_role ||
          decode(admin_option, 'YES',
       ' (With Admin Option)',
          null) what_granted, a.username
from      sys.dba_users a, sys.dba_role_privs b
where     a.username = b.grantee
order by  1;
```

Roles granted by grantee

```
select   granted_role  ||
         decode(admin_option, 'YES',
      ' (With Admin Option)', null) what_granted,
         grantee
from     sys.dba_role_privs
where    not exists
        (select 'x'
         from sys.dba_users
         where username = grantee)
order by 1;
```

Usernames with corresponding granted privileges

```
select a.username,
 b.granted_role || decode(admin_option,'YES',
    ' (With Admin Option)',null) what_granted
from   sys.dba_users a, sys.dba_role_privs b
where  a.username = b.grantee
UNION
select a.username,
b.privilege || decode(admin_option,'YES',
    ' (With Admin Option)', null) what_granted
from   sys.dba_users a, sys.dba_sys_privs b
where  a.username = b.grantee
UNION
select   a.username,
         b.table_name || ' - ' || b.privilege
         || decode(grantable,'YES',
      ' (With Grant Option)',null) what_granted
from     sys.dba_users a, sys.dba_tab_privs b
where    a.username = b.grantee
order by 1;
```

TIP
Document the privileges that you have for your system so you are ready for any type of security situation.

Usernames with corresponding profile, default tablespace, and temporary tablespace

```
Select   username, profile, default_tablespace,
         temporary_tablespace, created
from     sys.dba_users
order by username;
```

Wait Events V$ Views

This section contains several V$ scripts that show wait events. Personally, I prefer using the Statspack Report, the AWR Report, or Enterprise Manager to find wait events. That said, this section presents some nice views to look at wait events. Several new views have been added over the years, but the *best* thing in 11*g* and 12*c* is that everything you found in V$SESSION_WAIT in the past is now in V$SESSION.

To find out who is waiting right now, query V$SESSION_WAIT or V$SESSION:

```
select event, sum(decode(wait_time,0,1,0)) "Waiting Now",
       sum(decode(wait_time,0,0,1)) "Previous Waits",
       count(*) "Total"
from v$session_wait
group by event
order by count(*);

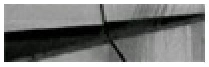
WAIT_TIME = 0 means that it's waiting
WAIT TIME > 0 means that it previously waited this many ms

EVENT                        Waiting Now       Previous Waits     Total
---------------------------- ------------      --------------     -------
db file sequential read      0                 1                  1
db file scattered read       2                 0                  2
latch free                   0                 1                  1
enqueue                      2                 0                  2
SQL*Net message from client 0               254                480
...

select event, sum(decode(wait_time,0,1,0)) "Waiting Now",
       sum(decode(wait time,0,0,1)) "Previous Waits",
       count(*) "Total"
from v$session
group by event
order by count(*);

EVENT                        Waiting Now       Previous Waits     Total
---------------------------- ------------      --------------     --------
db file sequential read      0                 1                  1
db file scattered read       2                 0                  2
latch free                   0                 1                  1
enqueue                      2                 0                  2
SQL*Net message from client 0               254                480
...
```

To view specific waits for who is waiting right now, query V$SESSION_WAIT:



```
SELECT /*+ ordered */ sid, event, owner, segment_name, segment_type,p1,p2,p3
FROM   v$session wait sw, dba extents de
WHERE  de.file id = sw.p1

AND    sw.p2 between de.block_id and de.block_id+de.blocks - 1
AND    (event = 'buffer busy waits' OR event = 'write complete waits')
AND    p1 IS NOT null
ORDER BY event,sid;
```

To view the last ten waits for who is waiting, query V$SESSION_WAIT_HISTORY:

```
SELECT /*+ ordered */ sid, event, owner, segment_name, segment_type,p1,p2,p3
FROM   v$session_wait_history sw, dba_extents de
WHERE  de.file_id = sw.p1
AND    sw.p2 between de.block_id and de.block_id+de.blocks - 1
AND    (event = 'buffer busy waits' OR event = 'write complete waits')
AND    p1 IS NOT null
ORDER BY event,sid;
```

To find what P1, P2, and P3 stand for, query V$EVENT_NAME:

```
col name for a20
col p1 for a10
col p2 for a10
col p3 for a10
select event#,name,parameter1 p1,parameter2 p2,parameter3 p3
from   v$event_name
where  name in ('buffer busy waits', 'write complete waits');

 EVENT#       NAME                  P1         P2         P3
------------- -------------------- ---------- ---------- ----------
          143 write complete waits file#      block#
          145 buffer busy waits    file#      block#     id
```

To view all waits since the session started, query V$SESSION_EVENT:

```
select sid, event, total_waits, time_waited
from   v$session_event
where  time_waited > 0
order  by time_waited;

SID        EVENT                          TOTAL_WAITS TIME_WAITED
---------- ------------------------------ ----------- -----------
       159 process startup                          2           1
       167 latch: redo allocation                   4           1
       168 log buffer space                         2           3
       166 control file single write                5           4
...
```

To view all SESSION waits by class, query V$SESSION_WAIT_CLASS:

```
select sid, wait_class, total_waits
from   v$session_wait_class;

       SID WAIT_CLASS           TOTAL_WAITS
---------- -------------------- -----------
       168 Other                          2
       168 Concurrency(locking)           1
       168 Idle                       12825
       168 User I/O                      12
       168 System I/O                  4448
       169 Other                          1
       169 Idle                       12812
       170 Idle                       13527
```

To view all waits since the system started, query V$SYSTEM_EVENT:

```
select event, total_waits, time_waited, event_id
from   v$system_event
where  time_waited > 0
order  by time waited;

EVENT                               TOTAL_WAITS TIME_WAITED   EVENT_ID
----------------------------------- ----------- ----------- ----------
enq: TX - row lock contention              1196      366837  310662678
enq: TM - contention                        170       52074  668627480
db file sequential read                   17387       31630 2652584166
control file parallel write               12961       23117 4078387448
db file scattered read                     4706       15762  506183215
class slave wait                             20       10246 1055154682
```

To view SYSTEM waits by class, query V$SYSTEM_WAIT_CLASS (you could also do a sum(total_waits) in the SELECT and add a group by wait_class):

```
select wait_class, total_waits
from   v$system_wait_class
order  by total_waits desc;

WAIT_CLASS           TOTAL_WAITS
-------------------- -----------
Idle                      161896
Other                      65308
System I/O                 24339
User I/O                   22227
Application                 1404
Commit                       524
Network                      522
Concurrency                  221
Configuration                 55
...
```

To view SYSTEM waits by class, query V$ACTIVE_SESSION_HISTORY. This view also has many columns to check INMEMORY (INMEMORY_QUERY and others) as well as a SQL_ADAPTIVE_PLAN_RESOLVED column. Here are a couple of queries to the V$ACTIVE_SESSION_HISTORY view:

```
-- In the query below, the highest count session in non-idle wait events.
select session_id,count(1)
from   v$active_session_history
group  by session_id
order by 2;

-- In the query below, find the SQL for the leader in non-idle wait events.
select c.sql_id, a.sql_text
from v$sql a, (select sql_id,count(1)
                       from v$active_session_history b where sql_id is not null
                       group by sql_id
                       order by 2 desc) c
where rownum <= 5
order by rownum;
```

TIP
All wait event columns that are in V$SESSION_WAIT are now in V$SESSION. So make sure you query V$SESSION for wait information since it's a faster view. V$ACTIVE_SESSION_HISTORY (ASH) rolls many of the great statistics into one view as well as one report (ASH Report).

Some of the Major V$ View Categories

The views in this section are categorized according to their primary function. Not all are listed (please see Appendix B for a complete listing of the V$ views with X$ table queries). You will often need to join one category to another category to retrieve the desired information. The V$ views can be queried the same as any other Oracle view, but keep in mind that the information in these tables changes rapidly. You can insert the information from the V$ views into a pre-created table to allow for the compilation of data over a period of time—data to be analyzed later or to build statistical reports and alerts based on different conditions in your database.

Most DBA monitoring tools on the market today use the V$ view (and X$ table) information. Querying this database information without a DBA monitoring tool requires that you have an in-depth understanding of the information stored in each view and how to query the view properly. Table 12-1 contains a list of V$ views categorized according to their primary function. The views are listed in categories related to the operation that they monitor. This list is not exhaustive. It contains only the most commonly used views. Some views have changed from version to version of Oracle.

Category	Description and Associated V$ Views
Pluggable databases (new in 12c)	Information related to pluggable databases (PDBs) **V$ view:** V$PDBS (also note V$ views include CDB_PDBS, CDB_PDB_HISTORY, CDB_TABLES, and CDB_DATA_FILES)
In-Memory (new in 12c)	Information related to In-Memory (IM) Column Store **V$ views:** V$INMEMORY_AREA, V$INMEMORY_XMEM_AREA, V$IM_SEGMENTS, V$IM_SEGMENTS_DETAIL, VIM_COLUMN_LEVEL, VIM_COL_CU, VIM_HEADER, VIM_SEG_EXT_MAP, V$IM_USER_SEGMENTS, and V$KEY_VECTOR
Advisors	Information related to cache advisors **V$ views:** V$ADVISOR_PROGRESS, V$DB_CACHE_ADVICE, V$JAVA_POOL_ADVICE, V$MEMORY_TARGET_ADVICE, VPGA_TARGET_ADVICE, VPGA_TARGET_ADVICE_HISTOGRAM, VPX_BUFFER_ADVICE, VSHARED_POOL_ADVICE, V$SGA_TARGET_ADVICE, and V$STREAMS_POOL_ADVICE
ASM	Information related to Automatic Storage Management **V$ views:** VASM_ALIAS, VASM_ATTRIBUTE, VASM_CLIENT, VASM_DISK, VASM_DISK_IOSTAT, VASM_DISK_STAT, V$ASM_DISKGROUP, V$ASM_DISKGROUP_STAT, VASM_FILE, VASM_OPERATION, V$ASM_TEMPLATE, V$ASM_USER, V$ASM_USER_GROUP, and V$ASM_USERGROUP_MEMBER
Backup/recovery	Information related to database backups and recovery, including last backup, archive logs, state of files for backup, and recovery **V$ views:** V$ARCHIVE, V$ARCHIVED_LOG, V$ARCHIVE_DEST, V$ARCHIVE_DEST_STATUS, V$ARCHIVE_GAP, V$ARCHIVE_PROCESSES, V$BACKUP, V$BACKUP_ASYNC_IO, V$BACKUP_CORRUPTION, V$BACKUP_DATAFILE, V$BACKUP_DEVICE, V$BACKUP_PIECE, V$BACKUP_REDOLOG, V$BACKUP_SET, V$BACKUP_SYNC_IO, V$BLOCK_CHANGE_TRACKING, V$COPY_CORRUPTION, V$DATABASE_BLOCK_CORRUPTION, V$DATABASE_INCARNATION, V$DATAFILE_COPY, V$DELETED_OBJECT, V$FAST_START_SERVERS, V$FAST_START_TRANSACTIONS, V$INSTANCE_RECOVERY, V$MTTR_TARGET_ADVICE, V$PROXY_ARCHIVEDLOG, V$PROXY_DATAFILE, V$RMAN_CONFIGURATION, V$RECOVERY_FILE_STATUS, V$RECOVERY_LOG, V$RECOVERY_PROGRESS, V$RECOVERY_STATUS, V$RECOVER_FILE, V$BACKUP_ARCHIVELOG_DETAILS, V$BACKUP_ARCHIVELOG_SUMMARY, V$BACKUP_CONTROLFILE_DETAILS, V$BACKUP_CONTROLFILE_SUMMARY, V$BACKUP_COPY_DETAILS, V$BACKUP_COPY_SUMMARY, V$BACKUP_DATAFILE_DETAILS, V$BACKUP_DATAFILE_SUMMARY, V$BACKUP_FILES, V$BACKUP_PIECE_DETAILS, V$BACKUP_SET_DETAILS, V$BACKUP_SET_SUMMARY, V$BACKUP_SPFILE, V$BACKUP_SPFILE_DETAILS, V$BACKUP_SPFILE_SUMMARY, V$DATABASE, V$DATAFILE, V$DATAFILE_HEADER, V$FLASHBACK_DATABASE_LOG, V$FLASHBACK_DATABASE_LOGFILE, V$FLASHBACK_DATABASE_STAT, V$FLASHBACK_TXN_GRAPH, V$FLASHBACK_TXN_MODS, VHM_CHECK, VINSTANCE, V$OBSOLETE_BACKUP_FILES, V$OFFLINE_RANGE, V$PROXY_ARCHIVELOG_DETAILS, V$PROXY_ARCHIVELOG_SUMMARY, V$PROXY_COPY_DETAILS, V$PROXY_COPY_SUMMARY, V$RECOVERY_AREA_USAGE, V$RECOVERY_FILE_DEST(10,1), V$RESTORE_POINT, V$RMAN_BACKUP_JOB_DETAILS, V$RMAN_BACKUP_SUBJOB_DETAILS, V$RMAN_BACKUP_TYPE, V$RMAN_COMPRESSION_ALGORITHM, V$RMAN_ENCRYPTION_ALGORITHMS, V$RMAN_OUTPUT, V$RMAN_STATUS, and V$UNUSABLE_BACKUPFILE_DETAILS

Category	Description and Associated V$ Views
Caches	Information related to the various caches, including objects, library, cursors, and the dictionary **V$ views:** V$ACCESS, V$BUFFER_POOL, V$BUFFER_POOL_STATISTICS, V$CPOOL_CC_INFO, V$CPOOL_CC_STATS, V$CPOOL_CONN_INFO, V$CPOOL_STATS, VDB_CACHE_ADVICE, VDB_OBJECT_CACHE, V$JAVA_POOL_ADVICE, V$LIBRARYCACHE, V$LIBRARY_CACHE_MEMORY, V$PGASTAT, V$MEMORY_CURRENT_RESIZE_OPS, V$MEMORY_DYNAMIC_COMPONENTS, V$MEMORY_RESIZE_OPS, V$PGA_TARGET_ADVICE, V$PGA_TARGET_ADVICE_HISTOGRAM, V$RESULT_CACHE_DEPENDENCY, V$RESULT_CACHE_MEMORY, V$RESULT_CACHE_OBJECTS, V$RESULT_CACHE_STATISTICS, V$ROWCACHE, V$ROWCACHE_PARENT, V$ROWCACHE_SUBORDINATE, V$SESSION_CURSOR_CACHE, V$SESSION_OBJECT_CACHE, V$SGA, V$SGASTAT, V$SGA_CURRENT_RESIZE_OPS, V$SGA_DYNAMIC_COMPONENTS, V$SGA_DYNAMIC_FREE_MEMORY, VSGA_RESIZE_OPS, VSGAINFO, V$SHARED_POOL_ADVICE, V$SHARED_POOL_RESERVED, VSQL, VSQLAREA, V$SYSTEM_CURSOR_CACHE, V$SUBCACHE, V$JAVA_LIBRARY_CACHE_MEMORY, V$PROCESS_MEMORY, and V$SGA_TARGET_ADVICE
Cache fusion/RAC	Information related to RAC **V$ views:** V$ACTIVE_INSTANCES, V$BH, V$CACHE, V$CACHE_TRANSFER, V$CLUSTER_INTERCONNECTS, V$CONFIGURED_INTERCONNECTS, VCR_BLOCK_SERVER, VCURRENT_BLOCK_SERVER, V$DYANMIC_REMASTER_STATS, V$GC_ELEMENT, V$GC_ELEMENTS_WITH_COLLISIONS, V$GCSHVMASTER_INFO, V$GCSPFMASTER_INFO, V$GES_BLOCKING_ENQUEUE, V$GES_ENQUEUE, V$HVMASTER_INFO, V$INSTANCE_CACHE_TRANSFER, V$LIBRARYCACHE, V$PX_INSTANCE_GROUP, and V$RESOURCE_LIMIT
Control files	Information related to instance control files **V$ views:** V$CONTROLFILE, V$CONTROLFILE_RECORD_SECTION, and V$DATABASE
Cursors/SQL statements	Information related to cursors and SQL statements, including the open cursors, statistics, and actual SQL text **V$ views:** V$OPEN_CURSOR, V$SQL, V$SQLAREA, V$SQLFN_ARG_METADATA, V$SQLFN_METADATA, V$SQLTEXT, V$SQLTEXT_WITH_NEWLINES, V$SQL_BIND_DATA, V$SQL_BIND_METADATA, V$SQL_CS_HISTOGRAM, V$SQL_CS_SELECTIVITY, V$SQL_CS_STATISTICS, VSQL_CURSOR, VSQL_OPTIMIZER_ENV, VSQL_PLAN, VSQL_PLAN_MONITOR, V$SQL_PLAN_STATISTICS, V$SQL_PLAN_STATISTICS_ALL, V$SQL_REDIRECTION, V$SESSION_CURSOR_CACHE, VSQL_SHARED_CURSOR, VSQL_SHARED_MEMORY, V$SQL_MONITOR, V$SQLCOMMAND, V$SQLSTATS_PLAN_HASH, V$SQL_WORKAREA, V$SQL_WORKAREA_ACTIVE, V$SQL_WORKAREA_HISTOGRAM, V$SYS_OPTIMIZER_ENV, V$SYSTEM_CURSOR_CACHE, V$MUTEX_SLEEP, V$MUTEX_SLEEP_HISTORY (for those dubious shared latches), V$SQL_BIND_CAPTURE, V$SQL_JOIN_FILTER, V$SQL_AREA_PLAN_HASH, V$SQLSTATS, V$SYS_OPTIMIZER_ENV, and V$VPD_POLICY
Database instances	Information related to the actual database instance **V$ views:** V$ACTIVE_INSTANCES, V$ARCHIVER_PROCESSES, V$BGPROCESS, V$DATABASE, V$INSTANCE, V$PROCESS, VSGA, VSGASTAT, V$BLOCKING_QUIESCE, and V$CLIENT_STATS **RAC views:** V$BH and V$ACTIVE_INSTANCES

Category	Description and Associated V$ Views
Direct Path operations	Information related to the SQL*Loader (and the Direct Path API) direct load option **V$ views:** V$LOADISTAT and V$LOADPSTAT
Distributed/ heterogeneous services	Information related to Distributed Services V$ views: V$DBLINK, V$GLOBAL_TRANSACTION, V$GLOBAL_BLOCKED_LOCKS, V$HS_AGENT, V$HS_PARAMETER, V$HS_SESSION, and V$IOSTAT_NETWORK
File mapping interface	Information related to file mapping **V$ views:** VMAP_COMP_LIST, VMAP_ELEMENT, V$MAP_EXT_ELEMENT, V$MAP_FILE, VMAP_FILE_EXTENT, VMAP_FILE_IO_STACK, V$MAP_LIBRARY, and V$MAP_SUBELEMENT
Fixed view	Information related to the V$ tables themselves **V$ views:** V$FIXED_TABLE, V$FIXED_VIEW_DEFINITION, and V$INDEXED_FIXED_COLUMN
General	General information related to various pieces of system information **V$ views:** VDB_PIPES, VCONTEXT, V$GLOBALCONTEXT, V$LICENSE, V$OPTION, V$RESERVED_WORDS, V$SQLCOMMAND, V$TEMPORARY_LOBS, V$THRESHOLD_TYPES, V$TIMER, V$TIMEZONE_NAMES, V$TOPLEVELCALL, V$TYPE_SIZE, V$_SEQUENCES, V$VERSION, V$DB_TRANSPORTABLE_PLATFORM, V$TRANSPORTABLE_PLATFORM, and V$SCHEDULER_RUNNING_JOBS
I/O	Information related to I/O, including files and statistics **V$ views:** V$DATAFILE, V$DATAFILE_HEADER, V$DBFILE, V$DNFS_CHANNELS, V$DNFS_FILES, V$DNFS_SERVERS, V$DNFS_STATS, V$FILESPACE_USAGE, V$FILESTAT, V$WAITSTAT, V$TEMPSTAT, V$FILE_HISTOGRAM, V$FILEMETRIC, V$FILEMETRIC_HISTORY, V$IOFUNCMETRIC, V$IOFUNCMETRIC_HISTORY, V$IO_CALIBRATION_STATUS, V$IOSTAT_CONSUMER_GROUP, V$IOSTAT_FILE, V$IOSTAT_FUNCTION, V$IOSTAT_FUNCTION_DETAIL, V$IOSTAT_NETWORK, V$NFS_CLIENTS, VNFS_LOCKS, VNFS_OPEN_FILES, V$SECUREFILE_TIMER, V$SEGMENT_STATISTICS, V$SYSAUX_OCCUPANTS, V$TABLESPACE, V$TEMP_SPACE_HEADER, V$TEMPFILE, and V$TEMPSEG_USAGE
Latches/locks	Information related to latches and locks **V$ views:** V$ACCESS, V$ENQUEUE_LOCK, V$ENQUEUE_STAT, V$EVENT_NAME, V$GLOBAL_BLOCKED_LOCKS, V$LATCH, V$LATCHHOLDER, V$LATCHNAME, V$LATCH_CHILDREN, V$LATCH_MISSES, V$LATCH_PARENT, V$LIBCACHE_LOCKS, V$LOCK, V$LOCK_TYPE, V$LOCKED_OBJECT, V$RESOURCE, V$RESOURCE_LIMIT, V$TRANSACTION_ENQUEUE, V$_LOCK, V$_LOCK1, and V$ENQUEUE_STATISTICS **RAC views:** VCR_BLOCK_SERVER, VGCSHVMASTER_INFO, V$GCSPFMASTER_INFO, V$GC_ELEMENT, V$GES_BLOCKING_ENQUEUE, V$GES_ENQUEUE, V$HVMASTER_INFO, V$NFS_LOCKS, V$GES_RESOURCES, and V$PROCESS
Log Miner	Information related to Log Miner **V$ views:** V$LOGMNR_CALLBACK, V$LOGMNR_CONTENTS, V$LOGMNR_DICTIONARY, V$LOGMNR_LATCH, V$LOGMNR_LOGS, V$LOGMNR_PARAMETERS, V$LOGMNR_PROCESS, V$LOGMNR_REGION, V$LOGMNR_SESSION, V$LOGMNR_STATS, V$LOGMNR_TRANSACTION, and V$LOGMNR_DICTIONARY_LOAD
Metrics	Information related to metrics **V$ views:** V$METRICNAME, V$SERVICEMETRIC, V$EVENTMETRIC, V$FILEMETRIC, V$FILEMETRIC_HISTORY, V$IOFUNCMETRIC, V$METRIC, V$METRIC_HISTORY, V$RSRCMGRMETRIC, V$RSRCMGRMETRIC_HISTORY, V$SERVICEMETRIC_HISTORY, V$SESSMETRIC, V$SYSMETRIC, V$SYSMETRIC_HISTORY, V$SYSMETRIC_SUMMARY, V$THRESHOLD_TYPES, V$WAITCLASSMETRIC, and V$WAITCLASSMETRIC_HISTORY

Category	Description and Associated V$ Views
Multithreaded/shared servers	Information related to multithreaded and parallel servers, including connections, queues, dispatchers, and shared servers **V$ views:** V$CIRCUIT, V$DISPATCHER, V$DISPATCHER_RATE, V$QUEUE, V$QUEUEING_MTH, V$REQDIST, V$SHARED_SERVER, V$SHARED_SERVER_MONITOR, and V$DISPATCHER_CONFIG
Object usage	Information related to object use and dependencies **V$ views:** V$OBJECT_DEPENDENCY, V$OBJECT_PRIVILEGE, and V$OBJECT_USAGE
Overall system	Information related to the overall system performance **V$ views:** V$ALERT_TYPES, V$EMON, V$EVENTMETRIC, V$EVENT_HISTOGRAM, V$EVENT_NAME, V$GLOBAL_TRANSACTION, VHM_CHECK, VMEMORY_CURRENT_RESIZE_OPS, V$OSSTAT, V$RESUMABLE, V$SEGMENT_STATISTICS, V$SHARED_POOL_RESERVED, VSGA, VSORT_SEGMENT, V$STATNAME, V$SYS_OPTIMIZER_ENV, VSYS_TIME_MODEL, VSYSSTAT, V$SYSTEM_CURSOR_CACHE, V$SYSTEM_EVENT, V$SYSTEM_FIX_CONTROL, V$TEMPFILE, V$TEMPORARY_LOBS, V$TEMPSEG_USAGE, V$TEMP_EXTENT_MAP, V$TEMP_EXTENT_POOL, V$TEMP_SPACE_HEADER, V$TRANSACTION, V$SYSTEM_WAIT_CLASS, V$TEMP_HISTOGRAM, V$WAITSTAT, and V$XML_AUDIT_TRAIL
Parallel query and parallel execution	Information related to the Parallel Query option **V$ views:** V$EXECUTION, V$PARALLEL_DEGREE_LIMIT_MTH, V$PQ_SESSTAT, V$PQ_SLAVE, V$PQ_SYSSTAT, V$PQ_TQSTAT, V$PX_INSTANCE_GROUP, V$PX_PROCESS, V$PX_PROCESS_SYSSTAT, V$PX_SESSION, and V$PX_SESSTAT
Parameters	Information related to various Oracle parameters, including initialization and NLS per session **V$ views:** V$NLS_PARAMETERS, V$NLS_VALID_VALUES, V$OBSOLETE_PARAMETER, V$PARAMETER, V$PARAMETER2, V$SPPARAMETER, V$SYSTEM_PARAMETER, V$SYSTEM_PARAMETER2, and V$PARAMETER_VALID_VALUES
Redo logs	Information related to redo logs, including statistics and history **V$ views:** V$INSTANCE, V$LOG, V$LOGFILE, V$LOGHIST, V$LOG_HISTORY, V$REDO_DEST_RESP_HISTOGRAM, and V$THREAD (RAC related)
Replication and materialized views	Information related to replication and materialized views **V$ views:** V$MVREFRESH, V$REPLPROP, and V$REPLQUEUE
Resource Manager	Information related to resource management **V$ views:** V$ACTIVE_SESSION_POOL_MTH, V$ACTIVE_SESSION_HISTORY, V$IO_CALIBRATION_STATUS, V$IOSTAT_CONSUMER_GROUP, V$RSRC_CONS_GROUP_HISTORY, V$RSRC_CONSUMER_GROUP, V$RSRC_CONSUMER_GROUP_CPU_MTH, V$RSRC_PLAN, V$RSRC_PLAN_CPU_MTH, V$RSRC_PLAN_HISTORY, V$RSRC_SESSION_INFO, V$RSRCMGRMETRIC, and V$RSRCMETRIC_HISTORY
Rollback segments and UNDO	Information on rollback segments, including statistics and transactions **V$ views:** V$ROLLNAME, V$ROLLSTAT, V$TRANSACTION, and V$UNDOSTAT
Security/privileges	Information related to security **V$ views:** V$ENABLEDPRIVS, V$OBJECT_PRIVILEGE, V$PWFILE_USERS, V$VPD_POLICY, V$WALLET, and V$XML_AUDIT_TRAIL

Category	Description and Associated V$ Views
Sessions (includes some replication information and heterogeneous services)	Information related to a session, including object access, cursors, processes, and statistics **V$ views:** V$ACTIVE_SESSION_HISTORY, V$ARCHIVE_PROCESSES, V$BGPROCESS, V$CONTEXT, V$MYSTAT, V$PROCESS, V$SESS_TIME_MODEL, V$SESSION, V$SESSION_BLOCKERS,V$SESSION_CONNECT_INFO, V$SESSION_CURSOR_CACHE, V$EMON, V$SESSION_EVENT, V$SESSION_FIX_CONTROL, V$SESSION_LONGOPS, V$SESSION_OBJECT_CACHE, V$SESSION_WAIT, V$SESSION_WAIT_CLASS, V$SESSION_WAIT_HISTORY, V$SESSTAT, V$SESS_IO, V$SES_OPTIMIZER_ENV, V$SESSMETRIC, and V$CLIENT_STATS, V$TSM_SESSIONS, and V$WAIT_CHAINS
Services	Information related to Services **V$ views:** V$ACTIVE_SERVICES, V$SERV_MOD_ACT_STATS, V$SERVICE_EVENT, V$SERVICEMETRIC, V$SERVICEMETRIC_HISTORY, V$SERVICE_STATS, V$SERVICE_WAIT_CLASS, and V$SERVICES
Sorting	Information related to sorting **V$ views:** V$SORT_SEGMENT, V$TEMPSEG_USAGE, V$TEMP_EXTENT_MAP, V$TEMP_EXTENT_POOL, V$TEMP_SPACE_HEADER, V$TEMPFILE, and V$TEMPSTAT
Standby databases (Data Guard)	Information related to standby databases **V$ views:** V$ARCHIVE_DEST, V$ARCHIVE_DEST_STATUS, V$ARCHIVE_GAP, V$ARCHIVED_LOG, V$DATABASE, V$DATAGUARD_STATUS, V$INSTANCE, V$FOREIGN_ARCHIVED_LOG, V$FS_FAILOVER_STATS, V$LOGSTDBY_STATS, V$MANAGED_STANDBY, V$STANDBY_LOG, V$DATAGUARD_CONFIG, V$DATAGUARD_STATS, V$LOGSTDBY_PROCESS, V$LOGSTDBY_PROGRESS, V$LOGSTDBY_STATE, V$LOGSTDBY_TRANSACTION, and V$STANDBY_EVENT_HISTOGRAM
Streams/AQ	Information related to streams and Advanced Queuing **V$ views:** VAQ, VARCHIVE_DEST_STATUS, V$ARCHIVED_LOG, V$DATABASE, V$BUFFERED_PUBLISHERS, V$BUFFERED_QUEUES, V$BUFFERED_SUBSCRIBERS, V$METRICGROUP, V$PERSISTENT_PUBLISHERS, V$PERSISTENT_QMN_CACHE, V$PERSISTENT_QUEUES, V$PERSISTENT_SUBSCRIBERS, V$PROPAGATION_RECEIVER, V$PROPAGATION_SENDER, V$QMON_COORDINATOR_STATS, V$QMON_SERVER_STATS, V$QMON_TASK_STATS, V$QMON_TASKS, V$RULE, V$RULE_SET, V$RULE_SET_AGGREGATE_STATS, V$STREAMS_APPLY_COORDINATOR, V$STREAMS_APPLY_READER, V$STREAMS_APPLY_SERVER, V$STREAMS_CAPTURE, V$STREAMS_MESSAGE_TRACKING, V$STREAMS_POOL_ADVICE, V$STREAMS_POOL_STATISTICS, V$STREAMS_TRANSACTION, V$XSTREAM_CAPTURE, V$XSTREAM_MESSAGE_TRACKING, V$XSTREAM_OUTBOUND_SERVER, and V$XSTREAM_TRANSACTION
Statistics	Information related to statistics in general **V$ views:** V$SEGMENT_STATISTICS, V$SEGSTAT, V$SEGSTAT_NAME, V$SESSSTAT, V$SGASTAT, V$SQLSTATS, V$SQLSTATS_PLAN_HASH, V$STATISTICS_LEVEL, V$STATNAME, V$TEMPSTAT, V$UNDOSTAT, and V$WAITSTAT
Transactions	Information related to transactions in general **V$ views:** V$CORRUPT_XID_LIST, V$GLOBAL_TRANSACTION, V$LOCKED_OBJECT, V$LOGSTDBY_TRANSACTION, V$RESUMABLE, V$STREAMS_TRANSACTION, V$TRANSACTION, V$TRANSACTION_ENQUEUE, V$UNDOSTAT, and V$XSTREAM_TRANSACTION

Category	Description and Associated V$ Views
Misc. recent V$	Recent Views with Miscellaneous Information **V$ views:** V$ASM_ATTRIBUTE, V$ASM_DISK_IOSTAT, V$CALLTAG, V$CLIENT_RESULT_CACHE_STATS, V$CORRUPT_XID_LIST, V$CPOOL_CC_INFO, V$CPOOL_CC_STATS, V$CPOOL_STATS, V$DETACHED_SESSION, V$DIAG_INFO, V$DNFS_CHANNELS, V$DNFS_FILES, V$DNFS_SERVERS, V$DNFS_STATS, V$DYNAMIC_REMASTER_STATS, V$ENCRYPTED_TABLESPACES, V$ENCRYPTION_WALLET, V$FLASHBACK_TXN_GRAPH, V$FLASHBACK_TXN_MODS, V$FOREIGN_ARCHIVED_LOG, V$FS_FAILOVER_HISTOGRAM, V$FS_FAILOVER_STATS, V$HM_CHECK, VHM_CHECK_PARAM, VHM_FINDING, VHM_INFO, VHM_RECOMMENDATION, VHM_RUN, VINCMETER_CONFIG, V$INCMETER_INFO, V$INCMETER_SUMMARY, V$IOFUNCMETRIC, V$IOFUNCMETRIC_HISTORY, V$IOSTAT_CONSUMER_GROUP, V$IOSTAT_FILE, V$IOSTAT_FUNCTION, V$IOSTAT_NETWORK, V$IO_CALIBRATION_STATUS, V$IR_FAILURE, V$IR_FAILURE_SET, V$IR_MANUAL_CHECKLIST, VIR_REPAIR, VLOBSTAT, V$MEMORY_CURRENT_RESIZE_OPS, V$MEMORY_DYNAMIC_COMPONENTS, V$MEMORY_RESIZE_OPS, V$MEMORY_TARGET_ADVICE, V$NFS_CLIENTS, V$NFS_LOCKS, VNFS_OPEN_FILES, VOBJECT_PRIVILEGE, V$PERSISTENT_PUBLISHERS, V$PERSISTENT_QUEUES, V$PERSISTENT_SUBSCRIBERS, V$PROCESS_GROUP, V$PX_INSTANCE_GROUP, V$REDO_DEST_RESP_HISTOGRAM, V$RESULT_CACHE_DEPENDENCY, V$RESULT_CACHE_MEMORY, V$RESULT_CACHE_OBJECTS, V$RESULT_CACHE_STATISTICS, V$RMAN_COMPRESSION_ALGORITHM, V$RMAN_ENCRYPTION_ALGORITHMS, V$RSRCMGRMETRIC, V$RSRCMGRMETRIC_HISTORY, V$SECUREFILE_TIMER, V$SESSION_FIX_CONTROL, V$SQL_CS_HISTOGRAM, V$SQL_CS_SELECTIVITY, V$SQL_CS_STATISTICS, V$SQL_FEATURE, V$SQL_FEATURE_DEPENDENCY, V$SQL_FEATURE_HIERARCHY, V$SQL_HINT, V$SQL_MONITOR, V$SQL_PLAN_MONITOR, V$SQLFN_ARG_METADATA, V$SQLFN_METADATA, V$SSCR_SESSIONS, V$STREAMS_MESSAGE_TRACKING, V$SUBSCR_REGISTRATION_STATS, V$SYSTEM_FIX_CONTROL, V$WAIT_CHAINS, V$WORKLOAD_REPLAY_THREAD, V$XS_SESSION, V$XS_SESSION_ATTRIBUTE, and V$XS_SESSION_ROLE
Misc. V$	Other Miscellaneous **V$ views:** V$ASM_ACFSSNAPSHOTS, V$ASM_ACFSVOLUMES, V$ASM_FILESYSTEM, V$ASM_USER, V$ASM_USERGROUP, V$ASM_USERGROUP_MEMBER, VASM_VOLUME, VASM_VOLUME_STAT, V$CPOOL_CONN_INFO, V$EMON, V$IOSTAT_FUNCTION_DETAIL, V$LIBCACHE_LOCKS, V$PERSISTENT_QMN_CACHE, V$QMON_COORDINATOR_STATS, V$QMON_SERVER_STATS, V$QMON_TASK_STATS, V$QMON_TASKS, V$SQLCOMMAND, V$STANDBY_EVENT_HISTOGRAM, V$STREAMS_POOL_STATISTICS, and V$TOPLEVELCALL

TABLE 12-1. *V$ Views Categories*

NOTE
The V$ROLLNAME view is created slightly differently than the other V$ views. The

V$ROLLNAME is a join of an X$ table and the UNDO$ table. Some of the V$ timing fields are dependent on the TIMED_STATISTICS `init.ora` *parameter being set to TRUE; otherwise, there will be no timing data in these fields*.

Tips Review

- The V$ views that are accessed by SYSTEM are actually synonyms that point to the V_$ views that are views of the original V$ views based on the X$ tables.
- When other DBAs need access to the V$ view information, but *not* the SYS or SYSTEM passwords, grant the user access to the V_$ views. The user may then access the V$ views that have public synonyms to the V_$ views. However, scripts could always be written to query the SYS. V_$ views directly, to avoid the performance cost of dereferencing the public synonym, but this savings is small.
- Query V$FIXED_TABLE to obtain a listing of all GV$ and V$ views in the database. The GV$ views are the exact same as the V$ views, except the instance ID contains an identifier, and the GV$ views contain data for all instances of an Oracle RAC database.
- Access the V$FIXED_VIEW_DEFINITION view to get all information about the underlying X$ tables that make up a V$ view. CON_ID (Container ID) is a new column you'll see in 12*c* for pluggable databases in many V$ views.
- The DBA_ views are not derived from the X$ tables or V$ views. The fact that you can delete rows from OBJ$ and ruin your database is a great reason to never be the SYS superuser. There is a CDB_ view for every DBA_ view, and the Root CDB_ views also contain PDB information about all PDBs.
- Query V$VERSION and V$DATABASE to view basic database information such as the version, to find out when your database was created, and to find out basic archiving information.
- Query V$SYSAUX_OCCUPANTS to ensure that the Automatic Workload Repository (AWR) isn't taking up too much space. Use DBMS_STATS to check history and retention.
- Query the V$OPTION view to retrieve the Oracle options you have installed. The V$VERSION view gives you the versions of the installed base options.
- Query the V$IM_SEGMENTS and V$IM_COLUMN_LEVEL views to retrieve detailed information about specific objects that are stored in the In-Memory (IM) column store (only available in 12.1.0.2+).
- Access the V$SGA view to get a baseline idea of the system's physical memory allocated for data, shared pool, large pool, Java pool, and log buffering of Oracle. A new SGA parameter to set is INMEMORY_SIZE.
- Querying V$SGASTAT provides a detailed breakdown for the Oracle SGA and details all aggregated buckets of shared pool allocation.Query V$PARAMETER to get the current values for the initialization parameters. V$PARAMETER also shows which initialization parameters have been changed from their original defaults: ISDEFAULT= FALSE. It also shows which

parameters may be changed only for a given session if ISSES_MODIFIABLE=TRUE. Lastly, it shows which parameters may be changed without shutting down and restarting the database for ISSYS_MODIFIABLE=IMMEDIATE as well as ISSYS_MODIFIABLE=DEFERRED for a parameter that is enforced for all new logins but not currently logged-on sessions. If the parameter ISSYS_MODIFIABLE=FALSE, then the instance must be shut down and restarted for the parameter to take effect. See Chapter 4 for more information on the initialization parameters.

- Query V$CONTAINERS and V$PDBS to get detailed information on both containers and pluggable databases. When connected to the PDB, you only see information related to that specific PDB. Query V$LIBRARYCACHE to see how often your SQL and PL/SQL are being read from memory. The pinhitratio should generally be at 95 percent or greater, and the number of reloads should not be greater than 1 percent. Query V$SQL_BIND_CAPTURE to see if binds per SQL are too high and CURSOR_SHARING is needed. Use the Result Cache to force results from a query to remain in the Result Cache Memory portion of the shared pool.
- Query the V$DB_OBJECT_CACHE view to find objects that are not pinned and are also potentially large enough to cause fragmentation problems in the shared pool.
- Query the V$SQLAREA to find problem queries (and users).
- Query V$SESSION, V$SQLTEXT, and V$SESS_IO to find the problem users and what they are executing at a given point in time.
- Query V$ACCESS to find all objects that are being accessed by a user at a given time. This can help to pinpoint problem objects, while also being helpful when modifying a particular object (find out who is accessing it). However, this operation would be very expensive on a system with a large shared pool and hundreds of users.
- Use the V$OBJECT_USAGE view to find out if indexes are being used. Perhaps some indexes are not needed.
- Identify users who are locking others and kill their session (if necessary).
- Identify users who are holding multiple sessions and determine whether the problem is administrative (the user is using multiple terminals) or system related (sessions are not being cleaned or are spawning runaway processes).
- The views V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES provide file I/O activity across all database datafiles and disks. Ensure that both datafiles and disks are properly balanced for optimal performance.
- Document the privileges that you have for your system so you are ready for any type of security situation. The Oracle STIG (Security Technical Implementation Guide) Profile is provided in Oracle 12*c*.

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CHAPTER 13

The X$ Tables and Internals Topics (Advanced DBA)

Why do people climb mountains? Because they are there! Why do people open the hood of their car and look at what's inside? Because they can! Why do DBAs look at the X$ tables? Because they are there and they can!

Oracle now has 1312 X$ tables in 12*c*R2 (there were 945 in 11*g*R2), and they are the last frontier for the expert DBA to explore and analyze the deepest cavern of the Oracle database. Querying the X$ tables can give secrets to undocumented features and parameters, information about future Oracle versions, and shorter or faster routes to database information. The X$ tables are rarely mentioned in the Oracle documentation or the Oracle user community. Therefore, I am including them in this book as one of the only detailed references available. The queries in this chapter were tested accessing version 12.2 of the database.

The tips covered in this chapter include:

- Introducing the X$ tables
- Creating V$ views and X$ tables in 12*c*
- X$ tables comprising the V$ views (including V$MEMORY_AREA and V$PDBS)
- Obtaining a list of all the X$ tables in 12*c*
- Obtaining a list of all the X$ indexes in 12*c*
- Using hints with X$ tables and indexes
- Monitoring space allocations in the shared pool
- Creating queries to monitor the shared pool
- Obtaining information about redo log files
- Setting initialization parameters and X$KSPPCV (undocumented)
- Exploring buffer cache/data block details
- Obtaining database- and instance-specific information
- Effective X$ table use and strategy

- Oracle internals topics
- Reading the trace file
- Some common X$ table groups
- Some common X$ table and non-V$ fixed view associations
- Common X$ table joins
- X$ table naming conventions (including 12*c*)—my favorite section of the book!
- X$ 12*c* tables including CON_ID and INMEMORY

Introducing the X$ Tables

The X$ tables are intriguing to mischievously curious DBAs. There are 1312 X$ tables in 12*c*R2, compared to only 945 X$ tables in 11*g*R2 (11.2.0.1). There are also 799 indexes on the X$ tables. Appendix C shows how to list all of these. The Oracle dynamic tables are designed similarly to many of the robust Oracle application data models. A set of tables is available to users (DBAs) via a set of synonyms on a set of views based on these tables. The synonym names start with *V$* and are the object names published in the reference manual of the Oracle documentation set. These synonyms on the V$ views are used as the primary method of querying data from these tables. Interested DBAs, however, keep and use a toolkit of practical X$ table queries that supplement their V$ view queries.

The X$ tables contain instance-specific information spanning a variety of areas. They contain information about the current configuration of the instance, information about the sessions connected to the instance, and a gold mine of performance information. The X$ tables are platform-specific. The documented column definitions of the V$ views may be consistent from platform to platform, but the underlying SQL statements referencing the X$ tables may differ. The Oracle kernel consists of layers. The X$ table names contain an abbreviation for the particular kernel layer to which they pertain. They have been expanded for pluggable databases (PDBs) with CON_ID (Container ID) on many current tables/views (new X$ tables such as X$CON) and expanded in 12.1.0.2+ for In-Memory column store (X$KTSIMAU).

The X$ tables are not permanent or even temporary tables that reside in database datafiles. The X$ tables reside only in memory. When you start up your instance, they are created. They exist even before you create your control file. When you shut down your instance, they are destroyed. All 1312 X$ tables are defined right after the instance is started (before mount). They are defined, but they cannot all be queried. Many of them require at least a mounted, if not open, database. To observe this, query the X$KQFTA and X$KQFDT table after starting your instance with the NOMOUNT option.

The X$ tables are owned by the SYS database user and are read-only, which is why they are referred to as *fixed tables* and the V$ views are referred to as *fixed views*. This statement might be a juicy invitation for you to try to verify this read-only property. Any attempt to alter these tables with a DDL or DML statement is met with an ORA-02030 error.

Oracle has extensively used the DECODE function in the underlying SQL statements of the data dictionary views. If you compare the V$ view underlying SQL statements from version to version, you will likely find differences in the implementation of some V$ views. The columns of the V$ views may stay more constant in terms of their name and meaning, which allows Oracle RDBMS engineers to change the X$ tables from version to version while not disrupting too much of the Oracle user community's use of the V$ views. The fact that the V$ views are accessed through synonyms gives Oracle engineers another level of flexibility to alter the underlying structures, also with little or no impact on the user community's use of the V$ views. Oracle's extensive use of the DECODE function in the underlying V$ view SQL statements also facilitates the platform-specific implementation of a query, returning the generic data that a user of a particular V$ view expects from platform to platform. Consequently, running the correct scripts when upgrading a database is important to ensure the dictionary views are created in a way that matches the underlying X$ tables.

NOTE
Application designers and developers may save themselves some development and maintenance pain by adopting a similar strategy. They can employ views and synonyms for application software access to an application's underlying tables and stored programmatic objects (Java and PL/SQL).

Although this section is by no means a complete treatment of useful X$ table queries, it introduces some of the commonly used X$ table queries, grouped by the major tuning areas to which they pertain. Because X$ table queries are a supplement to queries of fixed views rather than a replacement for them, this section includes queries of both X$ tables and related fixed views.

Misconceptions About the X$ Tables

Do not use the X$ tables if you have a heart condition or are an inexperienced DBA—or you may ruin the entire database. (At least this is what some people will tell you. Sounds pretty scary!)

The most common misconception about the X$ tables is that the DBA can drop one or update one, thus ruining the database. However, X$ tables cannot be ruined. The only user who can select from these tables is the SYS user. A SELECT statement is the only command available to be performed on these X$ tables. An error occurs if you attempt to grant SELECT access to a user. Consider the following attempts to drop or alter an X$ table in the following listings. In the first listing, you cannot drop any of the X$ tables (even as the SYS user):

```
connect sys/change_on_install as sysdba
drop table x$ksppi;
ORA-02030: can only select from fixed tables/views
```

In this next listing, you are not able to update, insert, or delete any data in the X$ tables (even as the SYS user):

```
update  x$ksppi
set     ksppidf = 'FALSE'
where   ksppidf = 'TRUE';
ORA-02030: can only select from fixed tables/views
```

TIP
When you mention the X$ tables, most people say, "Oh, pretty scary. I would never touch those tables." The fact is DML commands (UPDATE, INSERT, DELETE) are not allowed on the X$ tables, even as the SYS superuser in 12cR2 (I tried).

Granting Access to View the X$ Tables

You cannot grant access to the X$ tables even if you are the SYS user. If you try to make grants to the X$ tables, you get the error in the following listing:

```
connect sys/change_on_install as sysdba
grant select on X$ksppi to richn;
ORA-02030: can only select fixed from fixed tables/views
```

Although the error message for attempting to grant access to X$KSPPI in the previous code is a little cryptic at first, it clarifies that you can perform only a SELECT and that the grant is not allowed. However, you may build your own X$ views from the original X$ tables and then grant access to those views. Consider the examples in the following six listings, which give access to the X$KSPPI table via a view called X$_KSPPI and a synonym called X$KSPPI.

Connecting to the SYS superuser

```
connect sys/change_on_install as sysdba
Connected.
```

Creating a view mirroring the X$KSPPI table

```
create view rich$_ksppi as
select       *
from         x$ksppi;

View created.
```

Creating a synonym for the newly created view

```
create public synonym x$_ksppi for rich$_ksppi;
Synonym created.
```

Granting the desired user access to the newly created view

```
grant select on x$_ksppi to richn;
Grant succeeded.
```

Connecting as the desired user

```
conn richn/tusc
Connected.
```

Accessing the X$_KSPPI view via the synonym created for X$_KSPPI

```
select      count(*)
from        x$_ksppi;

COUNT(*)
46499
```

You can now give access to the X$ table information without giving the password to the SYS account. The key is creating a view that references the original SYS-owned X$ tables.

TIP
A DBA may need access to the X$ table information, but not the SYS password. Create a view under a different name that mirrors the desired tables. Name these tables according to the appropriate synonyms of the original tables.

Creating V$ Views and X$ Tables in 12*c*

The X$ tables are virtual or fixed tables, which are created in memory at database startup and maintained real-time in memory. These tables store up-to-date information on the current activity of the database at the current point in time or since the last database startup. In the SGA, V$ views are created (see Chapter 12) on these X$ tables to allow users to view this information in a more readable format. The X$ tables are fixed tables, and because they have been created in memory, access to these tables is very limited.

The V$ views are known as the virtual tables, fixed tables, V$ tables, dynamic performance tables, and by a half-dozen other names. The first hurdle to understanding the X$ tables is to become familiar with their creation, security, content, and relationship to the V$ views.

In addition, these X$ tables are very cryptic in nature. They are similar to the underlying table construction of the Oracle data dictionary. Therefore, Oracle creates V$ views that are more readable and practical. In addition, Oracle has built other views (USER, DBA, ALL) within the scripts called by the `catalog.sql` script for easier use. Oracle has also created a public synonym on V_$ views in the `cdfixed.sql` file that changes the name back to a view with a prefix of V$. An example of a V_$ view and the creation of a V$ public synonym in `cdfixed.sql` is shown here (it resides in the $ORACLE_HOME/rdbms/admin directory):

```
create or replace view v_$datafile as select * from v$datafile;
create or replace public synonym v$datafile for v_$datafile;
grant select on v_$datafile to SELECT_CATALOG_ROLE;
```

NOTE
See Chapter 12 and Appendix B for detailed V$ view information and Appendix C for detailed X$ information.

Once the `catalog.sql` file has been executed, the V$ views are available only to users with the SELECT_CATALOG_ROLE privilege. At this point, you can grant access to V$ views by granting SELECT on the V$ view. Therefore, all SELECTs performed against the V$ views are actually retrieving information out of the SGA, more specifically out of the X$ tables. DBAs cannot modify X$ tables in any manner, and they cannot create indexes on these tables. Oracle began providing indexes on the X$ tables in version 8. In addition, the V$ views are the underlying views that are used for Oracle monitoring tools. Here you can see how to get a listing of all V$ views:

```
select   kqfvinam name
from     x$kqfvi
order    by  kqfvinam;
```

Here is the partial output:

```
NAME
GO$SQL_BIND_CAPTURE
GV$ACCESS
GV$ACTIVE_INSTANCES
GV$ACTIVE_SERVICES
GV$ACTIVE_SESSION_HISTORY
GV$ACTIVE_SESS_POOL_MTH
GV$ADVISOR_CURRENT_SQLPLAN
GV$ADVISOR_PROGRESS
...
V$ZONEMAP_USAGE_STATS
V$_LOCK

V$_LOCK1
V$_SEQUENCES

1457 rows selected.
```

Note that the GV$ views are the same as the V$ tables except that you can see multiple instances with Oracle Real Application Clusters (RAC). The only difference between the GV$ and V$ tables is a column that shows the instance ID.

The X$ Tables Comprising the V$ Views

To obtain a list of the X$ tables that comprise the V$ views, you must access the V$FIXED_VIEW_DEFINITION view. This view shows how the V$ views were created. By knowing which X$ tables comprise a V$ view, you may be able to build a faster query that goes directly to the X$ tables, as shown here (note that the CON_ID [Container ID] column has been added to many X$ tables for pluggable databases; see Chapter 12 for details):

```
select   *
from     v$fixed_view_definition
where    view_name = 'GV$FIXED_TABLE';
```

Here is the output:

```
VIEW NAME         VIEW DEFINITION
GV$FIXED_TABLE    select inst_id,kqftanam, kqftaobj, 'TABLE', indx, con_id
                   from x$kqfta
                   union all
                   select inst_id,kqfvinam, kqfviobj, 'VIEW', 65537, con_id
                   from x$kqfvi
                   union all
                   select inst_id,kqfdtnam, kqfdtobj, 'TABLE', 65537, con_id
                   from x$kqfdt
```

TIP
Access the X$KQFVI table for a listing of all V$ and GV$ views. Access the V$FIXED_VIEW_DEFINITION view to get all of the information regarding the underlying X$ tables that comprise a V$ view, including new views for containers (pluggable databases) and In-Memory column store (see both below).

V$INMEMORY_AREA and X$KTSIMAU in 12*c*R2

Also consider that there are now parameters and tables related to the INMEMORY setting used with the In-Memory column store (as of 12.1.0.2+). Here is the underlying X$ table behind the X$KTSIMAU view:

```
select   *
from     v$fixed_view_definition
where    view_name = 'GV$INMEMORY_AREA';
```

Here is the output:

```
VIEW NAME         VIEW DEFINITION
GV$INMEMORY_AREA   select INST_ID,POOL,ALLOCATED_LEN,USED_LEN,STATUS, CON_ID
                   from x$ktsimau
```

In 12*c* (12.1.0.2+), KTSIMAU stands for Kernel Transaction Segment In Memory Allocation Unit, which makes use of the GV$INMEMORY_AREA view (and in turn the V$INMEMORY_AREA view). See the section on naming conventions later in this chapter for a full list.

V$CONTAINERS and V$PDBS and X$CON in 12*c*R2

Also consider that there are now parameters and tables related to PDBs in 12*c*. Here is the underlying X$ table (X$CON) behind the V$CONTAINERS and V$PDBS views:

```
select      *
from        v$fixed_view_definition
where       view name in ('GV$PDBS','GV$CONTAINERS');
```

Here is the output:

```
VIEW NAME           VIEW DEFINITION
GV$PDBS             select inst_id, con_id, dbid, con_uid, guid, name...etc.

                    from x$con

                    where con_id >1;

GV$CONTAINERS       select inst_id, con_id, dbid, con_uid, guid, name...etc.

                    from x$con
```

In 12*c*, there are new X$ tables for containers. X$CON is the primary X$ for containers that makes use of the V$PDBS and V$CONTAINERS views.

TIP
The X$ tables and V$ views have been expanded for pluggable databases with CON_ID (Container ID) on many current tables/views (new X$ tables such as X$CON) and expanded in 12.1.0.2+ for In-Memory column store (X$KTSIMAU).

Obtaining a List of All the X$ Tables in 12*c*

The names of the X$ tables are in the X$KQFTA table (which contains 1,275 of the X$ tables), the X$KQFDT table (which contains another 37 of the X$ tables), and the X$KQFVI table, which contains the V$/GV$ as described in the previous section. The V$FIXED_TABLE view combines all three of these tables so you can obtain a listing of any desired grouping. The query in this next listing shows how to obtain a listing of just the 1,312 X$ tables:

```
select      name
from        v$fixed_table
where       name like 'X%'
order by    name;
```

Following is the partial output (for a complete listing, see Appendix C):

```
NAME
----------------------
X$ABSTRACT_LOB
X$ACTIVECKPT
X$ASH
X$BH
X$BUFFER
X$BUFFER2
X$BUFFERED_PUBLISHERS
X$BUFFERED_QUEUES
X$BUFFERED_SUBSCRIBERS
X$CELL_NAME
... (there are 1312 in Oracle 12cR2)
```

The following query shows output from X$KQFDT, which is a partial listing of the X$ tables:

```
select      kqfdtnam, kqfdtequ
from        x$kqfdt;

KQFDTNAM                        KQFDTEQU
------------------------------ ---------
X$KSLLTR_CHILDREN               X$KSLLTR
X$KSLLTR_PARENT                 X$KSLLTR
X$KCVFHONL                      X$KCVFH
X$KCVFHMRR                      X$KCVFH
X$KCVFHALL                      X$KCVFH
X$KGLTABLE                      X$KGLOB
X$KGLBODY                       X$KGLOB
X$KGLTRIGGER                    X$KGLOB
X$KGLINDEX                      X$KGLOB
X$KGLCLUSTER                    X$KGLOB
X$KGLCURSOR                     X$KGLOB
... (there are 37 in Oracle 12cR2)
```

TIP

Query V$FIXED_TABLE for the names of the X$ tables, or you can also access the two X$ tables X$KQFTA and X$KQFDT for partial listings that, when combined, make up the full list. In 12c, new X$ tables include X$CON (containers) and X$KTSIMAU (In-Memory).

Obtaining a List of All the X$ Indexes in 12*c*

If you often query the V$ views or X$ tables for information, you will find it helpful to understand which indexes are being used, as shown here:

```
select    table_name, index_number, column_name
from      v$indexed_fixed_column
order by  table_name, index_number, column_name, column_position;

Here is the partial output:
```

```
TABLE_NAME                     INDEX_NUMBER COLUMN_NAME
------------------------------ ------------ ------------
X$ASH                                     1 NEED_AWR_SAMPLE
X$ASH                                     1 SAMPLE_ADDR
X$ASH                                     1 SAMPLE_ID
X$BUFFER                                  1 OBJNO
X$BUFFER2                                 1 OBJNO
X$DIAG_ADR_CONTROL                        3 COLA
X$DIAG_ADR_INVALIDATION                   3 ADR_PATH_IDX
X$DIAG_ALERT_EXT                          3 ADR_PATH_IDX
X$DIAG_AMS_XACTION                        3 ADR_PATH_IDX
X$DIAG_DDE_USER_ACTION                    3 ADR_PATH_IDX
X$DIAG_DDE_USER_ACTION_DEF                3 ADR_PATH_IDX
X$DIAG_DDE_USR_ACT_PARAM                  3 ADR_PATH_IDX

... (there are 799 X$ indexes in Oracle 12cR2)
```

Few of the X$ tables have multicolumn indexes, as shown in this listing:

```
SELECT   DISTINCT a.table_name, a.index_number,
         a.column_name,a.column_position
FROM     v$indexed_fixed_column a, v$indexed_fixed_column b
WHERE    a.table_name = b.table_name
AND      a.index_number = b.index_number
AND      a.column_name != b.column_name
ORDER BY a.table_name,a.index_number, a.column_position;

TABLE_NAME           INDEX_NUMBER COLUMN_NAME                    COLUMN_POSITION
-------------------- ------------ ------------------------------ ---------------
X$ASH                           1 SAMPLE_ADDR                                  0
X$ASH                           1 SAMPLE_ID                                    1
X$ASH                           1 NEED_AWR_SAMPLE                              2
X$KESWXMON                      2 SQLID_KESWXMON                               0
X$KESWXMON                      2 EXECID_KESWXMON                              1
X$KESWXMON                      2 EXECSTART_KESWXMON                           2
X$KESWXMON_PLAN                 2 SQLID_KESWXMONP                              0
X$KESWXMON_PLAN                 2 EXECID_KESWXMONP                             1
X$KESWXMON_PLAN                 2 EXECSTART_KESWXMONP                          2
X$KTFBUE                        1 KTFBUESEGTSN                                 0
X$KTFBUE                        1 KTFBUESEGFNO                                 1

X$KTFBUE                        1 KTFBUESEGBNO                                 2
X$KTSLCHUNK                     1 KTSLCHUNKTSN                                 0
X$KTSLCHUNK                     1 KTSLCHUNKSEGFNO                              1
X$KTSLCHUNK                     1 KTSLCHUNKSEGBLKNO                            2
… etc.
```

To see the data about the X$ tables from which the information is retrieved, perform this query to the V$FIXED_VIEW definition table:

```
select    *
from      v$fixed_view_definition
where     view_name = 'GV$INDEXED_FIXED_COLUMN';
```

Here is the output (notice the CON_ID column in 12*c* for containers):

```
VIEW_NAME                 VIEW_DEFINITION
V$INDEXED_FIXED_COLUMN    select   c.inst_id,   kqftanam,   kqfcoidx,
                                   kqfconam,    kqfcoipo, c.con_id
                          from     x$kqfco c,   x$kqfta t
                          where    t.indx = c.kqfcotab
                          and      kqfcoidx != 0
```

TIP
Access the V$INDEXED_FIXED_COLUMN view for a listing of all X$ table indexes.

Using Hints with X$ Tables and Indexes

As with other tables, you can also use hints with the X$ tables to achieve greater performance. The queries in the next two listings show the EXPLAIN PLAN and statistics while changing the driving table using an ORDERED hint. Note that I am using aliases for the tables and would need to hint the alias (and not the table) if I used a hint requiring the table (such as the index hint). The ORDERED hint does not require the table name but accesses tables in the order listed in the FROM clause.

Forcing the X$KSBDD table as the driving table

```
select   /*+ ordered */ p.ksbdppro, p.ksbdpnam,
         d.ksbdddsc,p.ksbdperr
from     x$ksbdd d, x$ksbdp p
where    p.indx = d.indx;

Execution Plan
--------------------------------------------------------------------------------
| Id  | Operation                 | Name            |Rows|Bytes|Cost (%CPU) Time     |
|   0 | SELECT STATEMENT          |                 | 100|8300 |     0   (0) 00:00:01|
|   1 |  NESTED LOOPS             |                 | 100|8300 |     0   (0) 00:00:01|
|   2 |   FIXED TABLE FULL        | X$KSBDD         | 100|4700 |     0   (0) 00:00:01|
|*  3 |   FIXED TABLE FIXED INDEX| X$KSBDP (ind:1)|   1|  36 |     0   (0) 00:00:01|
```

Using the ordered hint to force the driving table to be X$KSBDP

```
select    /*+ ordered  */ p.ksbdppro, p.ksbdpnam,
          d.ksbdddsc,p.ksbdperr
from      X$ksbdp p, X$ksbdd d
where     p.indx = d.indx;

Execution Plan
--------------------------------------------------------------------------------
| Id  | Operation                 | Name           |Rows Bytes Cost  (%CPU) Time     |
|   0 | SELECT STATEMENT          |                | 100  8300      0   (0) |00:00:01|
|   1 |  NESTED LOOPS             |                | 100  8300      0   (0) |00:00:01|
|   2 |   FIXED TABLE FULL        |X$KSBDP         | 100  3600      0   (0) |00:00:01|
|*  3 |   FIXED TABLE FIXED INDEX|X$KSBDD (ind:2)|   1    47      0   (0) |00:00:01|
```

TIP

Oracle generally uses the indexes as needed, but from time to time, you may use hints to achieve a desired result.

Monitoring Space Allocations in the Shared Pool

You can use the X$KSMLRU table to monitor space allocations in the shared pool that may be causing space allocation contention. The *relevant* columns in this table are as follows:

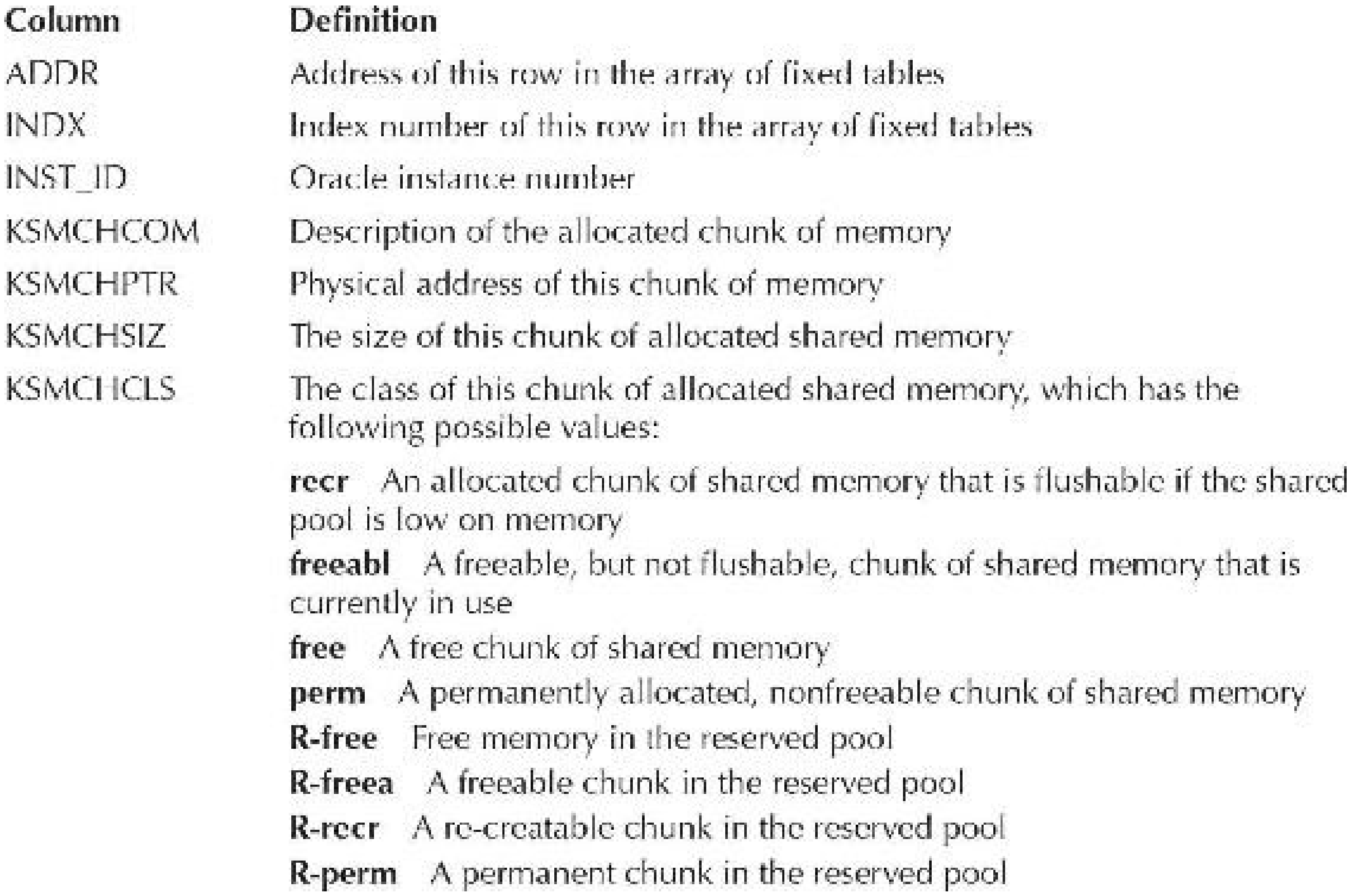
Column	Definition
ADDR	Address of this row in the array of fixed tables
INDX	Index number of this row in the array of fixed tables
INST_ID	Oracle instance number
KSMLRCOM	Description of allocation type
KSMLRSIZ	Size in bytes of the allocated chunk
KSMLRNUM	Number of items flushed from the shared pool to allocate space
KSMLRHON	Name of the object being loaded
KSMLROHV	Hash value of the object being loaded
KSMLRSES	Session performing the allocation, joins to V$SESSION.SADDR

You can use the X$KSMSP table to examine the current contents of the shared pool:

```
select    ksmchcls class, sum(ksmchsiz) memory
from      X$ksmsp
group by  ksmchcls;

CLASS    |          MEMORY
--------|----------------
R-free   |      16,857,968
R-freea  |       2,119,144
R-recr   |       3,985,736
free     |       5,660,160
freeabl  |      71,699,664
perm     |     175,106,600
recr     |      43,330,536
```

When you use the X$KSMSP table to examine the current contents of the shared pool, each row represents a chunk of memory in the shared pool. The *relevant* columns in this table are as follows (note that the preceding query groups the chunks into classes via the `ksmchcls` command):



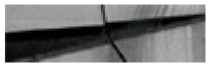
Column	Definition
ADDR	Address of this row in the array of fixed tables
INDX	Index number of this row in the array of fixed tables
INST_ID	Oracle instance number
KSMCHCOM	Description of the allocated chunk of memory
KSMCHPTR	Physical address of this chunk of memory
KSMCHSIZ	The size of this chunk of allocated shared memory
KSMCHCLS	The class of this chunk of allocated shared memory, which has the following possible values:
	recr An allocated chunk of shared memory that is flushable if the shared pool is low on memory
	freeabl A freeable, but not flushable, chunk of shared memory that is currently in use
	free A free chunk of shared memory
	perm A permanently allocated, nonfreeable chunk of shared memory
	R-free Free memory in the reserved pool
	R-freea A freeable chunk in the reserved pool
	R-recr A re-creatable chunk in the reserved pool
	R-perm A permanent chunk in the reserved pool

Creating Queries to Monitor the Shared Pool

The shared pool is often a key area impacted by performance. This section focuses on queries that help you investigate the shared pool.

ORA-04031 Errors

V$SHARED_POOL_RESERVED.REQUEST_FAILURES [or SUM(X$KGHLU.KGHLUNFU)] gives the number of ORA-04031 errors that have occurred since the instance was started. If any ORA-04031 errors are occurring, then SHARED_POOL_SIZE and/or JAVA_POOL_SIZE are too small, the shared pool is fragmented, or application code may not be being shared optimally. The query in this listing checks the ORA-04031 errors that have occurred since the instance was started. Also, see Chapter 4 for setting parameters related to automating memory management, including MEMORY_TARGET, MEMORY_MAX_TARGET, and/or SGA_TARGET.



```
-- Number of ORA-04031 errors since instance startup.
SELECT request_failures
  FROM v$shared pool reserved;
```

If any ORA-04031 errors have occurred, then some SHARED_POOL_SIZE, JAVA_POOL_SIZE, and/or application tuning is in order. Consider one or more of the following:

- Pin large, high-use [high values for X$KSMLRU.KSMLRSIZ, COUNT(X$KSMLRU.KSMLRHON), and/or X$KSMLRU.KSMLRNUM] PL/SQL packages in memory with DBMS_SHARED_POOL.KEEP:

  ```
  EXECUTE dbms_shared_pool.keep('PACKAGENAME');
  ```

- Pin large, high-use Java classes with DBMS_SHARED_POOL.KEEP. You can pin a Java class by enclosing it in double quotes:

  ```
  EXECUTE dbms_shared_pool.keep('"FullJavaClassName"', 'JC');
  ```

TIP

Enclose the class in double quotes if it contains a slash (/); otherwise, you will get an ORA-00995 error.

- Increase the size of the shared pool by increasing the SHARED_POOL_SIZE initialization parameter if the percentage of shared pool free memory is low *and* there is contention for library cache space allocation *and/or* more than zero occurrences of the ORA-04031 error. A section of Chapter 4 notes that increasing the shared pool is *not* always recommended if a low amount of shared pool memory is observed. If you are increasing the size of the shared pool, you might also need to raise the value of the parameters MEMORY_TARGET, MEMORY_MAX_TARGET, and/or SGA_TARGET (see Chapter 4 for additional information).
- Increase the size of the shared pool reserved area by increasing the SHARED_POOL_RESERVED_SIZE initialization parameter (the default is 5 percent of SHARED_POOL_SIZE).
- Promote the sharing of SQL, PL/SQL, and Java code by application developers.

Large Allocations Causing Contention

The object being loaded (X$KSMLRU.KSMLRHON) is a *keep* candidate (consider keeping it with DBMS_SHARED_POOL.KEEP) if the X$KSMLRU.KSMLRCOM value is MPCODE or PLSQL%.

If you use features such as Shared Servers (previously called MTS), Recovery Manager, or Parallel Query, you should configure a larger shared pool and also configure a large pool that is bigger than the default. These features will create large allocations in the shared pool and use the large pool instead if it is large enough.

```
      -- Amount of each type of shared pool allocation causing contention.

SELECT   ksmlrcom, SUM(ksmlrsiz)
FROM     x$ksmlru
GROUP BY ksmlrcom;

KSMLRCOM             SUM(KSMLRSIZ)
-------------------- -------------
                                 0
qkxr.c.kgght                  4156
idndef : qcuAllocId           4096
```

TIP
If X$KSMLRU.KSMLRCOM is similar to Fixed UGA, then a high amount of session-specific allocation is occurring, which suggests that OPEN_CURSORS may be set too high. This is relevant only in cases where Shared Servers are being used.

Shared Pool Fragmentation

This section takes a closer look at the shared pool using a plethora of queries to help you conduct detailed investigations when needed. (The shared pool is also discussed in detail in Chapter 4.) The shared pool may be fragmented if you observe a large number of entries in X$KSMLRU, particularly a large number of them with small KSMLRSIZ values, or if you observe many chunks of type “free” in X$KSMSP. Contrast this with a large number of entries in X$KSMLRU with medium to high values of KSMLRSIZ, which is not likely to be a symptom of a fragmented shared pool; rather, it indicates that large PL/SQL packages and/or Java classes need to be kept in the shared pool and possibly also that the shared pool itself is too small, and perhaps that application code is not being effectively shared (or some combination thereof). In identifying the problem, take the time to monitor the application code use over time to find out which code the user sessions are attempting to load. Network with application users, developers, designers, and application vendors. The queries in the following listings will help you find contention and fragmentation issues.

Finding contention and fragmentation issues

```
    -- Names of and sessions for shared pool allocations causing contention.
  SELECT ksmlrhon, ksmlrsiz, ksmlrses
    FROM x$ksmlru
   WHERE ksmlrsiz > 1000
ORDER BY ksmlrsiz;
```

```
Shared Pool Memory Allocated
    -- Shared pool memory allocated.
SELECT sum(ksmchsiz)||' bytes' "TotSharPoolMem"
  FROM x$ksmsp;

TotSharPoolMem
-----------------------------------------------
58719640 bytes
```

Fragmentation of shared pool

```
      -- Fragmentation of Shared Pool.
     SET VERIFY off
  COLUMN PctTotSPMem for all
  SELECT ksmchcls       "ChnkClass",
         SUM(ksmchsiz)  "SumChunkTypeMem",
         MAX(ksmchsiz)  "LargstChkofThisTyp",
         COUNT(1)       "NumOfChksThisTyp",
         ROUND((SUM(ksmchsiz)/tot_sp_mem.TotSPMem),2)*100||'%' "PctTotSPMem"
    FROM x$ksmsp,
         (select sum(ksmchsiz) TotSPMem from x$ksmsp) tot_sp_mem
GROUP BY ksmchcls, tot_sp_mem.TotSPMem
ORDER BY SUM(ksmchsiz);
```

Following is the output on a smaller system:

```
ChnkClas SumChunkTypeMem LargstChkofThisTyp NumOfChksThisTyp PctTotSPMem
-------- --------------- ------------------ ---------------- -----------
R-freea            59000              21984              173 0%
R-recr           3977156            3977156                1 1%
R-perm          16553296            4193168                5 5%
R-free          21397980            2097032               85 6%
free            31038572            2396208             8893 9%
perm            51740844            3981312               29 15%
recr            86619156              44908            40129 24%
freeabl        145125076             334348            46223 41%

8 rows selected.
```

Next is the output on a larger Linux system (12*c*R2):

```
ChnkClas|SumChunkTypeMem|LargstChkofThisTyp|NumOfChksThisTyp|PctTotSPMem
--------|---------------|                  |----------------|-----------
R-freea |        2119144|            138080|             285|1%
R-recr  |        3985736|           3977224|               2|1%
free    |        5516136|           3464168|            4992|2%
R-free  |       16857968|           2096960|              78|5%
recr    |       43418856|             96216|           25369|14%
freeabl |       71755368|            434976|           24727|23%
perm    |      175106600|           4177872|             518|55%
7 rows selected.
```

Information about SHARED_POOL_RESERVED_SIZE

```
    -- Information regarding shared_pool_reserved_size.
SELECT free_space,free_count,max_free_size,max_used_size,
       request_misses,max_miss_size
  FROM v$shared pool reserved;

FREE SPACE FREE COUNT MAX FREE SIZE MAX USED SIZE REQURST MISSES MAX MISS SIZE
---------- ---------- ------------- ------------- -------------- -------------
   2980600         14        212900             0              0             0
```

Low Free Memory in Shared and Java Pools

If a low percentage of the shared or Java pools' memory is free, then the shared and/or Java pools may have crossed the fine line between an optimal amount of free memory and not enough free memory. To determine this, consider how many free chunks exist, the size of the largest chunk, whether there is a high number of reloads, and whether there have been any ORA-04031 errors. The two queries shown here will help.

Amount of shared pool free memory

```
    -- Amount of shared pool free memory.
SELECT *
  FROM v$sgastat
 WHERE name = 'free memory'
   AND pool = 'shared pool';

POOL         NAME                           BYTES CON_ID
------------ -------------------------- ---------- ------
shared pool  free memory                   3819124      0
```

Amount of Java pool free memory

```
    -- Amount of java pool free memory.
SELECT *
  FROM v$sgastat
 WHERE name = 'free memory'
   AND pool = 'java pool';

POOL         NAME                           BYTES CON_ID
------------ -------------------------- ---------- ------
java pool    free memory                  44626368      0
```

Library Cache Memory Use

A low library cache hit ratio is a symptom of one of several problems. The shared and/or Java pools may be too small; the SHARED_POOL_RESERVED_SIZE may be too small; CURSOR_SHARING may need to be set to FORCE; there may be inefficient sharing of SQL, PL/SQL, or Java code; or there may be insufficient use of bind variables. Investigate which application code is being used over time and how efficiently it is used (code sharing). Monitor the shared and Java pool “free space” over time. If the amount of free memory in the shared and Java pools is relatively high, no ORA-04031 errors are occurring, and the library cache hit ratio is low, then poor code sharing is probably occurring. The queries in the following listings help you investigate this area. I include some V$ view queries here because of the applicable nature to this subject.

```
      -- Library cache hit ratio.
  SELECT ROUND(SUM(pinhits)/SUM(pins),2)*100||'%' "Library Cache Hit Ratio"
    FROM v$librarycache
ORDER BY namespace;

Library Cache Hit Ratio
-------------------------
90%
```

Library cache reload ratio (note PDB is now a namespace)

```
    -- Library cache reload ratio.
SELECT namespace,
       ROUND(DECODE(pins,0,0,reloads/pins),2)*100||'%' "Reload Ratio"
  FROM v$librarycache;

NAMESPACE                                                      Reload Ratio
-------------------------------------------------------------- ------------
SQL AREA                                                                 1%
TABLE/PROCEDURE                                                          4%
BODY                                                                     0%
TRIGGER                                                                  0%
INDEX                                                                   11%
CLUSTER                                                                  0%
DIRECTORY                                                                0%
QUEUE                                                                    0%
RULESET                                                                  0%
TEMPORARY TABLE                                                         76%
TEMPORARY INDEX                                                         19%
EDITION                                                                  0%
DBLINK                                                                   0%
OBJECT ID                                                                0%
SCHEMA                                                                   0%
DBINSTANCE                                                               0%
SQL AREA STATS                                                           0%
ACCOUNT_STATUS                                                           0%
SQL AREA BUILD                                                           0%
PDB                                                                      0%
AUDIT POLICY                                                             0%
USER PRIVILEGE                                                           0%
FED APP                                                                  0%
CMP                                                                      0%
```

Library cache high-use objects (make this a top 10 list by adding WHERE ROWNUM<11)

```
      -- Library cache high-use objects (You may want to limit listing).
  SELECT name,type
    FROM v$db_object_cache
ORDER BY executions;
```

Library cache object sizes

```
    -- Library cache object sizes (you may want to limit listing).
  SELECT *
    FROM v$db_object_cache
ORDER BY sharable_mem;
```

Shared pool object sharing efficiency (you may want to limit these)

```
Column name format a40
Column type format a15

      -- Execute counts for currently cached objects.
  SELECT name, type, COUNT(executions) ExecCount
    FROM v$db_object_cache
GROUP BY name, type
ORDER BY ExecCount;

      -- Currently cached objects that have execute counts of just 1.
      -- Consider converting these objects to use bind variables.
  SELECT distinct name, type
    FROM v$db_object_cache
GROUP BY name, type
  HAVING COUNT(executions) = 1;

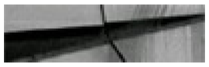
      -- Currently unkept, cached objects that have execute counts > 1.
      -- Consider pinning these objects.
  SELECT distinct name, type, COUNT(executions)
    FROM v$db_object_cache
   WHERE kept = 'NO'
GROUP BY name, type
  HAVING COUNT(executions) > 1
ORDER BY COUNT(executions);

-- Currently unkept, cached objects that are similar. Each of these
-- statements has at least 10 versions currently cached, but has only
-- been executed less than 5 times each. Consider converting these
-- objects to use bind variables and possibly also pinning them.
  SELECT SUBSTR(sql_text,1,40) "SQL", COUNT(1) , SUM(executions) "TotExecs"
    FROM  v$sqlarea
   WHERE executions < 5
     AND kept_versions = 0
GROUP BY SUBSTR(sql_text,1,40)
  HAVING COUNT(1) > 10
ORDER BY COUNT(1) ;
Clear columns
```

A high percentage of reloads indicates that the shared and/or Java pools are too small, code sharing is insufficient, and possibly also large code objects are repeatedly being used. Monitor the application code used over time. If particular large code objects are identified as frequently used, consider pinning them and/or increasing the size of the SHARED_POOL_RESERVED_SIZE. If features such as Shared Servers, Recovery Manager, or Parallel Query are used, consider a larger SHARED_POOL_SIZE and/or larger LARGE_POOL_SIZE (if setting parameters like MEMORY_TARGET and/or SGA_TARGET, please refer to Chapter 4 and ensure you *always* set a minimum for the SHARED_POOL_SIZE even if you use these other parameters).

High Number of Hard Parses

You should review similar queries with low numbers of executions to uncover opportunities to combine them into statements using bind variables. A high ratio of hard parses may mean that the shared pool itself is too small or perhaps a SQL statement is repeatedly nudging other code out of the precious shared pool or Java pool cache space. Identify these statements and consider pinning. Consider also setting the parameter CURSOR_SHARING = FORCE. The next listing shows various queries to view parse activity:



```
    -- Overall Parse Activity.
SELECT name, value
  FROM v$sysstat
 WHERE name = 'parse count (total)'
    OR name = 'parse count (hard)';

NAME                                                              VALUE
---------------------------------------------------------------- ----------
parse count (total)                                                   11357
parse count (hard)                                                      924

    -- Ratio of hard parses to total parses.
SELECT ROUND((b.value/a.value),2)*100||'%' HardParseRatio
  FROM v$sysstat a, v$sysstat b
 WHERE a.name = 'parse count (total)'
   AND b.name = 'parse count (hard)';

HARDPARSERATIO
---------------
8%

    -- SQL Statements experiencing a high amount of parse activity.
SELECT sql_text, parse_calls, executions
  FROM v$sqlarea
 WHERE parse_calls > 100
   AND kept_versions = 0
   AND executions < 2*parse_calls;

SQL_TEXT
--------------------------------------------------------------------------------
PARSE_CALLS EXECUTIONS
----------- ----------
lock table sys.mon_mods$ in exclusive mode nowait
        126        126
lock table sys.col_usage$ in exclusive mode nowait
        269        269
(...partial listing only)
```

Mutex/Latch Waits and/or Sleeps

If mutex (mutual exclusion; see Chapter 14 for detail on mutexes) or latch waits are high but shared and Java pool free space is also high, consider reducing the size of the shared and/or Java pools. When this happens, it could indicate that sessions are spending time scanning the unnecessarily large list of free shared pool chunks (be very careful before you do this—the goal is to get everything *in* memory—so ensure that you have enough allocated). Monitor the amount of shared and Java pool free space over time. If ample free space is available in these pools and no ORA-04031 errors are occurring, consider reducing the sizes of these pools. Investigate when the miss ratio and sleeps are high for any of the mutexes/latches in the following list:

- Row cache objects
- Library cache
- Shared pool
- Shared Java pool

If free space in the shared and Java pools is low, then you should consider the other tuning areas, such as increasing the shared and/or Java pools, pinning objects, and combining similar SQL statements to use bind variables. The query in the next listing helps you acquire some of these metrics. A mutex (which replaced many types of library cache latches other than the library load lock latch) is used to eliminate the possibility of two processes simultaneously using a common resource (while one or both are trying to change it); when one session is changing it, the second can't view it or change it, and when one session is viewing it, the second can't change it.

Oracle moved from latches to mutexes in some areas of the library cache because mutexes are lighter weight and provide more granular concurrency than latches. Mutexes require less memory space and fewer instructions. Oracle uses mutexes instead of library cache latches and library cache pin latches to protect objects in the library cache. With a mutex, if I have the resource and you can't get it after trying a specified number of times asking (spins), you sleep and try again a very short time later. Use the V$MUTEX_SLEEP view (covered in Chapter 12) in addition to the V$LATCH query listed next to query mutex/latch information:

```
Column name for a20
       Shared pool latch efficiency.
SELECT name,
       ROUND(misses/decode(gets,0,1,gets),2)*100||'%' as "WillToWaitMissRatio",
       ROUND(immediate_misses/decode(immediate_gets,0,1,
       immediate_gets),2)*100 ||'%' "ImmMissRatio",
       sleeps
  FROM v$latch
 WHERE name in ('row cache objects', 'shared pool');
Clear columns

NAME                 WillToWaitMissRatio
-------------------- ----------------------------------------
ImmMissRatio                                         SLEEPS
-------------------------------------------------- ----------
row cache objects    0%
0%                                                        0
shared pool          0%
0%                                                        3
```

No issues occur in the output above (minimal sleeps). Remember that before increasing the SHARED_POOL_SIZE, you should consider whether there are any shared pool or library latch/mutex waits. Depending on what you observe, it may actually be more appropriate to reduce the size of the shared pool, for instance, if you have a sufficient amount of free shared pool memory available, a low number of reloads, and a high number of shared pool latch waits. The reason to consider reducing the shared pool in this case is that, with an oversized shared pool, sessions will hold the shared pool latch slightly longer than is needed otherwise because the shared pool needs to scan a larger amount of space to determine exactly where to allocate the space it is requesting. Fixing the issues causing a shared pool issue and then ensuring it is large enough to fit all statements in memory is a key to good performance. Fix the problem and then make sure the shared pool is large enough (too many people make it way too small and problems occur!).

Miscellaneous X$ Table Notes

After exhausting the previously discussed shared and Java pool tuning options, you could consider some undocumented parameters. The number of the library cache hash table bucket count can be increased by setting _KGL_BUCKET_COUNT (see Appendix A for more information on the undocumented initialization parameters); note that 9 (the default) puts this at ((2 to the 9th power)*256)–1 = 131,071, which should be more than enough for most systems. Oracle 12*c* still has an _KGL_LATCH_COUNT parameter. Remember that you should never set the underscore parameters without direction from Oracle Support. In 12*c*, *each* library cache bucket (131,071) is protected by a mutex! Also, in 12*c*, the _KGL_LATCH_COUNT is set at 0 and probably doesn't need to be set, but consult with Oracle Support before setting this.

Adjusting this parameter is, as with all undocumented parameters, unsupported by Oracle. Implement such changes only under the direction of Oracle Support and after thoroughly testing under direct simulation of production conditions.

Note that any particular database may experience conditions that are a combination of two or more of the previous conditions. Frequently, you must evaluate multiple conditions and decide on two or more potential corrective measures.

Also note that after each query on X$KSMLRU, the values in this table are reset to zero. To effectively monitor the table, consider capturing the contents of it to a permanent table with an INSERT INTO … AS SELECT … statement or by simply spooling the output to a file. Furthermore, whenever you query X$KSMLRU, you might always want to select all of the columns instead of just one or the few you might be interested in at a particular moment; otherwise, you may miss some information that you later decide you want to see.

CAUTION
When "resetting" the X$KSMLRU table, note rows may still be in this table after each query. Do not interpret the remaining rows appearing after each query as entries pertaining to contention-causing code, but rather to preallocated entries in this table. If no problem statements are in X$KSMLRU, then the KSMLRHON and KSMLRSIZ values are NULL and zero, respectively. If they are non-NULL, then these rows pertain to contention-causing code. Make sure multiple DBAs do not simultaneously query X$KSMLRU, because each of them may observe misleading results.

Remember that when you decide to alter initialization parameters to remedy performance problems, you can now alter many of them by using an ALTER SYSTEM command. Despite the ease of doing this, you should first test such changes on a test system. For example, if you attempt to make the SHARED_POOL_SIZE too small, the SQL*Plus session may hang and/or consume a large amount of memory and CPU resources during the execution of the ALTER SYSTEM command. Or, prior to Oracle9*i*, if you set the _KGL_LATCH_COUNT parameter too high, you got an ORA-600 [17038] error when you next tried to start the database. The point here is to *be careful* and know what you're doing before changing any of these parameters.

Obtaining Information About Redo Log Files

The X$KCCCP table contains information about the current redo log file. The X$KCCLE table contains information about all redo log files, as shown here:

```
    -- Percentage full of the current redo log file.
SELECT ROUND((cpodr_bno/lesiz),2)*100||'%' PctCurLogFull
  FROM x$kcccp a, x$kccle b
 WHERE a.cpodr_seq = leseq;

PCTCURLOGFULL
----------------
35%
```

If you observe in V$LOG_HISTORY or in the "log file space waits" statistic that log switches are occurring more frequently than is appropriate for your database, you may decide to alter the redo log file configuration. You can perform this task while the database is open to users and all tablespaces are online. If you want to minimize the impact on database performance while this or other similar maintenance is performed that involves a DBA-induced log switch with the ALTER SYSTEM SWITCH LOG FILE command, you can use the query in the preceding listing to measure how much redo log information has to be copied to complete the archive of the current log file. This is particularly relevant in cases of databases with large redo log files (500M or larger).

You can also use this query as a tuning aid to measure how much redo activity is created by a particular transaction or process, if it is possible to isolate a particular database to one session that is guaranteed as the only creator of redo records, other than Oracle itself. Capturing before and after results of this query, when testing (such a transaction), may be useful.

Setting Initialization Parameters

The SPFILE allows DBAs to make persistent initialization parameter changes with the ALTER SYSTEM command without having to incorporate these changes manually into a traditional parameter file, or PFILE, to implement the persistence of the parameter change. SPFILEs also allow the DBA to save the current instance configuration instantaneously to a file for archival or backup purposes. This flexibility introduces a bit of initialization parameter management complexity in that the Oracle instance can be started with either a PFILE or an SPFILE. This complexity raises a few questions for the DBA when managing initialization parameters. The DBA must know what Oracle will use as an initialization parameter file at instance startup time, where the initialization parameters will be saved when an ALTER SYSTEM … SCOPE=SPFILE or ALTER SYSTEM … SCOPE=BOTH command is issued, and whether a currently running Oracle instance was started using a PFILE, an SPFILE, or both.

If the SPFILE in the platform-specific default location with the platform-specific default name exists, then Oracle uses it to start the instance. To get Oracle to use an SPFILE other than the one residing in the default location with the default filename, you must first rename, relocate, or delete this default SPFILE, and then relocate and/or rename the desired SPFILE from the nondefault location to the default location and name. Alternatively, you can specify this nondefault SPFILE in the SPFILE initialization parameter in a PFILE that is used to start the instance.

Note that the concept of the platform-specific default name and location for the PFILE still exists; this concept is used if no SPFILE is in the SPFILE default location and name. As in pre–Oracle9*i* versions, you can use a nondefault PFILE to start an instance with the PFILE option of the STARTUP command. These are the only ways that Oracle will use a nondefault parameter file to start the instance. There is no STARTUP SPFILE command. SPFILEs and PFILEs are not interchangeable. SPFILEs are (mostly) binary files that can be altered only with ALTER SYSTEM commands and can be created only with CREATE SPFILE commands.

As in pre-Oracle9*i* versions, PFILEs are simply text files that may be created and altered with a text editor. An attempt to use an SPFILE in the STARTUP PFILE command will result in an ORA-01078 error. If an instance was started with an SPFILE, then any changes made using the ALTER SYSTEM … SCOPE=SPFILE command or ALTER SYSTEM … SCOPE=BOTH command are saved to the SPFILE that was used to start the instance, even if the default SPFILE exists and was not used to start the instance. If both a PFILE and an SPFILE are used to start an Oracle instance, Oracle overrides any parameters specified in the PFILE with those specified in the SPFILE, if any conflicts occur.

The question of which file was used to start an Oracle instance has five possible answers:

- On startup, the database first looks for `spfile<SID>.ora` in the default location, and then looks for `spfile.ora` in the default location. An SPFILE in the default location was used with the default name and no PFILE was used.
- A PFILE in the default location with the default name was used and a nondefault SPFILE was used.
- A nondefault PFILE was used and a nondefault SPFILE was used.
- A PFILE in the default location with the default name was used and no SPFILE was used.
- A nondefault PFILE was used and no SPFILE was used.

NOTE

Both an SPFILE and a PFILE may have been used to start an instance, however. Check the following queries in the order listed to answer the question of which files may have been used for *the initialization parameters to start the instance.*

Case 1

Run the query in this listing to check for SPFILE-specified initialization parameters:

```
    -- Check for spfile specified initialization parameters.
SELECT count(*)
  FROM v$spparameter
 WHERE isspecified = 'TRUE';

  COUNT(1)
----------
        29
```

Or simply use the SQL*Plus command SHOW PARAMETER SPFILE. This tells you exactly which SPFILE was used to start the database (gets set automatically when the database is started without specifying a PFILE or SPFILE). If you start the database with the PFILE option, then this parameter is NULL. The following is the equivalent to the query in the preceding listing but involves less typing:

```
SQL> SHOW PARAMETER SPFILE

NAME       TYPE    VALUE
---------- ------- ------------------------------------------------------------
spfile     string  /u01/app/oracle/product/12.2.0/db_home_1/dbs/spfileorcl.ora
```

Case 2

Run this query to determine which SPFILE was used to start the instance:

```
    -- Determine which spfile was used to start the instance.
SELECT value
  FROM v$parameter
 WHERE name = 'spfile';
```

Look for a PFILE in the default location. If the SPFILE parameter value from the query in the preceding listing (to V$PARAMETER) is non-NULL and the value is not the default value for the SPFILE, then a PFILE was used, and it specified an alternate SPFILE in the SPFILE parameter. If this is the case and if the default PFILE exists, then it was used to start the instance.

Case 3

If the SPFILE parameter value from the query in the Case 2 listing (to V$PARAMETER) is non-NULL and the value is not the default value for the SPFILE, then a PFILE was used, and it specified an alternate SPFILE in the SPFILE parameter. If this is the case and if the default PFILE does not exist, then you must determine the location of the nondefault PFILE. See Case 5.

Case 4

If the SPFILE parameter value from the query in the listing in Case 2 (to V$PARAMETER) is NULL, then a PFILE was used and no SPFILE was used. If this is the case and if the default PFILE exists, then it was used to start the instance.

Case 5

If it is determined from Cases 1 through 3 that no SPFILE was used at all, and that the default PFILE was not used, then the remaining possibility is that a nondefault PFILE was used and no SPFILE was used. Many site-specific possibilities exist for a nondefault PFILE. A database startup, shutdown, or backup script, a third-party backup or database management software package, or a site-specific Oracle software directory structure may give a clue to what this file is. If there is uncertainty about this file, you can save the existing configuration initialization parameters by querying some of the Oracle X$ tables pertinent to initialization parameters. There is also the possibility that OEM, which can store a local copy of the parameter file, started the database.

Several X$ tables are relevant to initialization parameters: X$KSPSPFILE, X$KSPPSV, X$KSPPSV2, X$KSPPCV, X$KSPPCV2, X$KSPPI, and X$KSPPO. The X$KSPSPFILE table lists the contents of the SPFILE. The V$SPPARAMETER view, which is based on the X$KSPSPFILE table, excludes parameter names that start with an underscore, unless such “underscore” or “undocumented” parameters were explicitly specified in an SPFILE, in a PFILE, or with an ALTER SYSTEM command and/or Oracle had to modify the DBA-specified value to fit a functional requirement of the parameter, such as a requirement that a particular parameter value be a prime number or a multiple of another DBA-specified parameter value, for example. To see all the parameter names, including those that the V$SPPARAMETER view excludes, query the X$KSPSPFILE table.

Note that if an SPFILE was not used to start an instance, then all of the values in the KSPSPFFTCTXSPVALUE column of X$KSPSPFILE are NULL and all of the values in the KSPSPFFTCTXISSPECIFIED column are FALSE. Conversely, if an SPFILE was used to start an instance, the values in the KSPSPFFTCTXISSPECIFIED column for which the particular parameter was specified in the SPFILE are TRUE and the value in the KSPSPFFTCTXSPVALUE column for such parameters is a non-NULL value.

The X$KSPPSV table lists the parameter names and values that are currently in effect for the instance. The V$SYSTEM_PARAMETER view, which is based on the X$KSPPSV table, excludes parameters that start with an underscore and have not been modified from their default value.

The X$KSPPSV2 table is very similar to the X$KSPPSV table. The difference is in how parameter values are stored that consist of lists of values. This table, like the X$KSPPSV table, lists parameters and parameter values that are currently in effect for this Oracle instance. A new session inherits parameter values from the system values. Each list parameter value appears as a separate row in the table. Presenting the list parameter values in this format enables you to quickly determine the values for a list parameter. For example, if a parameter value is “a,b” looking at X$KSPPSV does not tell you whether the parameter has two values (“a” and “b”) or one value (“a,b”). X$KSPPSV2 makes the distinction between the list parameter values clear. Correspondingly, the V$SYSTEM_PARAMETER2 view is based on the X$KSPPSV2 table.

The X$KSPPCV and X$KSPPCV2 tables are similar to the X$KSPPSV and X$KSPPSV2 tables, except that the X$KSPPCV and X$KSPPCV2 tables apply to the current session, not necessarily the whole instance. If a parameter is changed with an ALTER SESSION command, the change is reflected in the X$KSPPCV and X$KSPPCV2 tables. The V$PARAMETER and V$PARAMETER2 fixed views are based on the X$KSPPCV and X$KSPPCV2 tables, respectively.

The X$KSPPI table lists the initialization parameter names, types, and statuses. The V$PARAMETER, V$PARAMETER2, V$SYSTEM_PARAMETER, and V$SYSTEM_PARAMETER2 fixed views are based on the X$KSPPCV, X$KSPPCV2, X$KSPPSV, and X$KSPPSV2 tables; each of these X$ tables is joined with the X$KSPPI table in these fixed views to get the associated parameter names and other information. The query in this next listing is the query on which V$SYSTEM_PARAMETER is based, excluding the line in V$SYSTEM_PARAMETER that excludes parameter names that start with an underscore. The underlying SQL statements of the V$PARAMETER, V$PARAMETER2, and V$SYSTEM_PARAMETER2 fixed views have the same structure as the query in the listing in Case 2 described previously.

```
     -- All initialization parameter settings in effect for the instance.
SELECT x.indx+1 InstanceNum,
       ksppinm ParamName,
       ksppity ParamType,
         ksppstvl ParamValue,
         ksppstdf IsDefaultVal,
         DECODE(bitand(ksppiflg/256,1),
                1,'TRUE',
                  'FALSE') IsSessModifiable,
         DECODE (bitand(ksppiflg/65536,3),
                1,'IMMEDIATE',
                2,'DEFERRED',
                  'FALSE') IsSysModifiable,
         DECODE (bitand(ksppstvf,7),
                1,'MODIFIED',
                  'FALSE') IsModified,
         DECODE (bitand(ksppstvf,2),
                  2,'TRUE',
                    'FALSE') IsAdjusted,
         ksppdesc Description,
         ksppstcmnt UpdateComment
    FROM x$ksppi x, x$ksppsv y
   WHERE (x.indx = y.indx)
ORDER BY ParamName;
```

The V$OBSOLETE_PARAMETER fixed view, which is based on the X$KSPPO table, lists obsolete initialization parameters. For some of these, such as SPIN_COUNT, you may note that they are now undocumented parameters.

Exploring Buffer Cache/Data Block Details

Four key performance-related buffer cache topics are the current buffer statuses, the identification of segments that are occupying the block buffers, the detection of hot (popular or high contention) data blocks, and the cause of buffer-cache-related latch contention and wait events. These topics are relevant to buffer cache tuning in all Oracle versions, but there are additional considerations in Oracle8, 8*i*, and 9*i*. Oracle8 introduced the concept of multiple buffer pools. Oracle9*i* introduced the concept of multiple data block sizes and, therefore, the need for multiple buffer cache buffer sizes. This continues in 12*c*R2.

The X$ tables are used in the buffer-cache-related queries that follow:

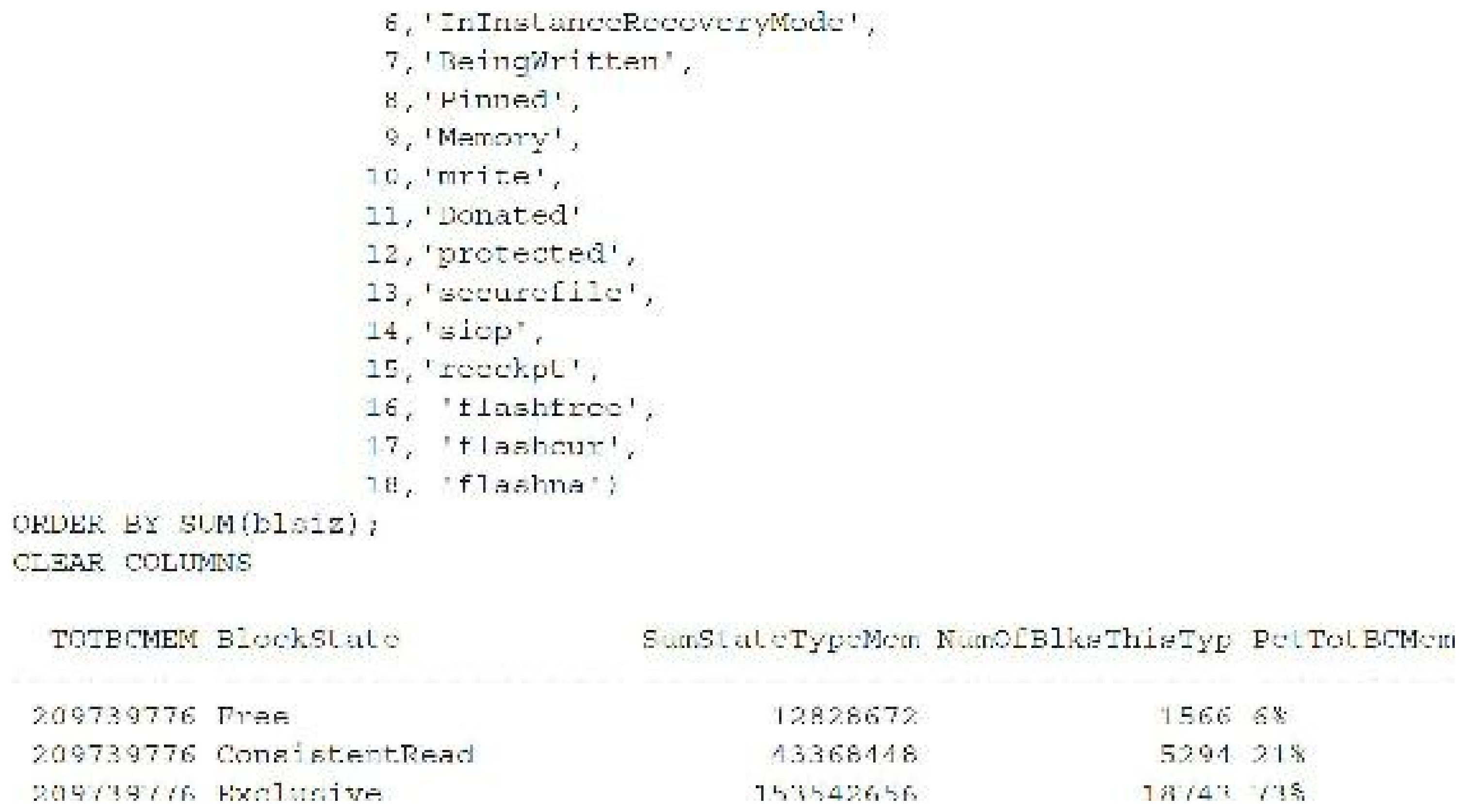
X$ Table	Definition
X$BH	Status and number of pings for every buffer in the SGA; has one row for every block in memory used for data (set with DB_CACHE_SIZE)
X$KCBWDS	Statistics on all buffer pools available to the instance
X$KCBWBPD	Statistics on all buffer pools available to the instance, including buffer pool names
X$KCBWAIT	Number of and time spent in waits for buffer pool classes
X$KCBFWAIT	Buffer cache wait count and time by file

The queries in the following sections are relevant to these topics.

Buffer Statuses

A low number of buffers with a status of "Free" in X$BH does not necessarily mean that the buffer cache is undersized. It may, in fact, mean that the buffer cache is optimally sized such that Oracle will not have to perform frequent organization and maintenance on a superfluous number of buffers. Unfortunately, this same thought process leads many DBAs to undersize the buffer cache and leave memory sitting idle on their system. Similarly, if a large percentage of buffers are consistently free, then perhaps the buffer cache is oversized. See the subsequent sections discussing buffer cache contents, latches, and wait events for a better indication of the proper sizing and configuration of the buffer cache as it relates to the segments that are being used. Tuning and looking at Oracle at the block level is covered in detail in Chapter 9. The query in this listing shows how to see the state of the buffers in the buffer cache:

```
      -- Buffer cache buffer statuses.
  SET VERIFY off
  COLUMN PctTotBCMem for a11
  SELECT /*+ ordered */
         tot_bc_mem.TotBCMem,
         decode(state,
                    0,'Free',
                    1,'Exclusive',
                    2,'SharedCurrent' ,
                    3,'ConsistentRead',
                    4,'BeingRead',
                    5,'InMediaRecoveryMode',
                    6,'InInstanceRecoveryMode',
                    7,'BeingWritten',
                    8,'Pinned',
                    9,'Memory',
                   10,'mrite',
                   11,'Donated'
                   12,'protected',
                   13,'securefile',
                   14,'siop',
                   15,'reckpt',
                   16, 'flashfree',
                   17, 'flashcur',
                   18, 'flashna') "BlockState",
         SUM(blsiz) "SumStateTypeMem",
         COUNT(1)   "NumOfBlksThisTyp",
         ROUND(SUM(blsiz)/tot_bc_mem.TotBCMem,2)*100||'%' "PctTotBCMem"
    FROM (SELECT sum(blsiz) TotBCMem
          FROM x$bh) tot_bc_mem,
               x$bh
GROUP BY tot_bc_mem.TotBCMem,
            decode(state,
                    0,'Free',
                    1,'Exclusive',
                    2,'SharedCurrent' ,
                    3,'ConsistentRead',
                    4,'BeingRead',
                    5,'InMediaRecoveryMode',
```



```
                         6,'InInstanceRecoveryMode',
                         7,'BeingWritten',
                         8,'Pinned',
                         9,'Memory',
                        10,'mrite',
                        11,'Donated'
                        12,'protected',
                        13,'securefile',
                        14,'siop',
                        15,'reckpt',
                        16, 'flashfree',
                        17, 'flashcur',
                        18, 'flashna')
ORDER BY SUM(blsiz);
CLEAR COLUMNS

  TOTBCMEM BlockState                SumStateTypeMem NumOfBlksThisTyp PctTotBCMem
---------- ------------------------- --------------- ---------------- -----------
 209739776 Free                             12828672             1566 6%
 209739776 ConsistentRead                   43368448             5294 21%
 209739776 Exclusive                       153542656            18743 73%
```

Here is a quick reference listing the buffer states in X$BH:

Buffer State	Meaning
0	Free
1	Exclusive/Current (CURR)
2	Shared Current
3	Consistent Read (CR)
4	Being Read
5	In Media Recovery Mode
6	In Instance Recovery Mode
7	Being Written
8	Pinned
9	Memory
10	Mwrite
11	Donated
12	Protected
13	Securefile
14	Siop
15	Rec Checkpoint
16	Flash Free
17	Flash Current
18	Flashna

Segments Occupying Block Buffers

Noting the distribution of segment owners, types, and names among the occupied buffers is useful. Note, in particular, which objects occupy the most buffers. Observe the indexes currently in the cache. Question whether these indexes are appropriate. If they are nonselective indexes being used by selective queries (or vice versa), these indexes could be occupying precious buffers that could be used more effectively by the corresponding table blocks or by the blocks of other segments experiencing "buffer busy waits" wait events. Query V$SQLTEXT to observe the SQL statements currently using the segments occupying the highest percentages of the buffers and determine whether index usage in these statements is appropriate. The two queries in the following listings show the segments occupying block buffers and also the percentage of buffers occupied by segments in the buffer cache.

```
      Segments Occupying Block Buffers (long listing / for testing usually).
SELECT o.*, d_o.owner, d_o.object_name, object_type, o.buffers, o.avg_touches
FROM (     SELECT obj object, count(1) buffers, AVG(tch) avg_touches
                      FROM x$bh
             GROUP BY obj) o,
dba_objects d_o
WHERE o.object = d_o.data_object_id
ORDER BY owner, object name;
```

Percentage of buffers occupied by segments in the buffer cache

```
  -- Percentage of Buffers Occupied by Segments in the Buffer Cache.
  -- Note that this percentage is the percentage of the number of
  -- occupied buffers, not the percentage of the number of allocated
  -- buffers.
 SELECT tot occ bufs.TotOccBufs,o.*,d o.owner, d o.object name, object type,
        ROUND((o.buffers/tot occ bufs.TotOccBufs)*100,2) || '%' PctOccBufs
 FROM   (SELECT obj object, count(1) buffers, AVG(tch) avg_touches
            FROM x$bh
        GROUP BY obj) o,
         (SELECT COUNT(1) TotOccBufs
            FROM x$bh
           WHERE  state != 0) tot_occ_bufs,
        dba objects d o
 WHERE o.object = d_o.data_object_id
ORDER BY round((o.buffers/tot occ bufs.TotOccBufs)*100,2),owner, object name;
```

Note also that only segments that are of the same block size as the block size of the default pool (the default block size) may be assigned to the keep or recycle pools. As of the first release of Oracle9*i*, the keep and recycle pools are not available for use by segments that are not the default block size. This defeats some of the strategy involved with tuning segments that are either high or low access and are not the default block size. However, other tuning options are available for such segments, such as partitioning.

Pool-specific buffer cache buffer occupation

```
     -- Pool Specific Buffer Cache Buffer Occupation
 SELECT DECODE(wbpd.bp_id,1,'Keep',
                         2,'Recycle',
                         3,'Default',
                         4,'2K Pool',
                         5,'4K Pool',
                         6,'8K Pool',
                         7,'16K Pool',
                         8,'32K Pool',
                           'UNKNOWN') Pool,
        bh.owner,
        bh.object_name object_name,
        count(1) NumOfBuffers
    FROM x$kcbwds wds, x$kcbwbpd wbpd,
        (SELECT set_ds,x.addr,o.name object_name,
                u.name owner
           FROM sys.obj$ o,
                sys.user$ u,
                x$bh x
          WHERE o.owner# = u.user#
            AND o.dataobj# = x.cbj
            AND x.state !=0
            AND o.owner# !=0 ) bh
   WHERE wds.set_id >= wbpd.bp_lo_sid
     AND wds.set_id <= wbpd.bp_hi_sid
     AND wbpd.bp_size != 0
     AND wds.addr=bh.set_ds
   GROUP BY
     DECODE(wbpd.bp_id,1,'Keep',
                        2,'Recycle',
                        3,'Default',
                        4,'2K Pool',
                        5,'4K Pool',
                        6,'8K Pool',
                        7,'16K Pool',
                        8,'32K Pool',
                          'UNKNOWN'),
     bh.owner,
     bh.object_name
ORDER BY 1,4,3,2;
```

Hot Data Blocks and the Causes of Latch Contention and Wait Events

The segment blocks returned by the query in the next listing are ones that are being accessed frequently, particularly if the value of the TCH (touch count) column changes (higher *and* lower) between consecutive executions of this query. The TCH column value is incremented every time a particular buffer is “touched” or “visited” by a transaction. This value can fluctuate as a buffer is moved up and down the Least Recently Used (LRU) list. The reason for the fluctuation is that Oracle internally adjusts the TCH value according to its position in the LRU list and other factors, such as how long it has been since the buffer was last touched. In some scenarios of this algorithm, Oracle internally resets the TCH value back to 1.

```
    -- Segments Occupying Hot Buffers (could be slow for a large cache / test).
    -- This query defines a "hot" buffer as a buffer that has
    -- a touch count greater than 10.
COL NAME FOR A35
SELECT /*+ ordered */ u.username ||'.'|| o.name  name,
       so.object_type type, bh.dbablk, bh.tch touches
FROM   x$bh  bh, dba_users u, sys.obj$ o, sys.sys_objects so
WHERE  bh.obj = o.obj#
and    bh.obj = so.object_id
and    o.owner# = u.user_id
AND    bh.tch  > 10
ORDER  BY bh.tch desc;

NAME                                TYPE                   DBABLK    TOUCHES
----------------------------------- ------------------ ---------- ----------
SYS.FILE$                           TABLE                     114        807
SYS.I_FILE#_BLOCK#                  INDEX                      82        804
SYS.C_USER#                         CLUSTER                    92        746
SYS.C_USER#                         CLUSTER                    90        737
SYS.I_FILE#_BLOCK#                  INDEX                      88        612
SYS.JOB$                            TABLE                    1473        506
SYS.JOB$                            TABLE                    1474        505
SYS.I_JOB_NEXT                      INDEX                    1490        485
SYS.I_FILE#_BLOCK#                  INDEX                      85        396
SYS.C_USER#                         CLUSTER                    91        344
SYS.I_OBJ1                          INDEX                   54721        340
(Output truncated...)

    -- Segments Occupying Hot Buffers (could be slow for a large cache / test).
    -- This query defines a "hot" buffer as a buffer that has
    -- a touch count greater than 10 and groups by OBJECT.
COL NAME FOR A35
SELECT /*+ ordered */ u.username ||'.'|| o.name  name,
       so.object_type type, count(bh.dbablk) blocks, sum(bh.tch) touches
FROM   X$bh  bh, dba_users u, sys.obj$ o, sys.sys_objects so
WHERE  bh.obj = o.obj#
and    bh.obj = so.object_id
and    o.owner# = u.user_id
AND    bh.tch  > 10
group  by u.username ||'.'|| o.name, so.object_type
ORDER  BY touches desc;

NAME                                TYPE                   BLOCKS    TOUCHES
----------------------------------- ------------------ ---------- ----------
SYS.C_FILE#_BLOCK#                  CLUSTER                   131      20263
SYS.OBJ$                            TABLE                      75      10407
SYS.I_FILE#_BLOCK#                  INDEX                      20       6063
SYS.I_OBJ1                            INDEX                           28         5453
SYS.C_USER#                           CLUSTER                          4         1984
SYS.JOB$                              TABLE                            2         1017
SYS.FILE$                             TABLE                            1          811
SYS.I_JOB_NEXT                        INDEX                            1          486
(Output truncated...)
```

Capture the SQL statements involving these segments by querying V$SQLTEXT for SQL_TEXT lines that contain these segment names, and analyze their execution plans with the EXPLAIN PLAN as described in Chapter 6. Consider the number of sessions accessing these blocks using the queries in this section and whether these blocks are tables or appropriate indexes. Table blocks appearing in this list that are being accessed by multiple sessions are candidates for the keep pool. Table segments in this list that incur frequent full table scans are candidates for being re-created in tablespaces that are configured for large block sizes (16K or larger). Conversely, table segments that incur single-row accesses are candidates for being re-created in tablespaces that are configured for smaller block sizes (2K, 4K, or 8K).

Note that you should balance rebuilding such single-row access tables in small block tablespaces with data locality considerations. If such a single-row access table is accessed *frequently* for similar data that is likely to be stored consecutively, then you should consider storing such segments in large block tablespaces instead of a small block tablespace. As a result, a lower number of physical block reads occurs because of the increased chance that the block containing the desired rows already resides in a buffer cache buffer from other recent queries.

Deciding how to size such objects depends on the default block size of the database and the amount of physical memory and SGA space available for creating a keep pool. Segments in buffers with a consistently low touch count are candidates for the recycle pool, depending on the block size of the particular table versus the default block size. You should review the application SQL code, particularly the indexing strategy, to reconsider the logic of accessing such blocks frequently, in an effort to reduce contention on them. The following queries will help. (Note that since 10*g*R2, the cache buffers chain latch can be shared—but not all the time. Also, in-memory UNDO [IMU] lessens issues with the buffer cache especially in 11*g*.) Although Oracle does in-memory updates *all* the time, this updating happens in the buffer cache. IMU is new because UNDO and REDO in Oracle9*i* had to be written out to disk quickly to protect the data.

```
  -- Segments Experiencing Waits on the Cache Buffers Chains Latch (slow - test)
SELECT  /*+ ordered */
        de.owner ||'.'|| de.segment_name  segment_name,
        de.segment_type  segment_type,
        de.extent_id  extent#,
        bh.dbablk - de.block_id + 1  block#,
        bh.lru_flag,
        bh.tch,
        lc.child#
 FROM   (SELECT MAX(sleeps) MaxSleeps
         FROM   v$latch_children
         WHERE  name='cache buffers chains') max_sleeps,
         v$latch_children  lc,
         X$bh  bh,
         dba_extents  de
  WHERE  lc.name      = 'cache buffers chains'
    AND  lc.sleeps   > (0.8 * MaxSleeps)
    AND  bh.hladdr    = lc.addr
    AND  de.file_id = bh.file#
    AND  bh.dbablk between de.block_id and de.block_id + de.blocks - 1
ORDER BY bh.tch;
```

Segments experiencing waits on the cache buffers’ LRU chain latch

```
   -- Segments Experiencing Waits on Cache Buffers LRU Chain Latch (slow - test)
SELECT  /*+ ordered */
        de.owner ||'.'|| de.segment_name  segment_name,
        de.segment_type  segment_type,
        de.extent_id  extent#,
        bh.dbablk - de.block_id + 1  block#,
        bh.lru_flag,
        bh.tch,
        lc.child#
  FROM  (SELECT MAX(sleeps) MaxSleeps
        FROM v$latch_children
        WHERE name='cache buffers lru chain') max_sleeps,
        v$latch_children  lc,
        X$bh  bh,
        dba_extents  de
WHERE   lc.name     = 'cache buffers lru chain'
  AND   lc.sleeps  > (0.8 * MaxSleeps)
  AND   bh.hladdr  = lc.addr
  AND   de.file_id = bh.file#
  AND   bh.dbablk between de.block_id and de.block_id + de.blocks - 1
ORDER BY bh.tch;
```

Sessions experiencing waits on the buffer busy waits or write complete waits events

```
    -- Sessions Experiencing Waits on the Buffer Busy Waits or Write
    -- Complete Waits Events. Note that the values returned by the p1, p2,
    -- and p3 parameters disclose the file, block, and reason for the wait.
    -- The cause disclosed by the p3 parameter is not externally published.
    -- The p3 parameter is a number that translates to one of several
    -- causes, among which are the buffer being read or written by
    -- another session.
  SELECT /*+ ordered */
         sid,event,owner,segment_name,segment_type,p1,p2,p3
    FROM v$session_wait sw, dba_extents de
   WHERE de.file_id = sw.p1
     AND sw.p2 between de.block_id and de.block_id + de.blocks - 1
     AND (event = 'buffer busy waits' OR event = 'write complete waits')
     AND p1 IS NOT null
ORDER BY event,sid;
```

Problem segments returned by queries in this section are likely to be the same as those returned by the query returning hot buffers earlier in this section. If they're not, a possible explanation may be that such a segment is accessed frequently by one session, as shown by the hot buffer query, but there may be no contention for it by other sessions, as may be shown by the absence of that segment from the result set of the other queries in this section. Other than that scenario, the segments returned by a hot buffers query are likely to also be returned by the other queries in this section that show the problem segment. Each of these queries conveniently includes the blocks of the particular segments associated with the latches or waits in question.

For table segments, you can use the DBMS_ROWID PL/SQL package to map the file and block numbers returned by these queries to the corresponding table rows. If one or a set of segments consistently shows up in the result sets of the queries in this section, then these are highly used segments. Investigate the application to reconsider the use of these popular segments. Ask questions such as the following:

- Is the indexing scheme appropriate?
- Are PL/SQL (or Java) loop exit conditions included where they should be?
- Are superfluous tables included in join queries?
- Can any SQL code be reengineered to alter a join strategy, either with reengineered subqueries, inline views, or similar alternatives?
- Should some hints, like ORDERED, USE_HASH, etc., be used?
- Are statistics up to date?
- Do any of the involved tables have a high watermark that is well beyond the actual blocks that contain rows?
- Could a table or index make advantageous use of partitioning or histograms?
- Should you use a keep pool?

If a variety of different segments are repeatedly showing up in the result of the buffer-busy query, the buffer cache is probably undersized or the disk subsystem is not writing changed (dirty) buffers out to the datafiles fast enough for them to be reused (or both). If there does not seem to be contention on particular segments, but rather on a varying set of segments, this problem indicates that Oracle is having trouble in general satisfying requests to load blocks into free buffers.

You should also review the storage parameter configuration of the problem segments returned by the queries in this section. Consider whether sufficient *free lists* are available for the tables and indexes that can be classified as high concurrent update (multiple sessions updating them concurrently). You should probably set free lists to two or higher for these segments, but do not set free lists higher than the number of CPUs in the database server. Another solution is to use Automatic Segment Space Management (ASSM). You should review the data block size and PCT_FREE because different conditions call for blocks of a table or index to contain more rows or fewer rows. In situations in which a particular segment block is popular, you may want to reconstruct the segment with a higher PCT_FREE; thus, the interblock contention for rows that were previously stored in the same block is reduced because the chance of those rows being stored in the same block has been reduced by simply reducing the number of rows that can be inserted into a block.

Obviously, more buffer cache buffers are required to accommodate a table reconstructed to have a larger PCT_FREE and, therefore, consist of more row-containing blocks. The trade-off is that this can reduce the performance of full table scan operations on such tables because more blocks must be visited to complete a full table scan. In general, you must consider the overall use of these tables and indexes to judge whether having more or fewer rows in the blocks of the particular table or index is more advantageous. These points can be summarized as follows:

- **Condition** Higher PCT_FREE and, therefore, fewer rows per block:
  - **Advantage** Less contention on updates of popular blocks.
  - **Disadvantage** The segment consists of more blocks and, therefore, reduces full table scan performance.
- **Condition** Lower PCT_FREE and, therefore, more rows per block:
  - **Advantage** There is a better chance that the block containing a requested row is already in a buffer cache buffer from a recent query. Full table scans will need to visit fewer blocks.
  - **Disadvantage** Blocks being updated may contain more contention. If a block contains a row to be updated, all the other rows (more of them) in that block are now in a copy of the block that is incompatible with other sessions requesting a read of other rows in that block; thus, another read-consistent copy of the block must be read into another buffer cache buffer.

Obtaining Database- and Instance-Specific Information

You can obtain some database- and instance-specific information from the X$KCCDI table. Consider the following queries, which you can use to find overall instance- and database-specific information:

```
-- MAXLOGMEMBERS setting for a database.
SELECT dimlm
  FROM x$kccdi;
```

Datafile creation times

```
    -- Datafile creation times.
    SELECT indx file_id,
           fecrc_tim creation_date,
           file_name,
           tablespace_name
      FROM x$kccfe int,
           dba_data_files dba
     WHERE dba.file_id = int.indx + 1
ORDER BY file_name;
```

Background process names and process IDs

```
-- Background process names and process ids.
SELECT ksbdpnam ProcessName, ksbdppro OSPid
  FROM x$ksbdp
WHERE  ksbdppro != '00' ;
```

```
PROCE OSPID
----- --------
PMON  437B9F3C
VKTM  437BAA14
GEN0  437BB4EC
DIAG  437BBFC4
DBRM  437BCA9C
VKRM  437CAE54
PSP0  437BD574
DIA0  437BE04C
MMAN  437BEB24
DBW0  437BF5FC
ARC0  437C626C
ARC1  437C6D44
ARC2  437C781C
ARC3  437C82F4
LGWR  437C00D4
CKPT  437C0BAC
SMON  437C1684
SMCO  437C5794
RECO  437C215C
CJQ0  437CA37C
QMNC  437C8DCC
MMON  437C2C34
MMNL  437C370C

23 rows selected.
```

Various instance resources

```
-- Various instance resources (very cool).
SELECT kviival ResourceValue, kviidsc ResourceName
    FROM x$kvii;
```

Note that the last query has different values returned for the resource values on different platforms.

Effective X$ Table Use and Strategy

Consider creating a separate X$ query user who has his or her own X$ views on the SYS X$ tables, as described earlier in the chapter. This user could manually, or with DBMS_JOB, perform periodic queries to capture X$ table data into some other tables so the contents of the X$ tables can be examined over time. If you do this, keep in mind that the data in the X$ tables is highly transient. Some scripts or jobs written to capture such information will likely miss a lot of it. On the other hand, you do not want to query these tables so frequently that the queries themselves and their associated activity information are a non-negligible percentage of the data in the tables.

In monitoring the X$KSMLRU table (and perhaps X$KSMSP and others), you may find it prudent to capture the contents of the table to a permanent table for analysis and comparison over time.

Oracle Internals Topics

Alas, more toys for the mischievously curious DBAs. Except for traces, you should not use the utilities described in the following sections in production without the guidance of Oracle Support. You can take them and run with them in a sandbox database to learn what useful information they provide.

Traces

Database sessions can be traced to collect session information about the work performed in the session and to diagnose problems. Traces can be turned on by a variety of methods:

- Set SQL_TRACE = TRUE with an ALTER SESSION command.
- Set SQL_TRACE = TRUE in the initialization parameter file.
- Execute the DBMS_SYSTEM.SET_SQL_TRACE_IN_SESSION( ) PL/SQL procedure for another session.
- Create traces with the `$ORACLE_HOME/rdbms/admin/dbmssupp.sql` script.
- Execute the DBMS_SYSTEM.SET_EV( ) PL/SQL procedure to set tracing events in another session.
- Use the ORADEBUG command.

CAUTION
If you set SQL_TRACE = TRUE in the parameter file, it generates traces for every process connected to the database, including the background processes.

The simplest method to invoke a trace of a session is for the session itself to enable tracing with the following command:

```
SQL> alter session set sql_trace=true;

Session altered.
```

Developers may do this themselves from SQL*Plus and may also include it in PL/SQL code using the EXECUTE IMMEDIATE facility. The DBA may optionally decide to make the trace files in the user dump destination readable by all (Unix and OpenVMS) by setting the hidden parameter _TRACE_FILES_PUBLIC to TRUE on instance startup.

Having users generate traces for themselves is simple but not always practical. Third-party applications usually do not permit the code to be modified for the insertion of `TRACE` commands, and there is usually no SQL prompt from where the trace can be started. You could use system logon triggers to identify the user connecting and optionally start a trace, but there are easier methods at your disposal.

In these situations, you need to be able to invoke a trace for another session. As the DBA, you have a number of methods to do this. In each case, however, you need to know the SID and the SERIAL# of the session you want to trace. You can find this information in the V$SESSION view, as shown here:

```
select sid, serial#
from   v$session where username = 'NICOLA';

       SID    SERIAL#
---------- ----------
       540         11
```

Once you have this information, you can use the SET_SQL_TRACE_IN_SESSION procedure of the DBMS_SYSTEM package to invoke the trace. The procedure takes three arguments: SID, SERIAL#, and a Boolean argument to start or stop the tracing. It is invoked as follows:

```
SQL> exec dbms_system.set_sql_trace_in_session(540,11,TRUE);
PL/SQL procedure successfully completed.
```

When sufficient tracing information has been collected, disable the trace as follows:

```
SQL> exec dbms_system.set_sql_trace_in_session(540,11,FALSE);
PL/SQL procedure successfully completed.
```

Alternatively, you can use the DBMS_SUPPORT package to start the trace. The DBMS_SUPPORT package is an option that can be loaded into the database from the rdbms/admin directory. To load the package, you must be connected to the database as a SYSDBA privileged user and then run the `dbmssupp.sql` script.

The DBMS_SUPPORT package offers much of the same functionality for tracing as the DBMS_SYSTEM package but with these additional features:

- It allows bind variables and session wait information to be optionally included in the trace file.
- It verifies the SID and SERIAL# specified for tracing, rejecting invalid combinations. This can be useful in critical situations. It can be very frustrating to have spent an hour believing you have collected useful trace information only to find that you mistyped something and the user

dump destination directory is empty.

Use the START_TRACE_IN_SESSION procedure of the DBMS_SUPPORT package to start the trace. The procedure takes four arguments: SID, SERIAL#, a Boolean specifying if wait information is recorded (default TRUE), and a Boolean specifying if bind variables are recorded (default FALSE). Invoke it as follows:

```
SQL> exec dbms_support.START_TRACE_IN_SESSION(540,13,TRUE,TRUE);
PL/SQL procedure successfully completed.
```

To stop tracing, use the STOP_TRACE_IN_SESSION procedure:

```
SQL> exec dbms_support.stop_trace_in_session(540,13);
```

Another method to invoke tracing for another session is to use the DBMS_SYSTEM.SET_EV method to set a tracing event for a session. This procedure allows database events to be set in any session in the database. By setting the 10046 event, you can gather complete tracing information about any session. As before, you need the SID and SERIAL# of the session you want to monitor. You can then set the event as follows:

```
SQL> exec dbms_system.set_ev(537,21,10046,12,'');
PL/SQL procedure successfully completed.
```

The first two arguments are the SID and SERIAL# of the session. The next argument is the event you want to set, which, in this case, is event 10046 to trace the session. The fourth argument sets the level of the event. Here the level is set to 12 to gather all wait and bind variable information in addition to the basic trace. The available levels are as follows:

Level	**Information Gathered**
0	All tracing disabled.
1	Standard tracing enabled.
2	Same as level 1.
4	Standard trace plus bind variable information.
8	Standard trace plus wait information. Very helpful for spotting latch waits.
12	Standard trace plus bind and wait information.
16	Generates STAT line dumps for each execution (see note below).

NOTE

STAT dumping was amended in 11g so individual dumps are not aggregated across all executions but are dumped after execution. This change addresses cases where the cursor is not closed and, therefore, the STAT information is not dumped. Now Oracle guarantees to capture the STAT information following the execution.

To stop tracing, you need to set the event level to zero as follows:

```
SQL> exec dbms_system.set_ev(537,21,10046,12,'');
PL/SQL procedure successfully completed.
```

Finally, you could use the ORADEBUG facility to invoke the required trace. This will be explored further later in this chapter.

Once a trace file has been generated, you can use the standard TKPROF utility to interpret the contents of the trace. (The TKPROF tool is covered in detail in Chapter 6.) Oracle also offers the more advanced Trace Analyzer tool, which can be downloaded from My Oracle Support (see Note 224270.1). The more adventurous DBA may wish to examine the raw trace file, which can sometimes yield information not shown by TKPROF. The Trace Analyzer takes the trace files generated by the methods described previously and produces a series of formatted reports. The reports are typically written to the user dump destination directory. The reports are very detailed and can take an extended period of time to produce, especially if your server is running poorly to begin with. To generate the report, you need to know the name of the trace file generated, and then you can invoke the Trace Analyzer as follows:

```
SQL> start /home/oracle/tusc/trca/run/trcanlzr.sql DEMOUC2_ora_16319.trc

Parameter 1:
Trace Filename or control_file.txt (required)

Value passed to trcanlzr.sql:
~~~~~~~~~~~~~~~~~~~~~~~~~~~~
TRACE_FILENAME: DEMOUC2_ora_16319.trc

Analyzing DEMOUC2_ora_16319.trc

To monitor progress, login as TRCANLZR into another session and execute:
SQL> SELECT * FROM trca$_log_v;

... analyzing trace(s) ...


Trace Analyzer completed.
Review first trcanlzr_error.log file for possible fatal errors.
Review next trca_e44266.log for parsing messages and totals.

Copying now generated files into local directory

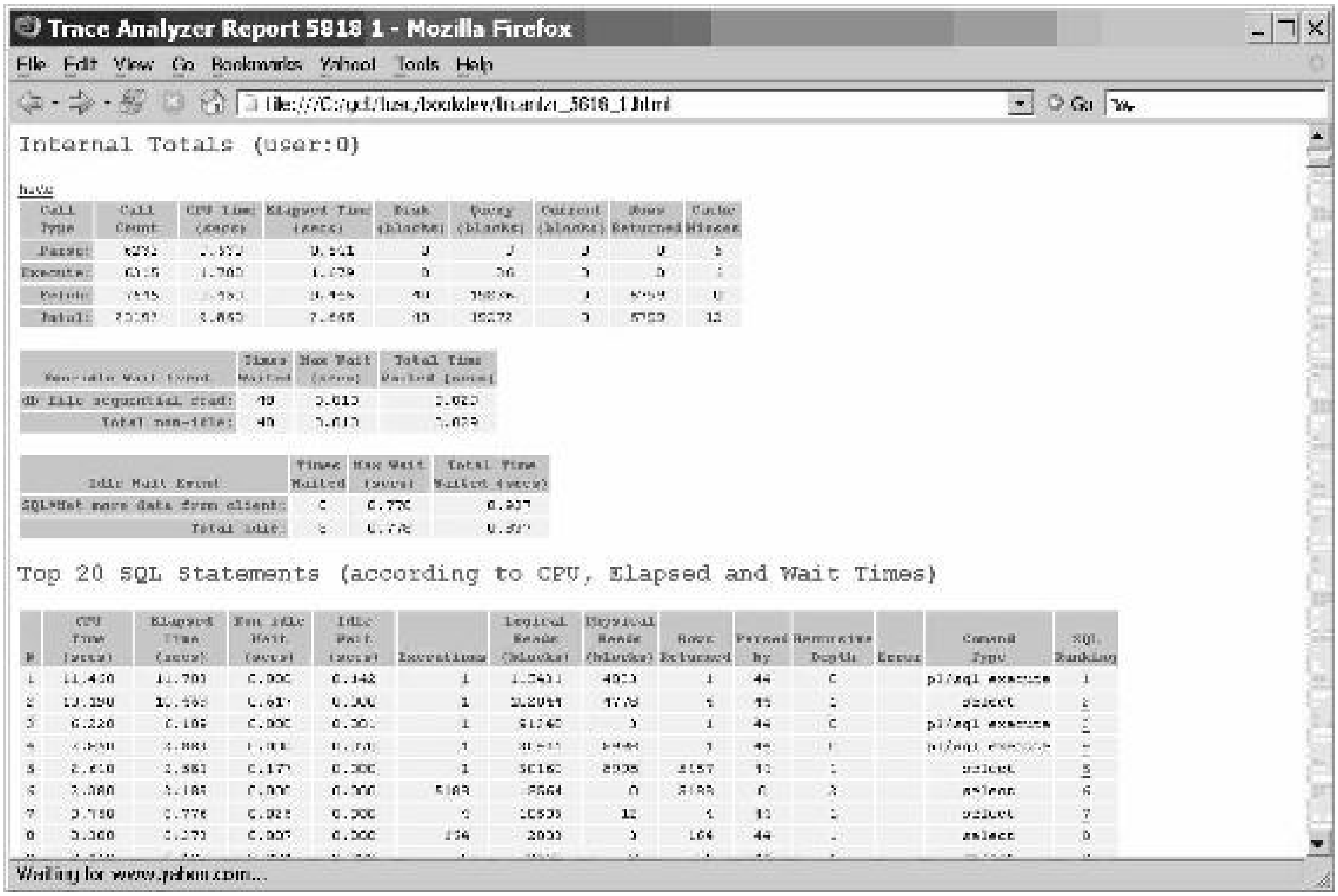
TKPROF: Release 11.2.0.1.0 - Development on Wed May 18 11:50:05 2011
Copyright (c) 1982, 2009, Oracle and/or its affiliates.  All rights reserved.

  adding: trca_e44266.html (deflated 89%)
  adding: trca_e44266.log (deflated 84%)
  adding: trca_e44266.tkprof (deflated 84%)
  adding: trca_e44266.txt (deflated 85%)
  adding: trcanlzr_error.log (deflated 81%)
test of trca_e44266.zip OK
deleting: trcanlzr_error.log
Archive:  trca_e44266.zip

  Length     Date   Time    Name
 --------    ----   ----    ----
   140676  05-18-11 11:50   trca_e44266.html
    15534  05-18-11 11:50   trca_e44266.log
    17065  05-18-11 11:50   trca_e44266.tkprof
    69535  05-18-11 11:50   trca_e44266.txt
 --------                   -------
   242810                   4 files

File trca_e44266.zip has been created

TRCANLZR completed.
```



Trace Analyzer Report 5818 1 - Mozilla Firefox

file:///C:/gd/tusc/bookdev/trcanlzr_5818_1.html

Internal Totals (user:0)

back

Call Type	Call Count	CPU Time (secs)	Elapsed Time (secs)	Disk (blocks)	Query (blocks)	Current (blocks)	Rows Returned	Cache Misses
Parse:	6292	[illegible]	0.541	0	0	0	0	5
Execute:	6155	1.703	1.079	0	36	3	0	[illegible]
Fetch:	7535	[illegible]	0.458	40	35836	1	5759	0
Total:	20057	3.860	2.068	40	35872	3	5759	12

Non-idle Wait Event	Times Waited	Max Wait (secs)	Total Time Waited (secs)
db file sequential read:	40	0.013	0.029
Total non-idle:	40	0.013	0.029

Idle Wait Event	Times Waited	Max Wait (secs)	Total Time Waited (secs)
SQL*Net more data from client:	6	0.770	0.807
Total idle:	6	0.770	0.807

Top 20 SQL Statements (according to CPU, Elapsed and Wait Times)

#	CPU Time (secs)	Elapsed Time (secs)	Non Idle Wait (secs)	Idle Wait (secs)	Executions	Logical Reads (blocks)	Physical Reads (blocks)	Rows Returned	Parsed By	Recursive Depth	Error	Command Type	SQL Ranking
1	11.430	11.703	0.000	0.142	1	1.0411	4003	1	44	0		pl/sql execute	1
2	10.190	10.558	0.617	0.000	1	1.2044	4778	5	44	1		select	2
3	6.220	6.108	0.000	0.000	1	61340	0	1	44	0		pl/sql execute	3
4	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	1	44	[illegible]		pl/sql execute	4
5	2.610	2.581	0.177	0.000	1	50160	2008	2157	11	1		select	5
6	2.080	2.185	0.000	0.000	5183	5564	0	5183	0	2		select	6
7	2.150	2.776	0.025	0.000	1	10533	12	1	11	1		select	7
8	2.360	2.273	0.007	0.000	154	2033	0	164	44	1		select	8

Waiting for www.yahoo.com...

FIGURE 13-1. *Sample Trace Analyzer report*

The finished HTML report summarizes the trace file (see Figure 13-1). The report includes all of the details found on TKPROF, plus additional information normally requested and used for a transaction performance analysis.

DBMS_TRACE Package

The DBMS_TRACE package is another method of tracing, but unlike the preceding examples, it is designed specifically to trace PL/SQL rather than individual sessions. It can be extremely useful when trying to debug PL/SQL programs. To use the DBMS_TRACE package, the DBA must first load the following scripts from the rdbms/admin directory as a SYSDBA user:

```
TRACETAB.SQL
DBMSPBT.SQL
PRVTPBT.PLB
```

Once the packages are loaded, PL/SQL can be traced using two methods:

```
SQL> alter session set plsql_debug=true;
```

All PL/SQL code created by the session after this point will have the additional hooks to allow it to be traced, including anonymous PL/SQL blocks. However, code created before this point cannot be traced with the DBMS_TRACE package. Alternatively, any existing PL/SQL package, procedure, or function can be recompiled using the following command:

```
SQL> alter [PROCEDURE | FUNCTION | PACKAGE BODY] <procedure name> compile debug;
```

TIP
Anonymous PL/SQL blocks cannot be traced using the "compile debug" method. PL/SQL tracing for the entire session must be enabled with the ALTER SESSION SET PLSQL_DEBUG=TRUE command.

Now to trace the PL/SQL code execution, you can start with the following command:

```
SQL> execute dbms_trace.set_plsql_trace(dbms_trace.trace_all_lines);
```

The argument here specifies which lines of PL/SQL to trace. The options are TRACE_ALL_LINES to trace every line executed, TRACE_ENABLED_LINES to trace only PL/SQL that was explicitly compiled with the debug option, TRACE_ALL_EXCEPTIONS to trace only exceptions, and TRACE_ENABLED_EXCEPTIONS to trace only exceptions of PL/SQL that was explicitly compiled with the debug option. When the tracing is complete, disable it with the following command:

```
SQL> execute dbms_trace.clear_plsql_trace();
```

The results of the trace can be seen in the PLSQL_TRACE_EVENTS table owned by the SYS schema, as shown here:

```
select event_seq as seq, stack_depth, event_kind as kind,
       event_unit as unit, event_line as line, event_comment
from   sys.plsql_trace_events;

    SEQ STACK_DEPTH  KIND UNIT                    LINE EVENT_COMMENT
------- ----------- ----- -------------------- ----- ------------------------------
 270001           7    51 RDBA_MONITOR_C         108 New line executed
 270002           7    51 RDBA_MONITOR_C         110 New line executed
 270003           8    51 RDBA_UTILITY           174 New line executed
 270004           8    51 RDBA_UTILITY           183 New line executed
 270005           8    51 RDBA_UTILITY           192 New line executed
 270006           8    51 RDBA_UTILITY           195 New line executed
 270007           9    51 DBMS_SQL                 9 New line executed
 270008          10    51 DBMS_SYS_SQL           882 New line executed
 270009          10    51 DBMS_SYS_SQL           883 New line executed
 270010           9    51 DBMS_SQL                 9 New line executed
 270011           9    51 DBMS_SQL                10 New line executed
 270012           8    51 RDBA_UTILITY           195 New line executed
 270013           8    51 RDBA_UTILITY           196 New line executed
```

Events

An *event* is similar to a system trigger in an Oracle instance. A trigger can capture pertinent information about the instance and individual database sessions to trace files. If an event is set in an initialization parameter file or with an ALTER SYSTEM or ALTER SESSION setting, then Oracle captures information to a trace file based on the conditions set in the event. Several events can be set. These can be described with the `oerr` command-line facility. Try the following command (in Unix only):

```
oerr ora 10046
```

A particularly useful tuning tool is event 10046 (described in Chapter 9 in detail). This event can be enabled in the initialization parameter file with the following line (although this is not something that you generally want to set at the database level):

```
event = '10046 trace name context forever, level 8'
```

Or it is more likely to be used at the session level with an ALTER SESSION command:

```
alter session set events '10046 trace name context forever,level 12';
```

The trace information is captured to a file in the USER_DUMP_DEST directory derived from the

DIAGNOSTIC_DEST parameter in the initialization parameter file. This event is equivalent to setting SQL_TRACE = TRUE in the initialization parameter file. At level 12, this event setting includes the values of bind variables and the occurrences of wait events. Other events are useful in troubleshooting database and performance issues. Do not set events in production databases without first consulting with Oracle Support and testing them in a test database.

You can use the ORADEBUG command (covered later in this chapter in the "ORADEBUG" section) or the DBMS_SUPPORT PL/SQL package to set events in sessions other than the current session. Also, to UNSET this event, you use

```
alter session set events '10046 trace name context off';
```

Dumps

Several structures in an Oracle instance or database can be dumped to a trace file for low-level analysis, such as these:

- Control files
- Datafile headers
- Redo log file headers
- Instance state
- Process state
- Library cache
- Data blocks (covered in detail in Chapter 9)
- Redo blocks

Create these dumps with these commands:

```
alter session set events 'immediate trace name CONTROLF level 10';
alter session set events 'immediate trace name FILE_HDRS level 10';
alter session set events 'immediate trace name REDOHDR level 10';
alter session set events 'immediate trace name SYSTEMSTATE level 10';

alter session set events 'immediate trace name PROCESSSTATE level 10';
alter session set events 'immediate trace name library cache level 10';
alter system dump datafile 10 block 2057;
alter system dump logfile '<logfilename>';
```

The trace files containing this dump information are in the USER_DUMP_DEST directory.

ORADEBUG

You use the ORADEBUG command for troubleshooting the instance or sessions. The ORADEBUG command can capture current instance state information, set events in sessions, and perform other low-level diagnostics. Type **oradebug help** from SQL*Plus to get the usage list shown next.

NOTE
You must be connected to AS SYSDBA to be able to access ORADEBUG (version dependent listing —run this for your own version).

```
SQL> oradebug help
HELP           [command]                 Describe one or all commands
SETMYPID                                 Debug current process
SETOSPID       <ospid>                   Set OS pid of process to debug
SETORAPID      <orapid> ['force']        Set Oracle pid of process to debug
SETORAPNAME    <orapname>                Set Oracle process name to debug
SHORT_STACK                              Get abridged OS stack
CURRENT_SQL                              Get current SQL
DUMP           <dump_name> <lvl> [addr]  Invoke named dump
DUMPSGA        [bytes]                   Dump fixed SGA
DUMPLIST                                 Print a list of available dumps
EVENT          <text>                    Set trace event in process
SESSION_EVENT  <text>                    Set trace event in session
DUMPVAR        <p|s|uga> <name> [level]  Print/dump a fixed PGA/SGA/UGA variable
DUMPTYPE       <address> <type> <count>  Print/dump an address with type info
SETVAR         <p|s|uga> <name> <value>  Modify a fixed PGA/SGA/UGA variable
PEEK           <addr> <len> [level]      Print/Dump memory
POKE           <addr> <len> <value>      Modify memory
WAKEUP         <orapid>                  Wake up Oracle process
SUSPEND                                  Suspend execution
RESUME                                   Resume execution
FLUSH                                    Flush pending writes to trace file
CLOSE_TRACE                              Close trace file
TRACEFILE_NAME                           Get name of trace file
LKDEBUG                                  Invoke global enqueue service debugger
NSDBX                                    Invoke CGS name-service debugger
-G             <Inst-List | def | all>   Parallel oradebug command prefix
-R             <Inst-List | def | all>   Parallel oradebug prefix (return output
SETINST        <instance# .. | all>      Set instance list in double quotes
SGATOFILE      <SGA dump dir>         Dump SGA to file; dirname in double quotes
DMPCOWSGA      <SGA dump dir> Dump & map SGA as COW; dirname in double quotes
MAPCOWSGA      <SGA dump dir>         Map SGA as COW; dirname in double quotes
```

```
HANGANALYZE     [level] [syslevel]          Analyze system hang
FFBEGIN                                     Flash Freeze the Instance
FFDEREGISTER                                FF deregister instance from cluster
FFTERMINST                                  Call exit and terminate instance
FFRESUMEINST                                Resume the flash frozen instance
FFSTATUS                                    Flash freeze status of instance
SKDSTTPCS       <ifname>  <ofname>          Helps translate PCs to names
WATCH           <address> <len> <self|exist|all|target>  Watch a region of memory
DELETE          <local|global|target> watchpoint <id>    Delete a watchpoint
SHOW            <local|global|target> watchpoints        Show  watchpoints
DIRECT_ACCESS   <set/enable/disable command | select query> Fixed table access
CORE                                        Dump core without crashing process
IPC                                         Dump ipc information
UNLIMIT                                     Unlimit the size of the trace file
PROCSTAT                                    Dump process statistics
CALL            [-t count] <func> [arg1]...[argn]  Invoke function with arguments
```

The following example shows using the ORADEBUG command to invoke a trace of another session. Let's say a user complains of slow performance on a database, or you have identified the process ID from the operation system. To get the SPID, use the following query:

```
select spid
from   v$process
where  addr = (select paddr from v$session where username = 'NICOLA');
```

Then you use the SETOSPID command to attach to the process and invoke the trace:

```
select spid
from   v$process
where  addr = (select paddr from v$session where username = 'NICOLA');
SQL> oradebug setospid 6943

Oracle pid: 28, Unix process pid: 18575, image: oracle@dc-umail13.myimunison.
com (TNS V1-V3)
```

Now that you are attached, you can invoke the trace by setting the 10046 event. Here, I select a level 12 to force all bind variables and wait information to be written to the trace file:

```
SQL> oradebug event 10046 trace name context forever, level 12
Statement processed.
```

The session is now tracing. If you want to see the name of the trace file being generated, use the TRACEFILE_NAME option as follows:

```
SQL> oradebug tracefile_name

/home/oracle/app/oracle/diag/rdbms/demouc2/DBMOUC2/trace/DBMOUC2_ora_18575.trc
```

This shows you the name and location of the trace file. This file can then be processed with the TKPROF analysis tool to obtain detailed information about the operations of the monitored process.

If your Oracle database has trace file-size limitations specified in the SPFILE or `init.ora` file, you can override this from ORADEBUG using the following command:

```
SQL> oradebug unlimit
Statement processed.
```

The DBA should remember, however, that Oracle buffers its writes to the trace file, and so the information contained in the file might not be completely up to date. Fortunately, the ORADEBUG command gives you the ability to flush the trace file write buffer as follows:

```
SQL> oradebug flush
Statement processed.
```

The ORADEBUG command can also be used to suspend the execution of a process. For example, you might have a long-running database job that is about to fail due to space, or an intensive update job that you want to disable during a backup. The ORADEBUG command allows specific sessions to be suspended as follows:

```
SQL> oradebug setospid 6943
Oracle pid: 11, Unix process pid: 6943, image: oraclelwdbwdc-mvndb3

SQL> oradebug suspend
Statement processed.
```

The Oracle operating system process 6943 is now suspended and will remain that way until you issue the ORADEBUG RESUME command.

TIP

Do not use ORADEBUG SUSPEND on the Microsoft Windows platform. Due to the thread-based processing model of Windows, the whole database will be suspended, not just the process you are *attached to.*

When you want to disable tracing for the specified session, you can use the following ORADEBUG command:

```
SQL> oradebug event 10046 trace name context off
Statement processed.
```

trcsess Utility

Oracle provides users with another tracing utility: *trcsess*. This utility can be found in the bin directory under Oracle Home. The tool is designed to read database trace files and extract information the DBA is interested in. Trace information can be located based on session information (SID and serial number), client identifier, service name, action name, or module name. The tool is primarily designed for use in shared server or connection pooling environments where multiple processes may have to be traced to capture all relevant information. The tool does not interpret the trace information; it simply aggregates multiple trace files into a single one based on the criteria provided. The result is a combined trace file that can be analyzed using TKPROF, TRCANLZR, or another tool. For additional information on this tool, see My Oracle Support Note 280543.1.

Reading the Trace File

The preceding section showed several methods that can be used to generate a trace of a session. Once the session being traced has completed, the DBA needs to locate, read, and interpret the trace file. The trace file is written to the directory pointed to by the user dump destination parameter. You can see it from SQL*Plus with the following command:

```
SQL> show parameter user_dump_dest

NAME                 TYPE      VALUE
-------------------- --------- ----------------------------------------------------
user_dump_dest       string    /home/oracle/app/oracle/diag/rdbms/demouc2/DEMOUC2/trace
```

The trace file has the filename format `<sid>_ora_<process id>.trc`. The process ID can be found in the V$PROCESS view as follows:

```
select spid
from   gv$process vp, gv$session vs
where  vs.sid = userenv('SID')
and    vs.paddr = vp.addr
and    vs.inst_id = vp.inst_id;

SPID
------------
4508
```

So, in this example, my trace file name is

```
/home/oracle/app/oracle/diag/rdbms/demouc2/DEMOUC2/trace/DEMOUC2 ora 4508.trc
```

Once located, I can read the trace file with the TKPROF tool (see Chapter 6) or the Trace Analyzer tool, shown earlier in this chapter. However, the curious DBA might be interested to see the contents of the trace file for himself or herself. Because the raw trace file is written in ANSI format, reading it can be accomplished with any standard file browser or editor. The trace file shows the traced session as a series of blocks. Each block represents a database call and is separated by a single line. At the top of the trace file is the standard trace file header that many DBAs are already familiar with:

```
Trace file /home/oracle/app/oracle/diag/rdbms/demouc2/DEMOUC2/trace/DEMOUC2_ora_16219.trc
Oracle Database 11g Release 11.2.0.1.0 - Production
ORACLE HOME - /home/oracle/app/oracle/product/11.2.0/dbhome 1
System name:     Linux
Node name:       dc-umail10.myinunison.com
Release: 2.6.18 164.el5
Version: 1 SMP Tue Aug 18 15:51:54 EDT 2009
Machine: i686
Instance name: DEMOUC2

Redo thread mounted by this instance: 1
Oracle process number: 28
Unix process pid: 16219, image: oracle@dc-umail10.myinunison.com (TNS V1-V3)
```

The trace file then shows each database call that was executed in the traced session in sequential order. The following example shows a simple SELECT statement:

```
PARSING IN CURSOR #7 len=57 dep=0 uid=86 oct=3 lid=86 tim=1305924518518576
hv=4215611583 ad='3b6289dc' sqlid='g12xs57xna6jz'
select birthdate from user_detail where firstname = :"SYS_B_0"
END OF STMT
PARSE #7:c=2000,e=1202,p=0,cr=0,cu=0,mis=1,r=0,dep=0,og=1,plh=0,t
im=1305924518518568
BINDS #7:
 Bind#0
  oacdty=01 mxl=32(06) mxlc=00 mal=00 scl=00 pre=00
  oacflg=10 fl2=0300 frm=01 csi=178 siz=32 off=0
  kxsbbbfp=009e47a0  bln=32  avl=06  flg=05
  value="Stacey"
EXEC #7:c=6999,e=51312,p=0,cr=84,cu=0,mis=1,r=0,dep=0,og=1,plh=1354678500,t
im=1305924518569996
WAIT #7: nam='SQL*Net message to client' ela= 5 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518570098
FETCH #7:c=0,e=142,p=0,cr=13,cu=0,mis=0,r=1,dep=0,og=1,plh=1354678500,t
im=1305924518570284
WAIT #7: nam='SQL*Net message from client' ela= 193 driver id=1650815232
#bytes=1 p3=0 obj#=91901 tim=1305924518570621
WAIT #7: nam='SQL*Net message to client' ela= 7 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518571472
FETCH #7:c=1000,e=1096,p=0,cr=145,cu=0,mis=0,r=15,dep=0,og=1,plh=1354678500,t
im=1305924518571755
WAIT #7: nam='SQL*Net message from client' ela= 282 driver id=1650815232
#bytes=1 p3=0 obj#=91901 tim=1305924518572099
WAIT #7: nam='SQL*Net message to client' ela= 2 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518572192
FETCH #7:c=0,e=83,p=0,cr=6,cu=0,mis=0,r=15,dep=0,og=1,plh=1354678500,t
im=1305924518572254
WAIT #7: nam='SQL*Net message from client' ela= 207 driver id=1650815232
#bytes=1 p3=0 obj#=91901 tim=1305924518572498
WAIT #7: nam='SQL*Net message to client' ela= 3 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518572574
FETCH #7:c=0,e=101,p=0,cr=8,cu=0,mis=0,r=15,dep=0,og=1,plh=1354678500,t
im=1305924518572659
WAIT #7: nam='SQL*Net message from client' ela= 218 driver id=1650815232
#bytes=1 p3=0 obj#=91901 tim=1305924518572912
WAIT #7: nam='SQL*Net message to client' ela= 1 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518572970
FETCH #7:c=1000,e=1035,p=0,cr=140,cu=0,mis=0,r=15,dep=0,og=1,plh=1354678500,t
im=1305924518573993
WAIT #7: nam='SQL*Net message from client' ela= 212 driver id=1650815232
#bytes=1 p3=0 obj#=91901 tim=1305924518574308
```

```
WAIT #7: nam='SQL*Net message to client' ela= 2 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518574474
FETCH #7:c=2999,e=2460,p=0,cr=354,cu=0,mis=0,r=9,dep=0,og=1,plh=1354679500,t
im=1305924518576842
STAT #7 id=1 cnt=70 pid=0 pos=1 obj=91901 op='TABLE ACCESS FULL ARIJAK (cr=666
pr=0 pw=0 time=0 us cost=193 size=231 card=11)'
```

The first line shows information about the statement being executed. The tags can be interpreted as follows:

Tag	Meaning
Len	Length of SQL statement.
Dep	Recursive depth of the cursor. Blocks where dep is not zero are recursive calls made by the database on the user's behalf. Time spent here contributes to the "recursive CPU" usage recorded in V$SYSSTAT.
Uid	Schema user ID of parsing user—see USER_ID in DBA_USERS.
Oct	Oracle command type.
Lid	Privilege user ID—may not be the same as parsing user if executing another user's PL/SQL code.
Tim	Timestamp—the value is the value in V$TIMER when the line was written. Pre-Oracle9*i*, the times recorded by Oracle are centiseconds (10 mS). As of Oracle9*i*, some times are microseconds (1/1,000,000ths of a second).
Hv	SQL hash—maps to SQL_HASH in V$SQLAREA.
Ad	SQL address—maps to SQL_ADDRESS in V$SQLAREA.
Sqlid	SQL ID—the SQLID of the statement.

The trace file then shows the text of the SQL statement being executed. In this case, I am selecting the BIRTHDATE from the USER_DETAIL table. You can also see from the trace file that this statement has been assigned cursor #7.

TIP
Cursors may be reassigned if the cursor is closed and released. Therefore, when reading a long trace file, remember that a cursor number referenced at one part of the trace file may not represent the same SQL statement as it does elsewhere in the trace file.

The trace file next shows the operations Oracle performs to actually satisfy the query. This basically amounts to a series of executions (EXEC) and fetches (FETCH). Both the EXEC and FETCH trace lines report the following tracing information:

Tag	Meaning
C	CPU time (100ths of a second)
E	Elapsed time (100ths of a second in Oracle 7, 8; microseconds in Oracle 9 upward)
P	Number of physical reads
Cr	Number of buffers retrieved for CR reads
Cu	Number of buffers retrieved in current mode
Mis	Cursor missed in the cache
R	Number of rows processed
Dep	Recursive call depth (0 – user SQL, >0 – recursive)
Og	Optimizer goal: 1 – all rows, 2 – first rows, 3 – rule, 4 – choose
Tim	Timestamp (large number in 100ths of a second)

Applying this knowledge to the EXEC line from my trace, I can determine the following:

```
EXEC #7:c=6999,e=51312,p=0,cr=84,cu=0,mis=1,r=0,dep=0,og=1,plh=1354678500,t
im=1305924518569996
```

- A total of 6999 ms of CPU was used for this EXEC.
- Total elapsed time was 51312 ms.
- Physical reads were zero.
- Buffers retrieved in CR (consistent read) mode were 84.
- Buffers retrieved in current mode were zero.
- Library cache misses was 1 (this statement was not found in the cache).
- Rows processed was zero.
- Recursive call depth was zero (this was a user call).
- Optimizer goal was all rows.

Wait Information and Response Time

The trace file also includes wait (WAIT) information. This shows the length of time Oracle spent waiting for certain items between parsing, executing, and fetching data. In this trace file, you can see this wait event:

```
WAIT #7: nam='SQL*Net message to client' ela= 5 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518570098
```

The NAM field shows the event that was waited on. The ELA field shows the length of time waited. The meaning of the P1, P2, and P3 fields depends on the event. The information shown can also be observed by inspecting the GV$SESSION_WAIT view during statement execution. In this example, you can also see that Oracle waited on a "SQL*Net message to client" event for 5 ms. The wait is followed by this:

```
FETCH #7:c=0,e=142,p=0,cr=13,cu=0,mis=0,r=1,dep=0,og=1,plh=1354678500,t
im=1305924518570284
```

The FETCH step takes 142 ms, reads 13 buffers in CR mode, and processes 1 row. The 142 ms includes the 5 ms from the WAIT step. Elapsed times for all WAIT events immediately preceding an EXEC or FETCH operation are incorporated in the total elapsed time shown for that event:

```
WAIT #7: nam='SQL*Net message from client' ela= 193 driver id=1650815232
#bytes=1 p3=0 obj#=91901 tim=1305924518570621
WAIT #7: nam='SQL*Net message to client' ela= 7 driver id=1650815232 #bytes=1
p3=0 obj#=91901 tim=1305924518571472
FETCH #7:c=1000,e=1096,p=0,cr=145,cu=0,mis=0,r=15,dep=0,og=1,plh=1354678500,t
im=1305924518571755
```

In the preceding example, the elapsed time for the FETCH operation shown on line 3 includes the elapsed times from lines 1 and 2.

Recursive Calls

The trace file identifies recursive calls by showing the call depth of each call. In the following extract, you see a user call (cursor #50) being serviced by a recursive call (cursor #54), which itself is serviced by two recursive calls (cursor #35).

```
EXEC #35:c=0,e=71,p=0,cr=0,cu=0,mis=0,r=0,dep=2,og=4,tim=4232475308506
FETCH #35:c=0,e=48,p=0,cr=3,cu=0,mis=0,r=1,dep=2,og=4,tim=4232475308664
EXEC #54:c=0,e=4986,p=0,cr=9,cu=0,mis=0,r=1,dep=1,og=4,tim=4232475308925
EXEC #50:c=30000,e=31087,p=0,cr=9,cu=0,mis=0,r=0,dep=0,og=4,tim=4232475335361
```

The CPU time, elapsed time, OS block reads, and CR and current block reads for all recursive calls are added to the totals for the originating call. In the preceding example, the total elapsed time for cursor #50 of 31,087 ms includes the 4,986 ms elapsed time for cursor #54, which itself includes the 71 ms spent executing in cursor #35 and the 48 ms spent fetching.

Module Info

The raw trace file includes module information recorded by calls to the DBMS_APPLICATION_INFO package:

```
APPNAME mod='SES' mh=3264509754 act='Job ID: 3407193' ah=1464295440
```

The entry includes the following tags:

Tag	Meaning
Mod	Module
Mh	Module hash value (see V$SESSION)
Act	Action
Ah	Action hash (see V$SESSION)

Commit

Commit operations are shown in the trace file as XCTEND (Transaction END) calls:

```
XCTEND rlbk=0, rd_only=0
```

The `rlbk` tag has a value of 1 if a rollback is performed or zero if it is committed. The `rd_only` tag has a value of 1 if the transaction was read-only or zero if blocks were changed.

The `rlbk` tag has a value of 1 if a rollback is performed or zero if it is committed. The `rd_only` tag has a value of 1 if the transaction was read-only or zero if blocks were changed.

Unmap

The unmap operation records when temporary tables are cleaned up:

```
UNMAP #1:c=0,e=0,p=0,cr=0,cu=0,mis=0,r=0,dep=0,og=4,tim=255943428
```

The flag records the same information as for EXEC and FETCH operations.

Bind Variables

One of the most powerful features of the 10046 trace with a level of 8 or 12 is that bind variable information is captured in the trace. You can see this in the raw trace file as a series of BIND operations. The following example is taken from an 11*g* database with cursor sharing set to FORCE:

```
PARSING IN CURSOR #7 len=57 dep=0 uid=86 oct=3 lid=86 tim=1305924518518576
hv=4215611583 ad='3b6289dc' sqlid='g12xs57xna85z'
select birthdate from arijak where firstname = :"SYS_B_0"
END OF STMT
PARSE #7:c=2000,e=1202,p=0,cr=0,cu=0,mis=1,r=0,dep=0,og=1,plh=0,t
im=1305924518518568
Bind#0
  oacdty=01 mxl=32(06) mxlc=00 mal=00 scl=00 pre=00
  oacflg=10 fl2=0001 frm=01 csi=178 siz=32 off=0
  kxsbbbfp=009efbd4  bln=32  avl=06  flg=05
  value="Alex"
```

In the preceding example, the SQL statement is shown as you see it in the V$SQLTEXT view, with the bind variable represented as SYS_B_0. However, the BIND operation listed shows that the bind variable zero of cursor 1 is being bound to the value ’Alex’. Note that you must be careful when interpreting the BIND information. Oracle replaces all static values with dynamically generated variable names such as SYS_B_*n*. However, named variables are *not* replaced. The BIND statements are listed in strict sequential order, with each value being bound to the next variable in the statement. Consider the following statement:

```
select *
from   SPROGS
where  name != 'Nicola'
and    birthday > ( to date(:BIRTHDAY,'DDMONYY'));
```

If CURSOR_SHARING is set to FORCE, the value ’Nicola’ is replaced with the variable SYS_B_0 and the value ’DDMONYY’ is replaced with SYS_B_1. For the purposes of binding, however, SYS_B_0 is treated as variable 0, BIRTHDAY is treated as variable 1, and SYS_B_1 is treated as variable 2:

```
PARSE #10:c=0,e=1397,p=0,cr=0,cu=0,mis=1,r=0,dep=0,og=4,tim=4646278930704
BINDS #10:
 bind 0: dty=1 mxl=32(06) mal=00 scl=00 pre=00 oacflg=10 oacfl2=0100 size=32 offset=0
   bfp=ffffffff7b957de8 bln=32 avl=06 flg=09
   value="Nicola"
 bind 1: dty=1 mxl=2000(200) mal=00 scl=00 pre=00 oacflg=03 oacfl2=0010 size=2000 offset=0
   bfp=ffffffff7ba79980 bln=2000 avl=07 flg=05
   value="03APR73"
 bind 2: dty=1 mxl=32(07) mal=00 scl=00 pre=00 oacflg=10 oacfl2=0100 size=32 offset=0
   bfp=ffffffff7b957d98 bln=32 avl=07 flg=09
   value="DDMONYY"
```

When tracing larger, more complex queries, remember that SYS_B_*n* does not necessarily bind to variable *n*.

Errors

The raw trace file will include errors that occur during the period of the trace. Two types of errors are recorded: execution errors and parsing errors. *Parsing errors* occur when the SQL statement cannot be parsed due to problems such as syntax or object permissions:

```
PARSE ERROR #7:len=50 dep=0 uid=44 oct=3 lid=44 tim=1515543106413 err=936
select date from birthday where name = :"SYS_B_0"
```

The preceding trace line shows error ORA-936 when parsing cursor #7. The information includes all of the same information as a successful parse operation, except for the SQL hash and address, as the failed statement is not stored in the library cache.

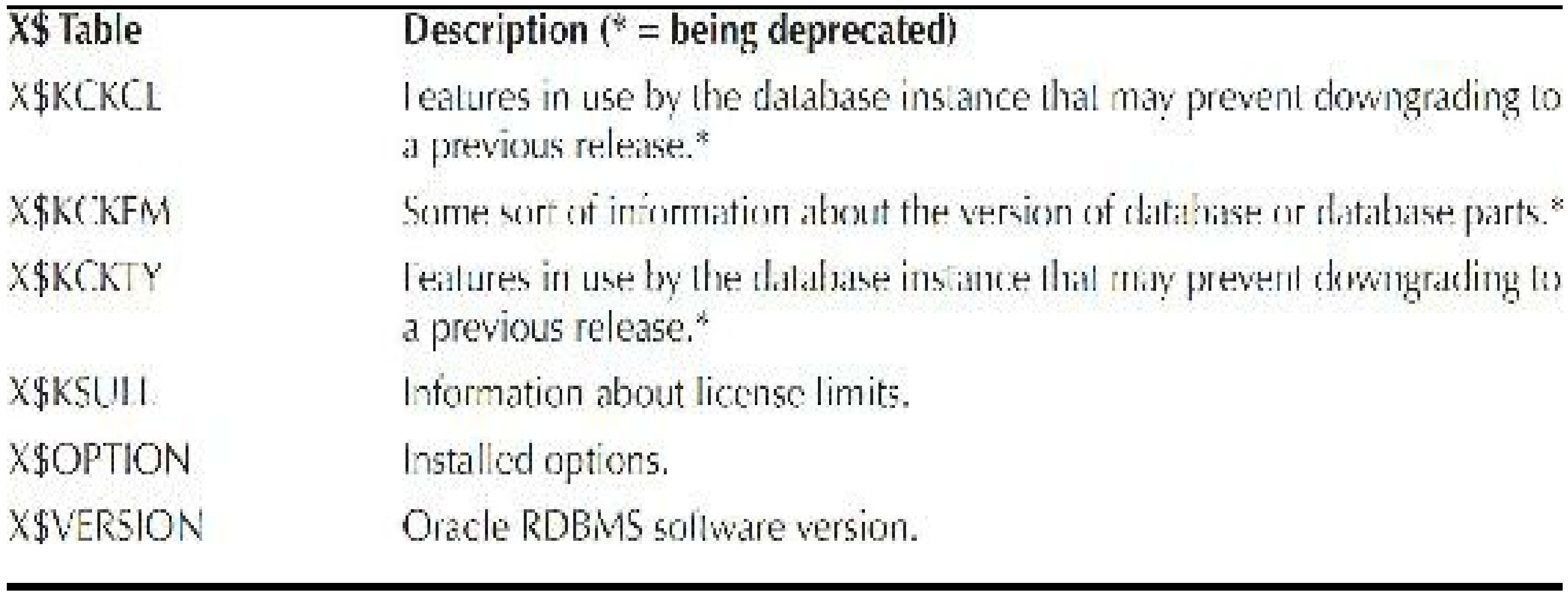
Execution errors simply list the error code and the time of the error:

```
ERROR #76:err=1555 tim=54406123
```

The preceding trace line shows that error ORA-1555 was raised during the execution of cursor #76.

Some Common X$ Table Groups

Some of the X$ tables can be logically grouped as shown in Tables 13-1 through 13-44. This is by no means a complete list. The descriptions for these tables are updated to the best of my knowledge (listed here are only a small and limited number of X$ tables even within a group). Oracle Corporation does not provide a full description list. In the final section of the chapter, I include a *very nice* definition tree structure that was provided for an earlier version of the X$ tables. You can certainly use this with most versions to help you understand the naming conventions much better.



X$ Table	Description (* = being deprecated)
X$KCKCL	Features in use by the database instance that may prevent downgrading to a previous release.*
X$KCKFM	Some sort of information about the version of database or database parts.*
X$KCKTY	Features in use by the database instance that may prevent downgrading to a previous release.*
X$KSULL	Information about license limits.
X$OPTION	Installed options.
X$VERSION	Oracle RDBMS software version.

TABLE 13-1. *Version/Installation*

X$ Table	Description
X$KSUSGSTA	Instance statistics.
X$KCCDI	Main source of information for V$DATABASE.
X$KSMSD	SGA component sizes ("SHOW SGA").
X$KSMSS	Detailed SGA statistics.
X$KSPPCV	Parameters and values that are in effect for the session.
X$KSPPCV2	Parameters and values that are in effect for the session. List parameter values appear as separate rows.
X$KSPPI	Parameter names and descriptions.
X$KSPPO	Obsolete parameters.
X$KSPPSV	Parameters and values that are in effect for the instance.
X$KSPPSV2	Parameters and values that are in effect for the instance. List parameter values appear as separate rows.
X$KSPVLD_VALUES	Valid values for parameters that accept ordinal values (also called list parameters).
X$KSPSPFILE	Parameter names specified with an SPFILE.
X$KSQDN	Database name.
X$OPTION	Installed options.
X$KVII	Instance limits and other instance metadata (includes miscellaneous information).
X$KVIT	State of various buffer cache conditions.
X$KSUXSINST	Main source of information for V$INSTANCE.
X$QUIESCE	Quiescent state of the instance.

TABLE 13-2. *Instance/Database*

X$ Table	Description
X$KSULV	Valid values of NLS parameters.
X$NLS_PARAMETERS	Current values of NLS parameters.

TABLE 13-3. *NLS (National Language Support)*

X$ Table	Description
X$TIMEZONE_NAMES	Time zone names.
X$TIMEZONE_FILE	Time zone file and version used by the database.

TABLE 13-4. *Time Zones*

X$ Table	Description
X$KCCAL	Information about archive log files from the control file.
X$KCRRARCH	Information about the ARCH processes for the current instance.
X$KCRRDSTAT	Archive destination status.

TABLE 13-5. *Archive Log Files/Destinations/Processes*

X$ Table	Description
X$KCCFE	File creation and other metadata.
X$KCCTF	Temp file I/O information.
X$KCVFH	Information source of V$DATAFILE and V$DATAFILE_HEADER.
X$KCFIO	File I/O information.
X$KCFTIO	Temp file I/O information.
X$KCVFHALL	Datafile information similar to information in V$DATAFILE.
X$KTFBFE	Free extents in files (ktfb free extents).
X$KTFBHC	Datafile information (similar to DBA_DATA_FILES).

TABLE 13-6. *Datafiles*

X$ Table	Description
X$KCCCF	Control file information.
X$KCCOR	Datafile offline information from the control file.
X$KCCRS	Information about the control file record sections.
X$KCCRT	Log file information from the control files.

TABLE 13-7. *Control Files*

X$ Table	Description
X$KCCCP	Redo log block information.
X$KCCFN	Information about file numbers. Info for all file types.
X$KCCLE	Information about redo log files in need of archiving.

TABLE 13-8. *Redo Log Files*

X$ Table	Description
X$KCCTS	Tablespace information.

TABLE 13-9. *Tablespaces*

X$ Table	Description
X$KCBTEK	Encrypted tablespaces.
X$KEWXOCF	SYSAUX tablespace occupants.
X$KTFTHC	Space usage in each temp tablespace.
X$KTFTME	Status of each unit of all temp tablespaces (temp map extents/blocks).
X$KTSSO	Sort segment activity by session.
X$KTSTFC	Temp segment usage: blocks used, cached, etc.
X$KTSTSSD	System temporary sort segment data.
X$KTTETS	Tablespace usage metrics.

TABLE 13-10. *Sort/Temp Segments*

X$ Table	Description
X$KTFBUE	Rollback/undo segment block/extent usage.
X$KTTVS	Rollback/undo segment stats.
X$KTUGD	Global rollback/undo data.
X$KTURD	Rollback/undo segment stats.
X$KTUSMST	Rollback/undo segment stats.
X$KTUXE	Rollback/undo segment activity: wraps, etc.

TABLE 13-11. *Rollback/Undo Segments*

X$ Table	Description
X$KCVFHTMP	Tempfile information.
X$KDLT	Temporary LOB information.

TABLE 13-12. *Temporary Objects*

X$ Table	Description
X$UGANCO	Database link information.

TABLE 13-13. *Database Links*

X$ Table	Description
X$KNSTMVR	Materialized view and refresh information.

TABLE 13-14. *Materialized Views*

X$ Table	Description
X$KNSTRPP	Current parallel propagation information for replication.
X$KNSTRQU	Replication deferred transaction queue statistics.

TABLE 13-15. *Replication*

X$ Table	Description
X$KCCBF	Information from the control file about datafile and control file backups (RMAN).
X$KCCBL	Information from the control file about redo and archived log backups (RMAN).
X$KCCBP	Backup piece information from the control file (RMAN).
X$KCCBS	Backup set information from the control file (RMAN).
X$KCCCC	Datafile copy corruptions from the control file (RMAN).
X$KCCDC	Datafile copy information from the control file (RMAN).
X$KCCFC	Corruption in datafile backups (RMAN).
X$KCVFHONL	Backup status of all online datafiles.
X$KSFQDVNT	Supported backup devices (RMAN).
X$KSFQP	Performance information about ongoing or recently completed backups.
X$KSFVQST	Backup information.
X$KSFVSL	Backup information.
X$KSFVSTA	Backup information.

TABLE 13-16. *Backup*

X$ Table	Description
X$KCRFX	Statistics about the current recovery process.
X$KCRMF	Statistics and status of files involved in recovery.
X$KCRMX	Statistics and status of files involved in recovery.
X$KCVFHMRR	Displays status of files during media recovery.
X$KRVSLV	Recovery slave status.
X$KRVSLVS	Recovery slave statistics.
X$KTPRXRS	Information about fast start servers performing parallel recovery.
X$KTPRXRT	Information about transactions Oracle is currently recovering.
X$ESTIMATED_MTTR	Estimates on the I/O work required if an instance recovery is needed right now.
X$TARGETRBA	Target recovery block accesses or target redo block accesses.

TABLE 13-17. *Recovery*

X$ Table	Description
X$KCCDL	Information about deleted objects. Recovery catalog resync operation uses this to speed its optimize operation.
X$KCCPA	Descriptions of archivelog backups taken with proxy copy.
X$KCCPD	Descriptions of datafile and control file backups taken with proxy copy.
X$KCCRM	RMAN configuration.
X$KCCRSR	RMAN status.

TABLE 13-18. *RMAN*

X$ Table	Description
X$KCCSL	Standby database log files.
X$KNSTACR	Standby database information: logical standby process stats.
X$KNSTASL	Standby database information: logical standby apply process.

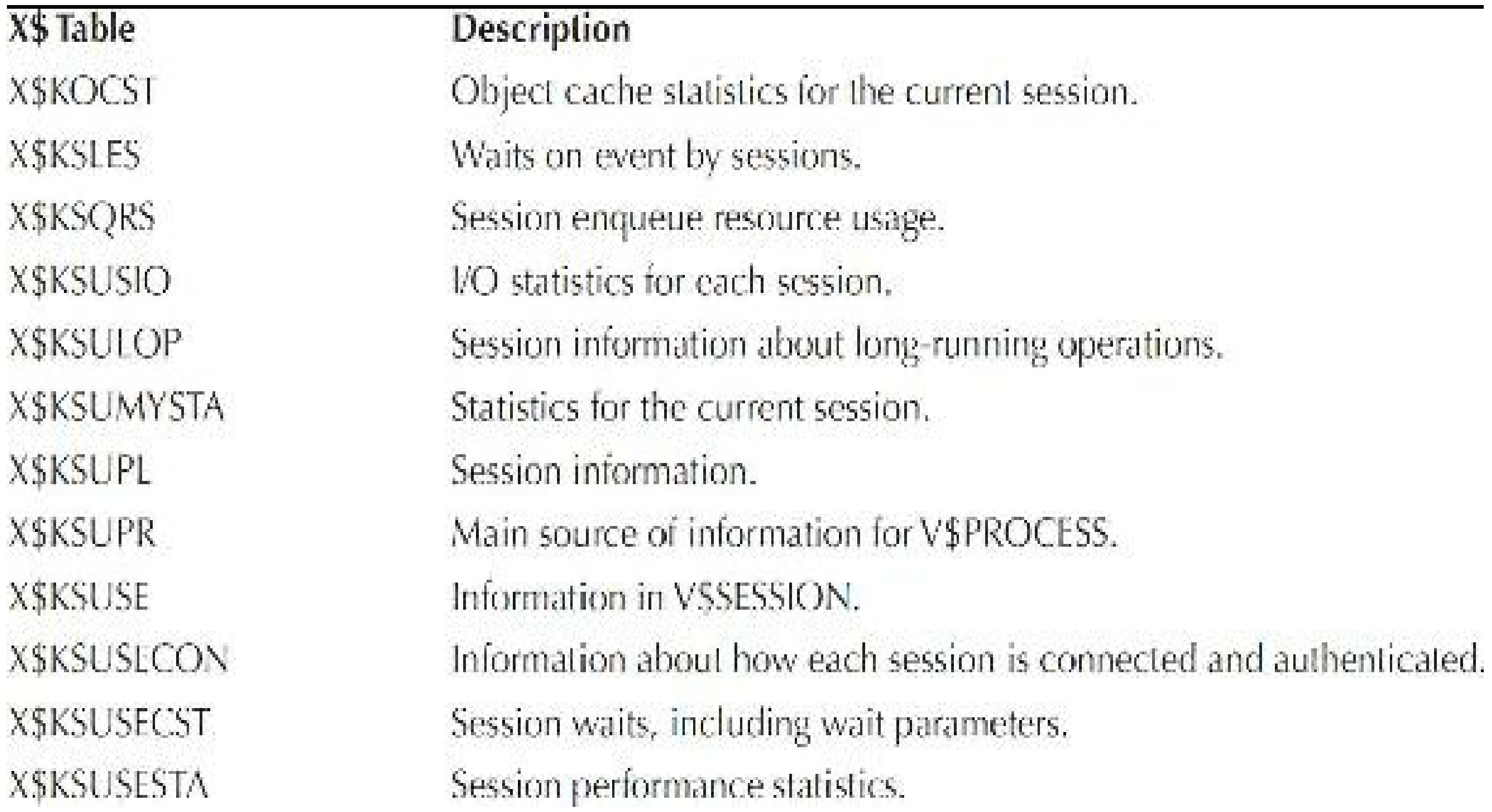
TABLE 13-19. *Standby Databases*

X$LOGMNR_CALLBACK
X$LOGMNR_COL$
X$LOGMNR_COLTYPE$
X$LOGMNR_CONTENTS
X$LOGMNR_DICTIONARY
X$LOGMNR_ENCRYPTED_OBJ$
X$LOGMNR_ENCRYPTION_PROFILES$
X$LOGMNR_IND$
X$LOGMNR_INDPART$
X$LOGMNR_LOGFILE
X$LOGMNR_LOGS
X$LOGMNR_PARAMETERS
X$LOGMNR_PROCESS
X$LOGMNR_OBJ$
X$LOGMNR_REGION
X$LOGMNR_SESSION
X$LOGMNR_TAB$
X$LOGMNR_TABCOMPART$
X$LOGMNR_TABSUBPART$
X$LOGMNR_TS$
X$LOGMNR_TYPE$
X$LOGMNR_TABPART$
X$LOGMNR_TABSUBPART$
X$LOGMNR_USER$

TABLE 13-20. *LogMiner*

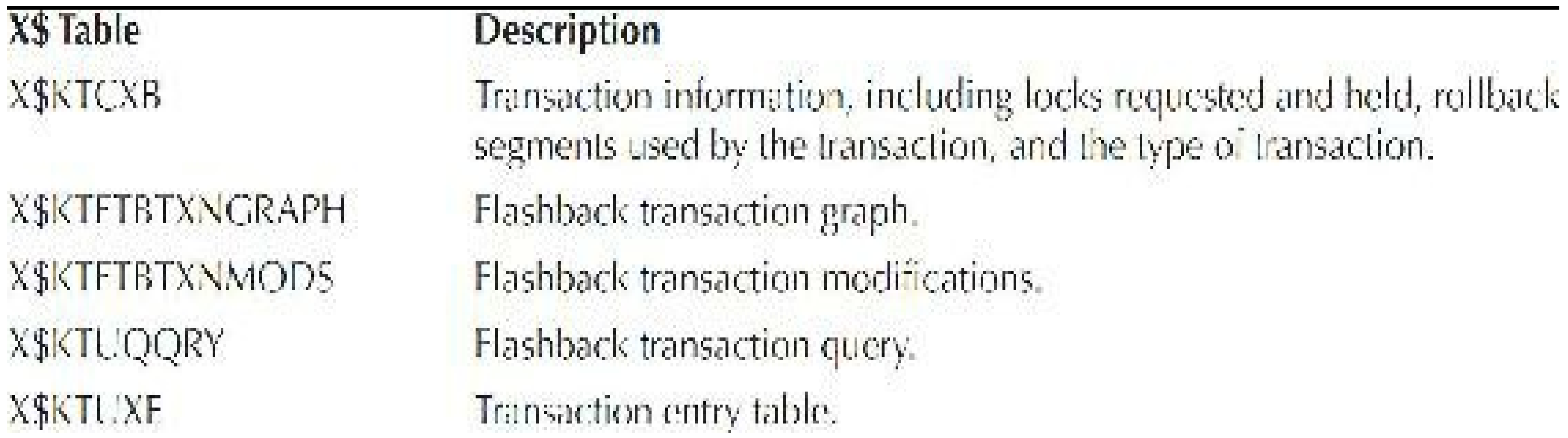
X$ Table	Description
X$KGSCC	Session cursor cache.
X$KMPCSO	Session client result cache info.
X$KSUPR	Process info.
X$KSUSE	Session info.
X$MESSAGES	Messages that each background process processes.
X$QESMMSGA	PGA memory limits, uses, estimates, etc.
X$QKSBGSES	Session optimizer fix control.

TABLE 13-21. *Sessions/Processes*



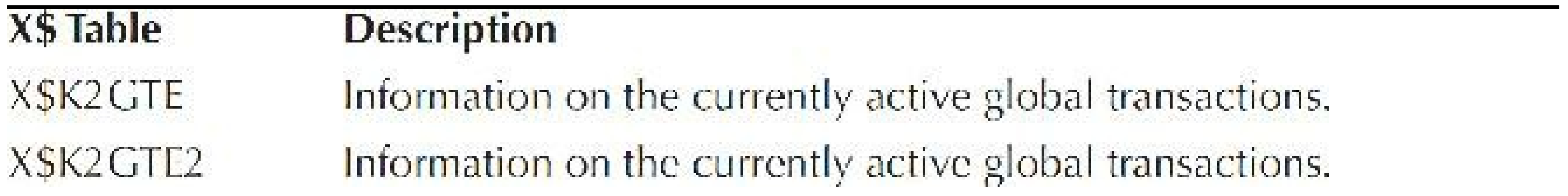
X$ Table	Description
X$KOCST	Object cache statistics for the current session.
X$KSLES	Waits on event by sessions.
X$KSQRS	Session enqueue resource usage.
X$KSUSIO	I/O statistics for each session.
X$KSULOP	Session information about long-running operations.
X$KSUMYSTA	Statistics for the current session.
X$KSUPL	Session information.
X$KSUPR	Main source of information for V$PROCESS.
X$KSUSE	Information in V$SESSION.
X$KSUSECON	Information about how each session is connected and authenticated.
X$KSUSECST	Session waits, including wait parameters.
X$KSUSESTA	Session performance statistics.

TABLE 13-22. *Session Performance*



X$ Table	Description
X$KTCXB	Transaction information, including locks requested and held, rollback segments used by the transaction, and the type of transaction.
X$KTFTBTXNGRAPH	Flashback transaction graph.
X$KTFTBTXNMODS	Flashback transaction modifications.
X$KTUQQRY	Flashback transaction query.
X$KTUXE	Transaction entry table.

TABLE 13-23. *Transactions*



X$ Table	Description
X$K2GTE	Information on the currently active global transactions.
X$K2GTE2	Information on the currently active global transactions.

TABLE 13-24. *Global Transactions*

X$ Table	Description
X$KGSKASP	All available active session pool resource allocation methods.
X$KGSKCFT	Data related to currently active resource consumer groups.
X$KGSKCP	All resource allocation methods defined for resource consumer groups.
X$KGSKDOPP	Available parallel degree limit resource allocation methods.
X$KGSKPFT	Names of all currently active resource plans.
X$KGSKQUEP	Available queue resource allocation methods.
X$KSRMSGDES	Queue messages.
X$KSRMSGO	Queue publisher/subscriber information.
X$KWQSI	Read/write statistics on queues.

TABLE 13-25. *Advanced Queuing (AQ)/Resource Management*

X$ Table	Description
X$KCLCRST	Information about block server background processes used in cache fusion.
X$KJBL	RAC DLM information.
X$KJBLFX	RAC information.
X$KJBR	RAC DLM resource statistics.
X$KJDRHV	RAC instance information (the current and previous master instances and the number of re-masterings of Global Enqueue Service resources).
X$KJDRPCMHV	RAC instance information (the current master instances and the number of re-masterings of Global Cache Service resources except those belonging to files mapped to a particular master).
X$KJDRPCMPF	RAC instance information (the previous master instances and the number of re-masterings of Global Cache Service resources except those belonging to files mapped to a particular master).
X$KJICVT	RAC DLM information (statistics for local and remote GES enqueue operations).
X$KJILKFT	RAC DLM information.
X$KJIRFT	RAC DLM information (information about all resources currently known to the DLM).
X$KJISFT	RAC DLM information (miscellaneous Oracle RAC statistics).
X$KJITRFT	RAC DLM information (information about the message ticket usage).
X$KJMDDP	RAC information.
X$KJMSDP	RAC information.
X$KJXM	RAC information.
X$KSIMAT	RAC information instance attributes.
X$KSIMAV	RAC information attribute values for all instances.
X$KSIMSI	Map of instance names to instance numbers for all instances mounting a particular database.

TABLE 13-26. *Real Application Clusters*

X$ Table	Description
X$KGLCLUSTER	Likely currently loaded or recently referenced clusters.
X$KGLCURSOR	Statistics on shared SQL area without the GROUP BY clause and contains one row for each child of the original SQL text entered.
X$KGLINDEX	Object names with currently held locks and other information about these locks.
X$KGLNA	Text of SQL statements belonging to shared SQL cursors.
X$KGLNA1	Text of SQL statements belonging to shared SQL cursors: newlines and tabs not replaced with spaces.
X$KGLOB	Database objects that are cached in the library cache. Objects include tables, indexes, clusters, synonym definitions, PL/SQL procedures and packages, and triggers.
X$KGLST	Library cache performance and activity information.
X$KKSBV	Bind variable data (depending on setting of CURSOR_SHARING) for cursors owned by the current session.
X$KKSCS	Information about why nonshared child cursors are nonshared.
X$KKSSRD	Redirected SQL statements.
X$KQFVI	SQL statements of all the fixed views.
X$KQLFXPL	Execution plan for each child cursor loaded in the library cache.
X$KQLSET	Information about subordinate caches currently loaded in the library cache.
X$KSLEI	Wait statistics (totals) for each event.
X$KXSBD	SQL or session bind data.
X$KXSCC	Shared cursor cache. V$SQL_CURSOR debugging information for each cursor associated with the session querying this view. Memory use by each cursor of a session SQL cursor cache.
X$QESMMIWT	Shared memory management instantaneous working. Join to X$QKSMMWDS.
X$QKSMMWDS	Shared memory management working data size. Library cache memory use by child cursors.

TABLE 13-27. *Library Cache*

X$ Table	Description
X$KGHLU	Shared pool reserved list performance information.
X$KGICS	Systemwide cursor usage statistics: opens, hits, count, etc.
X$KSMFSV	Shared memory information.
X$KSMHP	Shared memory information.
X$KSMLRU	Shared memory: specific, loaded objects and their sizes, pin candidates.
X$KSMFS	SGA sizes: fixed SGA, DB_BLOCK_BUFFERS, LOG_BUFFER.
X$KSMSS	SGA size: shared pool (also listed in Table 13-2, "Instance/Database").
X$KSMJS	SGA size: Java pool.
X$KSMLS	SGA size: large pool.
X$KSMPP	Very similar to X$KSMSP, without DUR and IDX columns varying numbers on Linux, Solaris, and NT.
X$KSMSP	Shared pool section sizes/values, etc.
X$KSMSPR	Shared pool reserved memory statistics/sizes.
X$KSMSP_DSNEW	Shared memory information.
X$KSMSP_NWEX	Shared memory information.
X$KSMUP	Instance and memory structure sizes/statistics.

TABLE 13-28. *Shared Memory*

X$ Table	Description
X$ACTIVECKPT	Checkpoint statistics information.
X$BH	Status and number of pings for every buffer in the SGA.
X$KCBBHS	DBWR histogram statistics.
X$KCBFWAIT	Buffer cache wait count and time by file.
X$KCBKPFS	Buffer cache block prefetch statistics.
X$KCBLSC	Buffer cache read/write/wait performance statistics.
X$KCBSC	Buffer cache set read performance statistics.
X$KCBWAIT	Number of and time spent in waits for buffer pool classes.
X$KCBWBPD	Statistics on all buffer pools available to the instance, including buffer pool names.
X$KCBWDS	Statistics on all buffer pools available to the instance.

TABLE 13-29. *Buffer Cache*

X$ Table	Description
X$KQRFP	Information about parent objects in the data dictionary.
X$KQRFS	Information about subordinate objects in the data dictionary.
X$KQRPD	Rowcache information: parent/child definition.
X$KQRSD	Rowcache information: subordinate cache definition.
X$KQRST	Rowcache performance statistics.

TABLE 13-30. *Rowcache*

X$ Table	Description
X$KGLLK	DDL locks currently held and requested.
X$KSQEQ	Locks held by sessions.
X$KSQST	Enqueue type, number of requests, number of waits, wait time, etc.
X$KTADM	DML lock info requested and held by sessions.

TABLE 13-31. *Locks/Enqueues*

X$ Table	Description
X$KSLLD	Latch names and levels.
X$KSLLW	Statistics on latch waits, plus latch names.
X$KSLPO	Latch posting.
X$KSLWSC	Statistics on latch wait sleeps, plus latch names.
X$KSUPRLAT	Information about current latch holders.
X$MUTEX_SLEEP	Mutex sleep information.
X$MUTEX_SLEEP_HISTORY	Mutex sleep history information.

TABLE 13-32. *Latches*

X$ Table	Description
X$KDXHS	Index histogram information.
X$KDXST	Index statistics from the last ANALYZE INDEX VALIDATE STRUCTURE command.

TABLE 13-33. *Optimizer*

X$ Table	Description
X$KMCQS	Multithread message queue information.
X$KMCVC	Virtual circuit connection message transport statistical information.
X$KMMDI	Shared Servers dispatcher performance information.
X$KMMDP	Shared Servers dispatcher performance information.
X$KMMRD	Shared Servers dispatcher information.
X$KMMSG	Shared Servers process performance information.
X$KMMSI	Shared Servers process information.

TABLE 13-34. *Shared Servers*

X$ Table	Description
X$KXFPCDS	PQ coordinator dequeue stats.
X$KXFPCMS	PQ coordinator message stats.
X$KXFPCST	PQ coordinator query stats.
X$KXFPDP	Metadata about current PQ sessions, such as number of degree of parallelism, etc.
X$KXFPPFT	Parallel query information.
X$KXFPSDS	PQ slave dequeue stats.
X$KXFPSMS	PQ slave message stats.
X$KXFPSST	PQ slave query stats.
X$KXFPYS	Parallel query system statistics.
X$KXFPNS	Performance statistics for sessions running parallel execution.
X$KXFQSROW	Statistics on parallel execution operations, query statistics row.

TABLE 13-35. *Parallel Query*

X$ Table	Description
X$KZDOS	Operation system role related security.
X$KZRTPD	Fine-grained security policies and predicates associated with the cursors currently in the library cache.
X$KZSPR	Privileges enabled for a session.
X$KZSRO	Roles enabled for a session.
X$KZSRT	List of users who have been granted SYSDBA and SYSOPER privileges (remote password file table entries).

TABLE 13-36. *Security-Granted Privileges and Roles, Fine-Grained Security Policies*

X$ Table	Description
X$KGSKPP	Available CPU resource allocation methods defined for resource plans.
X$KGSKQUEP	Available queuing resource allocation methods.
X$KGSKTE	Possibly RCG names.
X$KGSKTO	Possibly RCG types and attributes.

TABLE 13-37. *Resource/Consumer Groups*

X$ Table	Description
X$CONTEXT	Context information.
X$GLOBALCONTEXT	Context information.

TABLE 13-38. *Contexts*

NOTE
"Contexts" has nothing to do with Oracle Text, which used to be called "Context."

X$ Table	Description
X$HOFP	Init parameters in use by the HS server and agent.
X$HS_SESSION	Information about the HS agents currently running on a given host.

TABLE 13-39. *Heterogeneous Services*

X$ Table	Description
X$KWDDEF	PL/SQL reserved words.

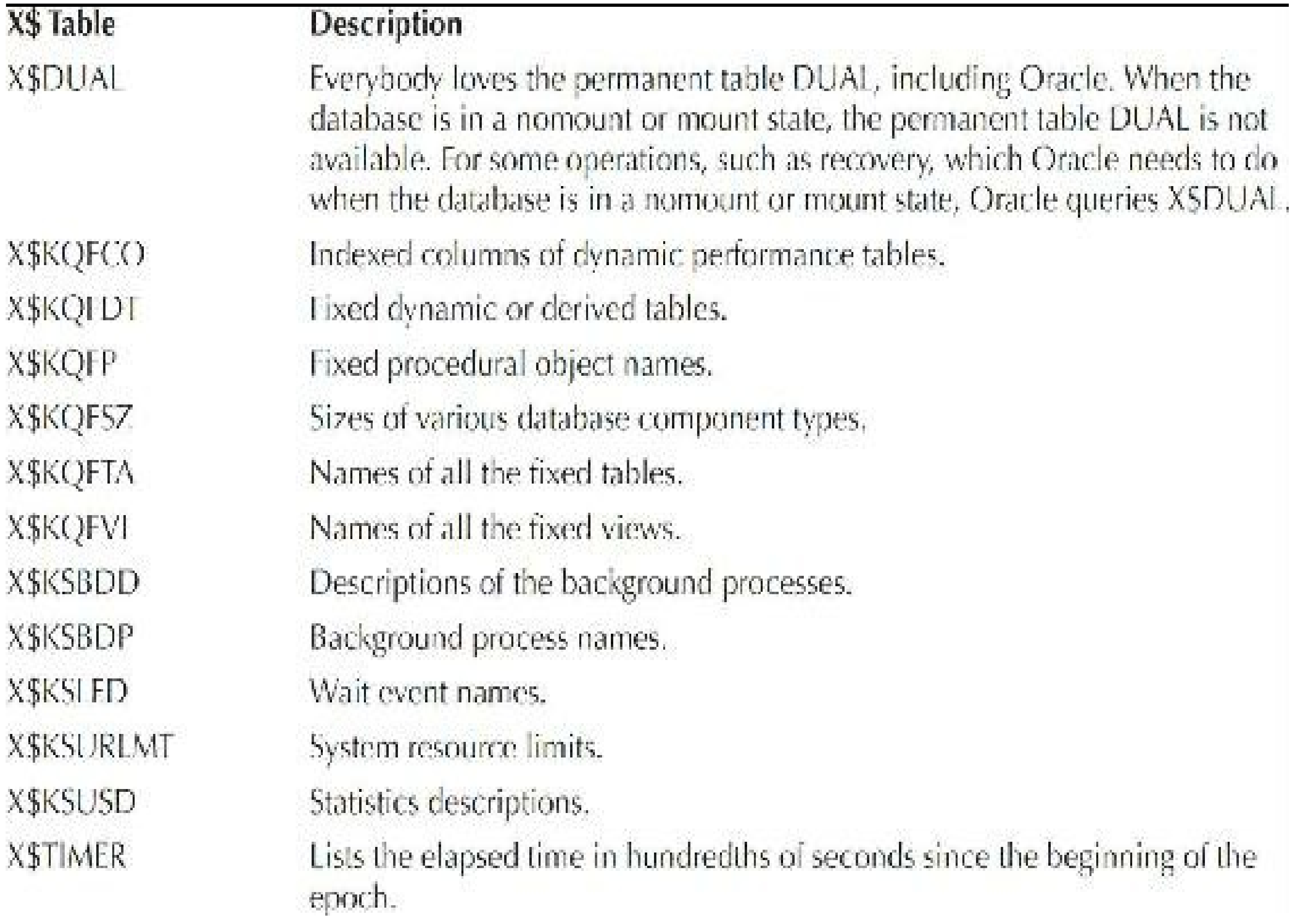
TABLE 13-40. *PL/SQL*

X$ Table	Description
X$KLCIE	Errors that occurred when updating indexes on a table during a load using the Direct Path API.
X$KLPT	Statistics about the number of rows loaded into a partition, or subpartition, during a load using the Direct Path API.

TABLE 13-41. *Loader/Direct Path API*

X$ Table	Description
X$JOXFC	Compile, resolve, reference information – Java classes.
X$JOXFD	Compile, resolve, reference information
X$JOXFR	Compile, resolve, reference information – Java resources.
X$JOXFS	Source name and/or code.
X$JOXFT	Reference names, resolve information, compile information, class name information.

TABLE 13-42. *Java Source*



X$ Table	Description
X$DUAL	Everybody loves the permanent table DUAL, including Oracle. When the database is in a nomount or mount state, the permanent table DUAL is not available. For some operations, such as recovery, which Oracle needs to do when the database is in a nomount or mount state, Oracle queries X$DUAL.
X$KQFCO	Indexed columns of dynamic performance tables.
X$KQFDT	Fixed dynamic or derived tables.
X$KQFP	Fixed procedural object names.
X$KQFSZ	Sizes of various database component types.
X$KQFTA	Names of all the fixed tables.
X$KQFVI	Names of all the fixed views.
X$KSBDD	Descriptions of the background processes.
X$KSBDP	Background process names.
X$KSLED	Wait event names.
X$KSURLMT	System resource limits.
X$KSUSD	Statistics descriptions.
X$TIMER	Lists the elapsed time in hundredths of seconds since the beginning of the epoch.

TABLE 13-43. *Miscellaneous Tables*

X$ Table	Probable Use
X$VINST	Unknown.
X$RFMTE	Unknown.
X$RFMP	Unknown.
X$KTSPSTAT	Undo/rollback information.
X$KSXRSG	Unknown.
X$KSRREPQ	Unknown.
X$KSXRMSG	Unknown.
X$KSXRCONQ	Unknown.
X$KSXRCH	Unknown.
X$KSXAFA	Node affinity.
X$KSUSEX	Session information.
X$KSURU	Resource usage by session.
X$KSUPGS	Unknown.
X$KSUPGP	Process group info.
X$KSUCF	Resource limits for Resource Manager.
X$KSRMPCTX	Unknown.
X$KSRCHDL	Unknown.
X$KSRCDES	Unknown.
X$KSRCCTX	Unknown.
X$KSMNS	Shared memory information.
X$KSMNIM	Shared memory information.
X$KSMMEM	Shared memory information.
X$KSMJCH	Shared memory information.
X$KSMDD	Shared memory information.
X$KRBAFF	Unknown.
X$KQDPG	PGA row cache cursor stats.
X$KKSAI	Cursor allocation info.
X$KGLXS	Library cache information.
X$KGLTRIGGER	Triggers in library cache.
X$KGLTR	Library cache information.
X$KGLTABLE	Tables in library cache.
X$KGLSN	Unknown.
X$KGLAU	Object authorizations.

X$KGLRD	Unknown.
X$KDNSSF	Lock information.
X$KCRMT	Cache fusion information.
X$KCLQN	Cache fusion information.
X$KCLLS	Cache fusion information.
X$KCLFX	Cache fusion information.
X$KCLCURST	Cache fusion information.
X$KCBWH	Information about functions pertaining to the buffer cache.
X$KCBSW	Buffer cache information.
X$KCBSH	Buffer cache information.
X$KCBSDS	Buffer cache information.
X$KCBLDRHIST	Buffer cache information.
X$KCBKWRL	Buffer cache write list.
X$KCBBF	Unknown.
X$KCBBES	Unknown.
X$CKPTBUF	Checkpoint information.
X$CON	Container information (for use with PDBs).
X$CKPTBUF	INMEMORY information (for use with In-Memory column store or IM).

TABLE 13-44. *Other X$ Tables*

Some Common X$ Table and Non-V$ Fixed View Associations

Table 13-45 lists non-V$ fixed views (V$ views are listed in Appendixes B and C) that are based on at least one X$ table. Many of the fixed views are based on one or more X$ tables, plus other fixed views. You can use this list with `$ORACLE_HOME/rdbms/admin/sql.bsq` and `$ORACLE_HOME/rdbms/admin/migrate.bsq` as an aid in deciphering the meaning of X$ table and column contents and in constructing queries that join X$ tables to other X$ tables or to fixed views.

Fixed View	Base X$ Tables and/or Fixed Views
COLUMN_PRIVILEGES	OBJAUTH$, COL$, OBJ$, USER$, X$KZSRO
DBA_BLOCKERS	V$SESSION_WAIT, X$KSQRS, V$_LOCK, X$KSUSE
DBA_DATA_FILES	FILE$, TS$, V$DBFILE, X$KTFBHC

DBA_DDL_LOCKS	V$SESSION, X$KGLOB, X$KGLLK
DBA_DML_LOCKS	V$_LOCK, X$KSUSE, X$KSQRS
DBA_EXTENTS	UET$, SYS_DBA_SEGS, FILE$, X$KTFBUE, FILE$
DBA_FREE_SPACE	TS$, FET$, FILE$, X$KTFBFE
DBA_FREE_SPACE_COALESCED	X$KTFBFE
DBA_KGLLOCK	X$KGLLK, X$KGLPN
DBA_LMT_FREE_SPACE	X$KTFBFE
DBA_LMT_USED_EXTENTS	X$KTFBUE
DBA_LOCK_INTERNAL	V$LOCK, V$PROCESS, V$SESSION, V$LATCHHOLDER, X$KGLOB, DBA_KGLLOCK
DBA_SOURCE	OBJ$, SOURCE$, USER$, X$JOXFS
DBA_TEMP_FILES	X$KCCFN, X$KTFTHC, TS$
DBA_UNDO_EXTENTS	UNDO$, TS$, X$KTFBUE, FILE$
DBA_WAITERS	V$SESSION_WAIT, X$KSQRS, V$_LOCK, X$KSUSE
DICTIONARY	V$ENABLEDPRIVS, OBJ$, COM$, SYN$, OBJAUTH$, X$KZSRO
DISK_AND_FIXED_OBJECTS	OBJ$, X$KQFP, X$KQFTA, X$KQFVI
EXU8FUL	X$KZSRO, USER$
EXU9FIL	FILE$, V$DBFILE, X$KTFBHC, TS$, X$KCCFN, X$KTFTHC
EXU9TNEB	X$KTFBUE
IMP9TVOID	OBJ$, USER$, TYPE$, SESSION_ROLES, OBJAUTH$, X$KZSRO
INDEX_HISTOGRAM	X$KDXST, X$KDXHS
INDEX_STATS	OBJ$, IND$, SEG$, X$KDXST, INDPART$, INDSUBPART$
LOADER_DIR_OBJS	OBJ$, DIR$, V$ENABLEDPRIVS, X$KZSRO
LOADER_TAB_INFO	OBJ$, V$ENABLEDPRIVS, X$KZSRO, TAB$, USER$, OBJAUTH$
LOADER_TRIGGER_INFO	OBJ$, USER$, TRIGGER$, OBJAUTH$, V$ENABLEDPRIVS, X$KZSRO
ORA_KGLR7_DEPENDENCIES	OBJ$, DEPENDENCY$, USER$, X$KZSRO, V$FIXED_TABLE, OBJAUTH$
ORA_KGLR7_IDL_CHAR	ORA_KGLR7_OBJECTS, IDL_CHAR$, OBJAUTH$, X$KZSRO
ORA_KGLR7_IDL_SB4	ORA_KGLR7_OBJECTS, IDL_SB4$, OBJAUTH$, X$KZSRO, SYSAUTH$
ORA_KGLR7_IDL_UB1	ORA_KGLR7_OBJECTS, IDL_UB1$, OBJAUTH$, X$KZSRO, SYSAUTH$

ORA_KGLR7_IDL_UB2	ORA_KGLR7_OBJECTS, IDL_UB2$, OBJAUTH$, X$KZSRO, SYSAUTH$
QUEUE_PRIVILEGES	OBJAUTH$, OBJ$, USER$, X$KZSRO
ROLE_SYS_PRIVS	USER$, SYSTEM_PRIVILEGE_MAP, SYSAUTH$, X$KZDOS
ROLE_ROLE_PRIVS	USER$, SYSAUTH$, X$KZDOS
ROLE_TAB_PRIVS	USER$, TABLE_PRIVILEGE_MAP, OBJAUTH$, OBJ$, COL$, X$KZDOS, SYSAUTH$
SESSION_ROLES	X$KZSRO
TABLE_PRIVILEGES	OBJAUTH$, OBJ$, USER$, X$KZSRO

TABLE 13-45. *X$ Table and Non-V$ Fixed View Associations*

Common X$ Table Joins

Table 13-46 lists the X$ table column joins used in fixed views.

X$ Table and Column	Associated X$ Table and Column
X$BH.LE_ADDR	X$LE.LE_ADDR
X$KCCFN.FNFNO	X$KTFTHC.KTFTHCTFNO
X$HS_SESSION.FDS_INST_ID	X$HOFP.FDS_INST_ID
X$KCBSC.BPID	X$KCBWBPD.BP_ID
X$KCBSC.INST_ID	X$KCBWBPD.INST_ID
X$KCBWDS.SET_ID	X$KCBWBPD.BP_LO_SID
X$KCBWDS.SET_ID	X$KCBWBPD.BP_HI_SID
X$KCCFE.FEFNH	X$KCCFN.FNNUM
X$KCCFE.FENUM	X$KCCFN.FNFNO
X$KCCFE.FENUM	X$KCCFN.FNFNO
X$KCCFE.FEPAX	X$KCCFN.FNNUM
X$KCCFN.FNFNO	X$KCVFHTMP.HTMPXFIL
X$KCCFN.FNFNO	X$KCVFH.HCFIL
X$KCCFN.FNFNO	X$KTFTHC.KTFTHCTFNO
X$KCCLE.INST_ID	X$KCCRT.INST_ID
X$KCCLE.LETHR	X$KCCRT.RTNUM
X$KCCTF.TFFNH	X$KCCFN.FNNUM
X$KCCTF.TFNUM	X$KCCFN.FNFNO
X$KCFTIO.KCFTIOFNO	X$KCCTF.TFNUM

X$KCRMF.FNO	X$KCCFN.FNFNO
X$KCRMF.FNO	X$KCCFN.FNFNO
X$KCRMX.THR	X$KCRFX.THR
X$KGLCRSOR.KGLHDADR	X$KZRTPD.KZRTPDAD
X$KGLCRSOR.KGLHDPAR	X$KZRTPD.KZRTPDPA
X$KGLCURSOR.KGLHDPAR	X$KZRTPD.KZRTPDPA, X$KKSSRD.PARADDR
X$KGLCURSOR.KGLOBHD6	X$KSMHP.KSMCHDS
X$KGLLK.KGLLKHDL	X$KGLDP.KGLHDADR
X$KGLLK.KGLLKUSE	X$KSUSE.ADDR
X$KGLLK.KGLNAHSH	X$KGLDP.KGLNAHSH
X$KGLOB.KGLHDADR	X$KGLDP.KGLRFHDL
X$KGLOB.KGLHDADR	X$KGLLK.KGLLKHDL
X$KGLOB.KGLNAHSH	X$KGLDP.KGLRFHSH
X$KQFVI.INDX	X$KQFVT.INDX
X$KSBDP.INDX	X$KSBDD.INDX
X$KSLEI.INDX	X$KSLED.INDX
X$KSLES.KSLESENM	X$KSLED.INDX
X$KSLLW.INDX	X$KSLWSC.INDX
X$KSPPI.INDX	X$KSPPSV.INDX
X$KSPPI.INDX	X$KSPPCV.INDX
X$KSPPI.INDX	X$KSPPCV2.INDX
X$KSPPI.INDX	X$KSPPSV2.KSPFTCTXPN
X$KSQEQ.KSQLKRES	X$KSQRS.ADDR
X$KSQEQ.KSQLKSES	X$KSUSE.ADDR
X$KSUSE.KSUSEPRO	X$KXFPDP.KXFPDPPRO
X$KSUSECST.KSUSSOPC	X$KSLED.INDX
X$KSUXSINST	Joined with X$KVIT and X$QUIESCE to create V$INSTANCE, but with no specific column joins
X$KTCXB.KSQLKRES	X$KSQRS.ADDR
X$KTCXB.KSQLKSES	X$KSUSE.ADDR
X$KTCXB.KSQLKSES	X$KSUSE.ADDR
X$KTCXB.KTCXBSES	X$KSUSE.ADDR
X$KTCXB.KTCXBXBA	X$KTADM.KSSOBOWN
X$TARGETRBA.INST_ID	X$ESTIMATED_MTTR.INST_ID

TABLE 13-46. *Common Table Joins*

NOTE
See Appendixes B and C for detailed listings of all V$ views and X$ tables. There are 1312 X$ tables in Oracle 12.2. Appendix C lists all X$ tables along with all indexes. There is also a cross-listing of many X$ to V$ tables.

X$ Table Naming Conventions (My Favorite Section of This Book!)

This summary lists X$ table definitions. The last revision was in Oracle 7.3.2, and the main purpose of this section is to show the naming conventions (these are great to get to know some of the Oracle acronyms; I've included these despite the fact that many are now outdated, but it is still nice to see where some of these names came from originally).

```
[K]ernel Layer
  [2]-Phase Commit
    [G]lobal [T]ransaction [E]ntry
      X$K2GTE  - Current 2PC tx
      X$K2GTE2 - Current 2PC tx

  [C]ache Layer
    [B]uffer Management
      Buffer [H]ash
        X$BH - Hash Table

      Buffer LRU Statistics
        X$KCBCBH - [C]urrent [B]uffers (buckets) - lru_statistics
        X$KCBRBH - [R]ecent [B]uffers (buckets) - lru_extended

      Buffer [WAIT]s
        X$KCBWAIT  - Waits by block class
        X$KCBFWAIT - Waits by File

      [W]orking Sets - 7.3 or higher
        X$KCBWDS - Set [D]escriptors

    [C]ontrol File Management
      [C]ontrol [F]ile List - 7.0.16 or higher
        X$KCCCF - Control File Names & status

      [D]atabase [I]nformation
        X$KCCDI - Database Information

      Data [F]iles
        X$KCCFE - File [E]ntries ( from control file )
        X$KCCFN - [F]ile [N]ames
    [L]og Files
      X$KCCLE - Log File [E]ntries
      X$KCCLH - Log [H]istory ( archive entries )

    Thread Information
      X$KCCRT - [R]edo [T]hread Information

  [F]ile Management
    X$KCFIO - File [IO] Statistics

  [L]ock Manager Component ( LCK )
    [H]ash and Bucket Tables - 7.0.15 to 7.1.1, and 7.2.0 or higher
      X$KCLFH - File [H]ash Table
      X$KCLFI - File Bucket Table

    X$LE - Lock [E]lements
    X$LE_STAT - Lock Conversion [STAT]istics
    X$KCLFX - Lock Element [F]ree list statistics - 7.3 or higher
    X$KCLLS - Per LCK free list statistics - 7.3 or higher
    X$KCLQN - [N]ame (hash) table statistics - 7.3 or higher

  [R]edo Component
    [M]edia recovery  - kcra.h - 7.3 or higher
      X$KCRMF - [F]ile context
      X$KCRMT - [T]hread context
      X$KCRMX - Recovery Conte[X]t

    [F]ile read
      X$KCRFX - File Read Conte[X]t -  7.3 or higher

  Reco[V]ery Component
    [F]ile [H]eaders
      X$KCVFH - All file headers
      X$KCVFHMRR - Files with [M]edia [R]ecovery [R]equired
      X$KCVFHONL - [ONL]ine File headers

  [K]ompatibility Management - 7.1.1 or higher
    X$KCKCE - [C]ompatibility Segment [E]ntries
    X$KCKTY - Compatibility [TY]pes
    X$KCKFM - Compatibility [F]or[M]ats ( index into X$KCKCE )

[D]ata Layer
  Sequence [N]umber Component
     X$KDNCE - Sequence [C]ache [E]ntries - 7.2 or lower

    [S]equence Enqueues - common area for enqueue objects
      X$KDNSSC - [C]ache Enqueue Objects - 7.2 or lower
      X$KDNSSF - [F]lush Enqueue Objects - 7.2 or lower
    X$KDNST - Cache [ST]atistics - 7.2 or lower
  Inde[X] Block Component
    X$KDXHS - Index [H]i[S]togram
    X$KDXST - Index [ST]atistics

[G]eneric Layer
  [H]eap Manager
    X$KGHLU - State (summary) of [L]R[U] heap(s) - defined in ksmh.h

  [I]nstantiation Manager
    [C]ursor [C]ache
      X$KGICC - Session statistics - defined in kqlf.h
      X$KGICS - System wide statistics - defined in kqlf.h

  [L]ibrary Cache Manager  ( defined and mapped from kqlf )
    Bind Variables
      X$KKSBV - Library Object [B]ind [V]ariables

    Object Cache
      X$KGLOB - All [OB]jects
      X$KGLTABLE   - Filter for [TABLE]s
      X$KGLBODY    - Filter for [BODY] ( packages )
      X$KGLTRIGGER - Filter for [TRIGGER]s
      X$KGLINDEX   - Filter for [INDEX]es
      X$KGLCLUSTER - Filter for [CLUSTER]s
      X$KGLCURSOR  - Filter for [CURSOR]s

    Cache Dependency
      X$KGLDP - Object [D]e[P]endency table
      X$KGLRD - [R]ead only [D]ependency table - 7.3 or higher

    Object Locks
      X$KGLLK - Object [L]oc[K]s

    Object Names
      X$KGLNA - Object [NA]mes (sql text)
      X$KGLNA1 - Object [NA]mes (sql text) with newlines - 7.2.0 or higher

    Object Pins
      X$KGLPN - Object [P]i[N]s

    Cache Statistics
      X$KGLST - Library cache [ST]atistics

    Translation Table
      X$KGLTR - Address [TR]anslation

    Access Table
      X$KGLXS - Object Access Table

    Authorization Table - 7.1.5 or higher
      X$KGLAU - Object Authorization table
```

```
    Latch Cleanup - 7.0.15 or higher
      X$KGLLC - [L]atch [C]leanup for Cache/Pin Latches

[K]ompile Layer
  [S]hared Objects
    X$KKSAI - Cursor [A]llocation [I]nformation - 7.3.2 or higher

[L]oader
  [L]ibrary
    X$KLLCNT - [C]o[NT]rol Statistics
    X$KLLTAB - [TAB]le Statistics

[M]ulti-Threaded Layer
  [C]ircuit component
    X$KMCQS - Current [Q]ueue [S]tate
    X$KMCVC - [V]irtual [C]ircuit state

  [M]onitor Server/dispatcher
    [D]ispatcher
      X$KMMDI - [D]ispatcher [I]nfo (status)
      X$KMMDP - [D]ispatcher Config ( [P]rotocol info )

    [S]erver
    X$KMMSI - [S]erver [I]nfo ( status )
    X$KMMSG - [SG]a info ( global statistics)
    X$KMMRD - [R]equest timing [D]istributions

s[Q]l Version and Option Layer
  Kernel [V]ersions
    X$VERSION - Library versions

  Kernel [O]ptions - 7.1.3 or higher
    X$OPTION - Server Options

[Q]uery Layer
  [D]ictionary Cache Management
    X$KQDPG - [PG]a row cache cursor statistics

  [F]ixed Tables/views Management
    X$KQFCO - Table [CO]lumn definitions
    X$KQFDT - [D]erived [T]ables
    X$KQFSZ - Kernel Data structure type [S]i[Z]es
    X$KQFTA - Fixed [TA]bles
    X$KQFVI - Fixed [VI]ews
    X$KQFVT - [V]iew [T]ext definition - 7.2.0 or higher

  [R]ow Cache Management
    X$KQRST - Cache [ST]atistics
    X$KQRPD - [P]arent Cache [D]efinition - 7.1.5 or higher
    X$KQRSD - [S]ubordinate Cache [D]efinition - 7.1.5 or higher
```

```
[S]ervice Layer
  [B]ackground Management
    [D]etached Process
      X$KSBDD - Detached Process [D]efinition (info)
      X$KSBDP - Detached [P]rocess Descriptor (name)
      X$MESSAGES - Background Message table

  [I]nstance [M]anagement - 7.3 or higher
    X$KSIMAT - Instance [AT]tributes
    X$KSIMAV - [A]ttribute [V]alues for all instances
    X$KSIMSI - [S]erial and [I]nstance numbers

  [L]ock Management
    [E]vent Waits
      X$KSLED - Event [D]escriptors
      X$KSLEI - [I]nstance wide statistics since startup
      X$KSLES - Current [S]ession statistics

    [L]atches
      X$KSLLD - Latch [D]escriptor (name)
      X$KSLLT - Latch statistics [ + Child latches @ 7.3 or higher ]
      X$KSLLW - Latch context ( [W]here ) descriptors - 7.3+
      X$KSLPO - Latch [PO]st statistics - 7.3 or higher
      X$KSLWSC- No[W]ait and [S]leep [C]ount stats by Context -7.3+

  [M]emory Management
    [C]ontext areas
      X$KSMCX - E[X]tended statistics on usage - 7.3.1 or lower

    Heap Areas
      X$KSMSP - SGA Hea[P]
      X$KSMPP - [P]GA Hea[P] - 7.3.2 and above
      X$KSMUP - [U]GA Hea[P] - 7.3.2 and above
      X$KSMHP - Any [H]ea[P] - 7.3.2 and above
      X$KSMSPR- [S]hared [P]ool [R]eserved List - 7.1.5 or higher

    [L]east recently used shared pool chunks
      X$KSMLRU - LR[U] flushes from the shared pool

    [S]GA Objects
      X$KSMSD - Size [D]efinition for Fixed/Variable summary
      X$KSMSS - Statistics (lengths) of SGA objects

    SGA [MEM]ory
      X$KSMMEM - map of the entire SGA - 7.2.0 or higher
      X$KSMFSV - Addresses of [F]ixed [S]GA [V]ariables - 7.2.1+

  [P]arameter Component
      X$KSPPI  - [P]arameter [I]nfo ( Names )
      X$KSPPCV - [C]urrent Session [V]alues - 7.3.2 or above
      X$KSPPSV - [S]ystem [V]alues - 7.3.2 or above
```

```
En[Q]ueue Management
  X$KSQDN - Global [D]atabase [N]ame
  X$KSQEQ - [E]n[Q]ueue Object
  X$KSQRS - Enqueue [R]e[S]ource
  X$KSQST - Enqueue [S]tatistics by [T]ype

[U]ser Management
  [C]ost
    X$KSUCF - Cost [F]unction (resource limit)

  [L]icense
     X$KSULL - License [L]imits

  [L]anguage Manager
    X$NLS_PARAMETERS - NLS parameters
    X$KSULV - NLS [V]alid Values - 7.1.2 or higher

  [MY] [ST]atistics
    X$KSUMYSTA - [MY] [ST]atisics (current session)

  [P]rocess Info
    X$KSUPL - Process (resource) [L]imits
    X$KSUPRLAT - [LAT]ch Holder
    X$KSUPR - Process object

  [R]esource
    X$KSURU - Resource [U]sage

  [S]tatistics
    X$KSUSD - [D]escriptors (statistic names)
    X$KSUSGSTA - [G]lobal [ST]atistics

  [SE]ssions
    X$KSUSECST - Session status for events
    X$KSUSESTA - Session [STA]tistics
    X$KSUSECON - [CON]nection Authentication - 7.2.1 or higher
    X$KSUSE - [SE]ssion Info
    X$KSUSIO - [S]ystem [IO] statistics per session

  [T]imer
    X$KSUTM - Ti[M]e in 1/100th seconds

  Instance [X]
    X$KSUXSINST - [INST]ance state

  [T]race management
    X$TRACE - Current traced events
    X$TRACES - All possible traces
    X$KSTEX - Code [EX]ecution - 7.2.1 or higher
  E[X]ecution Management
    Device/Node [A]ffinity - 7.3.2 and above
      X$KSXAFA - Current File/Node Affinity

[T]ransaction Layer
  Table [A]ccess [D]efinition
    X$KTADM - D[M]L lock

  [C]ontrol Component
    X$KTCXB - Transaction O[B]ject

  [S]or[T] Segments - 7.3 or higher
    X$KTSTSSD - [S]ort [S]egment [D]escriptor - per tablespace stats

  [T]ablespace
    X$KTTVS - [V]alid [S]aveundo

  [U]ndo
    X$KTURD - Inuse [D]escriptors
    X$KTUXE - Transaction [E]ntry (table) - 7.3.2 or above

Performance Layer [V] - 7.0.16 or higher
   [I]nformation tables
    X$KVII - [I]nitialisation Instance parameters
    X$KVIS - [S]izes of structure elements
    X$KVIT - [T]ransitory Instance parameters

Security Layer [Z]
  [D]ictionary Component
    X$KZDOS - [OS] roles

  [S]ecurity State
    X$KZSPR - Enabled [PR]ivileges
    X$KZSRO - Enabled [RO]les

  [R]emote Logins - 7.1.1 or higher
    X$KZSRT - [R]emote Password File [T]able entries

E[X]ecution Layer
  Parallel Query (Execute [F]ast) - 7.1.1 or higher
    [P]rocess and Queue Manager
      Statistics - 7.1.3 or higher
        X$KXFPYS - S[YS]tem Statistics
        X$KXFPDP - [D]etached [P]rocess (slave) statistics
        X$KXFQSROW - Table [Q]ueue Statistics - 7.3.2 or higher

      [C]oordinator Component
        X$KXFPCST - Query [ST]atistics
        X$KXFPCMS - [M]essage [S]tatistics
        X$KXFPCDS - [D]equeue [S]tatistics
        [S]lave Component
          X$KXFPSST - Query [ST]atistics
          X$KXFPSMS - [M]essage [S]tatistics
          X$KXFPCDS - [D]equeue [S]tatistics

    [S]hared Cursor
      X$KXSBD - [B]ind [D]ata - 7.3.2 and above
      X$KXSCC - SQL [C]ursor [C]ache Data - 7.3.2 and above

[N]etwork Layer - 7.0.15 or higher
  Network [CO]nnections
    X$UGANCO - Current [N]etwork [CO]nnections
```

X$ Table Naming Conventions with CON_ID and INMEMORY

In 12*c*, many X$ tables now have the CON_ID (Container ID) column for pluggable databases. The following are some major tables/views that include CON_ID in the X$ tables and V$ views:

X$ Table	Description
X$CON	Containers (Main container X$ table accessed by V$CONTAINERS and V$PDBS)
X$KSMSD	Kernel Service layer Memory management Size Definition (SGA–V$SGA)
X$KSMSP	Kernel Service layer Memory management SGA heaP (Shared Pool)
X$BH	Buffer Hash (Hash table for all blocks in DB Cache for Data–V$BH)
X$KSQRS	Kernel Service layer enQueue management ReSource (Locks–V$LOCK)
X$KSLLRT	Kernel Service layer Lock management Latches (TRee?) - (Latches–V$LATCH)
X$KSLWT	Kernel Service layer Lock WaiT (Waits–V$SESSION_WAIT)
X$KSUSGSTA	Kernel Service layer User Statistics Global STAtistics (V$SYSSTAT)
X$KSULOP	Kernel Service layer User management Longops - (slow–V$SESSION LONGOPS)
X$KGLST	Kernel Generic layer Library cache STatistics (Shared Pool–V$LIBRARYCACHE)
X$CELL_NAME	Cell Name (disk—hardware specific—also, V$CELL, V$CELL_DISK)

Also in 12*c*, there are several new INMEMORY V$ views (most identified earlier in the chapter) that access the X$ tables, particularly the X$KTSIMAU table:

X$ Table	Description
X$KTSIMAU	Kernel Transaction Segment In Memory Allocated Unit (V$INMEMORY_AREA)

Future Version Impact in 12*c*R2

As noted several times in this chapter, the V$ views and X$ tables are constantly being enhanced as more and more features are added to Oracle. In 12*c*, the performance of SELECTs on V$ views and X$ tables has improved and they have been expanded to include CON_ID (Container ID) on many of the underlying X$ tables for PDBs (as well as INMEMORY in views and tables). More changes will certainly come in the future (did you see Oracle Cloud coming?)!

Why don't I climb mountains? I don't have the time—I'm a DBA!

Why do I open the hood of my car and look at what's inside? To impress my wife!

Why do I look at the X$ tables? Because I don't spend a lot of time climbing mountains, and I don't know what's *really* under the hood of my car, but I do know how to use these to my advantage! Now you do, too!

Tips Review

- The X$ tables and V$ views have been expanded for pluggable databases with CON_ID (Container ID) on many current tables/views (new X$ tables such as X$CON) and expanded in 12.1.0.2+ for In-Memory column store (X$KTSIMAU).
- When you mention the X$ tables, most people say, "Oh, pretty scary. I would never touch those tables." The fact is that DML commands (UPDATE, INSERT, DELETE) are not allowed on the X$ tables, even as the SYS superuser in 12*c*R2 (I tried).
- Only the SYS superuser can SELECT from the X$ tables. An error occurs if an attempt is made to grant SELECT access to a user. But the X$ tables are not completely harmless. Because they are not documented, they could lead to data being misinterpreted. For example, if a V$ view definition is modified to use a brand-new X$ table, but the DBA has created his or her own view on the X$ tables, he or she might not have accurate information following an upgrade.
- A DBA may need access to the X$ table information, but *not* the SYS password. Create a view under a different name that mirrors the desired tables. Name these tables according to the appropriate synonyms of the original tables.
- Access the X$KQFVI table for a listing of all V$ and GV$ views. Access the V$FIXED_VIEW_DEFINITION view to get all of the information regarding the underlying X$ tables that comprise a V$ view, including new views for containers (pluggable databases) and In-Memory (IM).
- Query V$FIXED_TABLE for names of the X$ tables, or you can also access two X$ tables X$KQFTA and X$KQFDT for partial listings that, when combined, make up the full list. In 12*c*, new X$ tables include X$CON (containers) and X$KTSIMAU (In-Memory).

- Access the V$INDEXED_FIXED_COLUMN view for a listing of all X$ table indexes.
- Oracle generally uses the indexes and uses the correct driving table as needed for accessing the X$ tables, but from time to time, you may use hints to achieve a desired result.
- Enclose the class in double quotes if it contains a slash (/); otherwise, you will get an ORA-00995 error.
- If X$KSMLRU.KSMLRCOM is similar to Fixed UGA, then a high amount of session-specific allocation is occurring, which suggests that OPEN_CURSORS may be set too high. This is relevant only in cases where Shared Servers are being used.
- Anonymous PL/SQL blocks cannot be traced using the "compile debug" method. PL/SQL tracing for the entire session must be enabled with the ALTER SESSION SET PLSQL_DEBUG=TRUE command.
- Do not use ORADEBUG SUSPEND on the Microsoft Windows platform. Due to the thread-based processing model of Windows, the whole database will be suspended, not just the process you are attached to.
- Cursors may be reassigned if the cursor is closed and released. Therefore, when reading a long trace file, remember that a cursor number referenced at one part of the trace file may not represent the same SQL statement as it does elsewhere in the trace file.
- 12*c*R2 includes 1312 X$ tables. The naming conventions continue with a few changes for containers and In-Memory.

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Metalink Notes
186859.995, 1066346.6, 153334.995, 258597.999, 235412.999, 135223.1, 221860.999, 104933.1, 83222.996, 43600.1, 129813.999, 10630.996, 86661.999, 4256.997, 2497.997, 102925.1, 95420.1, 14848.997, 235412.999, 62172.1, 135223.1, 221860.999, 83222.996, 163424.1, 104397.1, 33883.1,

346576.999, 96845.1, 73582.1, 221860.999, 212629.995, 162866.1, 138119.1, 137483.1, 186859.995, 1066346.6, 153334.995, 258597.999, 235412.999, 135223.1, 221860.999, 104933.1, 83222.996, 43600.1, 129813.999, 10630.996, 86661.999, 4256.997, 2497.997, 102925.1, 210375.995, 39366.1, 62294.1, 187913.1, 171647.1, 39817.1, 224270.1, 62294.1, 39817.1, 104239.1, 280543.1, 175982.1

Graham Thornton updated the 11*g* version of the chapter. Graham Thornton and Kevin Gilpin helped with the incredible job of updating this chapter in 10*g*. (Please read it quietly and with an English accent.)

CHAPTER
14

Using Statspack and the AWR Report to Tune Waits, Latches, and Mutexes

If you could choose just two Oracle utilities to monitor and find performance problems on your system, you should choose Enterprise Manager (Chapter 5) and the Automatic Workload Repository (AWR) Report and/or Statspack (both covered in this chapter). In Oracle 12*c*R2, the AWR Report has much more information than you can find with Statspack—and a whole lot more when it comes to impact tuning! Statspack remains in 12*c*R2 but has *few* improvements and does not currently include In-Memory statistics. The Statspack utility has been available and free since Oracle 8.1.6 to monitor database performance. Statspack originally replaced the UTLBSTAT/UTLESTAT scripts available with earlier versions of Oracle. The AWR Report leverages the AWR statistics and can be executed within Oracle Enterprise Manager Cloud Control, if desired; it will probably replace Statspack for good in the future. Although the AWR Report has some very nice things in it that Statspack doesn't have, you must license the Oracle Diagnostics Pack to access the AWR dictionary views necessary for the AWR Report. Statspack is still a free utility that many people use (which is why I include coverage of it in this chapter). Although you are not supposed to modify the Statspack code, you can modify it. If you modify the code, however, Statspack is not supported.

In this chapter, you learn how to install the AWR Report and Statspack, how to manage them, and how to run and interpret the reports generated. Statspack includes data for both proactive and reactive tuning and is probably the best way to query most of the relevant V$ views and X$ tables and view the results in a single report. The AWR Report is a great way to mine the AWR for aggregate performance data in a report similar to, but better than, the Statspack Report. I'll cover Statspack first, but only because it's a starting point to the AWR, which is by far more advanced and comprehensive and should be used instead of Statspack if at all possible.

Tips covered in this chapter include the following:

- What's new in 12*c* for Statspack and the AWR (PERFSTAT at the CDB level in 12.2)
- Creating a tablespace to hold the Statspack data apart from your application and SYSTEM objects
- Finding the files needed to create, manage, and drop the Statspack objects
- Changing the PERFSTAT password and locking the account when it is no longer in use

- Selecting the proper level for your reporting
- Times to avoid running Statspack Reports
- Running the AWR Report and Statspack together: cautionary notes
- Using Oracle Enterprise Manager Cloud Control to run the AWR Report
- Tuning the top wait events, including Oracle Database 12*c* mutex wait events
- Using the Segment Statistics sections of the reports to find issues
- Tuning latches and mutexes, including 12*c*R2 In-Memory latches
- Tuning at the block level to find hot blocks and interested transaction list (ITL) problems
- The top ten things to look for in the 12*c*R2 AWR Report and Statspack output
- Managing the Statspack data and analyzing and purging it as needed
- Monitoring Statspack space usage
- Including Statspack data in your backup and upgrade plans
- Using the ADDM Report (text) as a stand-alone tool

What's New in 12*c*R2 (12.2) Statspack and the AWR Report

Oracle Database 12*c* offers a few new details in the reports. I have listed the ones here that I see as important and helpful to both the AWR and Statspack Reports. New features in 12*c*R2 include the following:

- Setting up Statspack and AWR for pluggable databases (PDBs) and the container database (CDB) is important. We'll discuss how to set them up and analyze for different PDBs and the CDB, but one very important setup note in 12.2 is that PERFSTAT can now be created in the CDB. In 12.1, you have to either create a common user (C##PERFSTAT) *or* only run the script in a PDB *or* run the `sqlsessstart.sql` script first in the CDB and then run `spcreate.sql`. In 12.2, the ALTER SESSION contained in `sqlsessstart.sql` is now part of `spcreate.sql`.
- MEMORY_TARGET is an initialization parameter for sizing all memory since Oracle 10*g* (see Chapter 4). With 12*c* (12.1.0.2), Oracle now includes INMEMORY_SIZE in the MEMORY_TARGET parameter (otherwise it's included in the SGA_TARGET if INMEMORY_SIZE is unset or set to 0).
- In the IO Stats section in 12.2, you will see some In-Memory (IM) population statistics.
- In the 12.2 LATCH MISS section, you'll see even more IM information on latches, including In-Memory columnar segment latch misses (and others).
- You must ensure that idle events are set (in 12.1 many of my top waits were idle events—in 12.2 this was corrected). In 12.1, there were many idle events inserted into

STATS$IDLE_EVENT (thanks!).

- You use `spup112.sql` to upgrade 11*g*R2 to 12*c* Statspack. You also use `spup12102.sql` and `spup12200.sql` to update to 12.1.0.2 and 12.2, respectively. The `spup112.sql` script adds many new and needed idle events.
- Sections on the new Foreground Processes, Background Processes, and a combination of both are now included in the report.
- DB time is contained in many sections.
- Physical memory is now displayed in gigabytes (G) instead of megabytes (M).
- In 12.1, some of the Statspack results in the PDBs versus the CDB didn't have the right statistics (i.e., sometimes Statspack showed the aggregate totals of the CDB in the PDB incorrectly, but percentages for the ratios at the PDB level were correct). In the AWR, it correctly showed the totals in the CDB and PDB, but had the wrong percent in the PDB. The things that I checked were correct at both levels in 12.2, so as with tuning and with different versions, ensure this is correct depending on which report you use.
- At the end of the report you'll see initialization parameters including these 12*c*R2 ones: COMPATIBLE=12.2.0.0.0, INMEMORY_SIZE, and PGA_AGGREGATE_LIMIT (you'll see them because you are now using them, hopefully).

Installing Statspack

Statspack must be installed in every database to be monitored (and that includes every pluggable database that you want to monitor separately). If you are using the AWR Report (preferable), you do not need to run Statspack. Prior to installing Statspack, you should create a tablespace to hold the Statspack data. If you don't specify a tablespace, the SYSAUX tablespace is used. During the installation process, you are prompted for the name of the tablespace to hold the Statspack database objects. You should also designate a temporary tablespace that will be large enough to support the large INSERTs and DELETEs Statspack may perform.

The installation script, named `spcreate.sql`, is found in the /rdbms/admin subdirectory under the Oracle software home directory. The `spcreate.sql` script creates a user named PERFSTAT. (In 12.1, while this works in a single PDB, if you run this in the main CDB, it will fail, as the CDB requires a common user, such as C##PERFSTAT. This is fixed in 12.2.)

TIP
Allocate at least 120M for the initial creation of the PERFSTAT schema's objects.

To start the `spcreate.sql` script, change your directory to ORACLE_HOME/rdbms/admin and log in to SQL*Plus using an account with SYSDBA privileges:

```
SQL> connect SYS as SYSDBA
SQL> @spcreate
```

During the installation process, you are prompted for the PERFSTAT user password (for security purposes, a default password is no longer included); then you are prompted for a default tablespace for the PERFSTAT user (a list of available tablespaces is displayed along with this prompt). You are also asked to specify a temporary tablespace for the user. Once you have provided default and temporary tablespaces for the PERFSTAT account, the account is created and the installation script logs in as PERFSTAT and continues to create the required objects. If there is not sufficient space to create the PERFSTAT objects in the specified default tablespace, the script returns an error.

The `spcreate.sql` script calls three scripts: `spcusr.sql` to create the user, `spctab.sql` to create the underlying tables, and `spcpkg.sql` to create the packages. When run, each of these scripts generates a listing file (`spcusr.lis`, etc.). Although you start the installation script while logged in as a SYSDBA-privileged user, the conclusion of the installation script leaves you logged in as the PERFSTAT user. If you want to drop the PERFSTAT user at a later date, you can run the `spdrop.sql` script (which calls `spdusr.sql` and `spdtab.sql`) located in the ORACLE_HOME/rdbms/admin directory.

Security of the PERFSTAT Account

The `spcusr.sql` script creates the PERFSTAT account and asks you to supply a password (the default was PERFSTAT in previous versions). The Statspack utility does not need to use the PERFSTAT default password; change the password after the installation process completes. Also, remember that in 12*c*, passwords are case sensitive. This is controlled by an initialization parameter SEC_CASE_SENSITIVE_LOGON. The default is TRUE, which makes passwords case sensitive by default. Set this to FALSE to disable this feature (see Chapter 4 for more information on initialization parameters). Consider the following case-sensitivity issue, if my username/password was perfstat/perfstat (which it shouldn't be, because it would be too easy to hack):

```
SQL> connect perfstat/perfstat
Connected.

SQL> connect PERFSTAT/perfstat
Connected.

SQL> connect perfstat/PERFSTAT
ERROR:
ORA-01017: Invalid username/password; logon denied.

Warning: You are no longer connected to ORACLE.
```

The PERFSTAT user is granted the SELECT_CATALOG_ROLE and privileges on many of the V_$ views (which allows you to query the corresponding V$ views; see Chapter 12). The

PERFSTAT user is also granted several system privileges (CREATE/ALTER SESSION, CREATE TABLE, CREATE VIEW, CREATE/DROP PUBLIC SYNONYM, CREATE SEQUENCE, and CREATE PROCEDURE). PERFSTAT is also granted EXECUTE privilege on DBMS_SHARED_POOL and DBMS_JOB. Any user who can access your PERFSTAT account can select from all of the dictionary views. For example, such a user could query all of the database account usernames from DBA_USERS, all the segment owners from DBA_SEGMENTS, and the currently logged-in sessions from V$SESSION. The PERFSTAT account, if left unprotected, provides a security hole that allows intruders to browse through your data dictionary and select targets for further intrusion.

In addition to the privileges it receives during the installation process, the PERFSTAT account also has any privileges that have been granted to PUBLIC. If you use PUBLIC grants instead of roles for application privileges, you must secure the PERFSTAT account. You can lock and unlock database accounts as needed. To lock the PERFSTAT account when you are not using Statspack, use the ALTER USER command, as shown in the following listing:

```
alter user PERFSTAT account lock;
```

When you need to gather statistics or access the Statspack data, you can unlock the account:

```
alter user PERFSTAT account unlock;
```

Post-Installation

Once the installation process is complete, the PERFSTAT account owns 72 tables and 72 indexes, 75 public synonyms (PUBLIC actually owns all of the public synonyms), a sequence, a view, and a package (with body).

You use the package, named Statspack, to manage the statistics collection process and the data in the tables. The collection tables, whose names all begin with "STATS$," use column definitions based on the V$ view definitions. For example, the columns in STATS$WAITSTAT are the columns found in V$WAITSTAT, with three identification columns added at the top:

```
desc stats$waitstat

Name                        Null?    Type
--------------------------- -------- -----------
SNAP_ID                     NOT NULL NUMBER(6)
DBID                        NOT NULL NUMBER
INSTANCE_NUMBER             NOT NULL NUMBER
CLASS                       NOT NULL VARCHAR2(18)
WAIT_COUNT                           NUMBER
TIME                                 NUMBER
```

The CLASS, WAIT_COUNT, and TIME columns are based on the CLASS, COUNT, and TIME columns from V$WAITSTAT. Statspack has added these identification columns:

Column	Description
SNAP_ID	An identification number for the collection. Each collection is called a *snapshot* and is assigned an integer value.
DBID	A numeric identifier for the database.
INSTANCE_NUMBER	A numeric identifier for the instance for RAC installations.

Each collection you perform is given a new SNAP_ID value that is consistent across the collection tables. You need to know the SNAP_ID values when executing the statistics report provided with Statspack.

Gathering Statistics

As mentioned in the previous description of the SNAP_ID column, each collection of statistics is called a *snapshot*. Snapshots of statistics have no relation to snapshots or materialized views used in replication. Rather, a snapshot is a point-in-time collection of the statistics available via the V$ views and is given a SNAP_ID value to identify it. You can generate reports on the changes in the statistics between any two snapshots. With Statspack, you can collect as many snapshots as you need and then generate reports against any combination of them. The Statspack Report is only valid if the database is *not* shut down and restarted between the evaluated snapshots.

TIP
Be sure the TIMED_STATISTICS database initialization parameter is set to TRUE prior to gathering statistics.

To generate a snapshot of the statistics, execute the SNAP procedure of the Statspack package, as shown in the following listing. You must be logged in as the PERFSTAT user to execute this procedure.

```
execute STATSPACK.SNAP;
PL/SQL procedure successfully completed.
```

When you execute the SNAP procedure, Oracle populates your STATS$ tables with the current statistics. You can then query those tables directly, or you can use the standard Statspack Report (to see the change in statistics between snapshots).

Snapshots should be taken in one of two ways, depending on the purpose:

- **To evaluate performance during specific tests of the system** For these tests, you can execute the SNAP procedure manually, as shown in the prior example.
- **To evaluate performance changes over a long period of time** To establish a baseline of system performance, you may generate statistics snapshots on a scheduled basis. For these snapshots, you should schedule the SNAP procedure execution via the Oracle Scheduler or via an operating system scheduler.

For the snapshots related to specific tests, you may wish to increase the collection level, which lets you gather more statistics. As noted in the section "Managing the Statspack Data" later in this chapter, each snapshot has a cost in terms of space usage and query performance. For example, since the V$SYSSTAT view has 1,688 rows in 12.2 (note we have CDB and PDBs now), whereas there were only 588 rows in Oracle 11.2 on Windows (628 on Linux), every snapshot generates 1,688 rows in STATS$SYSSTAT. In 10.2, there were only 347 rows in V$SYSSTAT. Avoid generating thousands of rows of statistical data with each snapshot unless you plan to use them.

To support differing collection levels, Statspack provides the I_SNAP_LEVEL parameter. By default, the level value is set to 5. Prior to changing the level value, generate several snapshots and evaluate the reports generated. The default level value is adequate for most reports. Alternative level values are listed in the following table:

Level	Description
0–4	General performance statistics on all memory areas, locks, latches, pools, cluster DB statistics, events, and segment statistics, such as ROLLBACK/UNDO segments.
5	Same statistics from the lower levels, plus the most resource-intensive SQL statements above set thresholds. At level 5 and greater, the snapshot takes longer for a larger shared pool size.
6	Includes the level 5 results plus SQL execution plans and plan usage data for high-resource usage SQL. The SQL must be in the shared pool at the time of the snapshot to be captured.
7–9	Introduced in Oracle 10*g*, levels 7–9 include level 6 results plus detailed segment level statistics, including logical reads, physical reads/writes, global cache cr/current served and buffer busy, ITL, and row lock waits.
10 and greater	Same statistics from level 6 plus parent/child latch data. These levels can take a long time to complete and should be used only when directed by Oracle Support.

The greater the collection level, the longer the snapshot will take. The default value (5) offers a significant degree of flexibility during the queries for the most resource-intensive SQL statements. The parameters used for the resource-intensive SQL portion of the snapshot are stored in a table named STATS$STATSPACK_PARAMETER. You can query STATS$STATSPACK_PARAMETER to see the settings for the different thresholds during SQL statement gathering. Its columns include SNAP_LEVEL (the snapshot level), EXECUTIONS_TH (threshold value for the number of executions), DISK_READS_TH (threshold value for the number of disk reads), and BUFFER_GETS_TH (threshold value for the number of disk reads).

For a level 5 snapshot using the default thresholds, SQL statements are stored if they meet any of the following criteria:

- The SQL statement has been executed at least 100 times.
- The number of disk reads performed by the SQL statement exceeds 1000.
- The number of parse calls performed by the SQL statement exceeds 1000.
- The number of buffer gets performed by the SQL statement exceeds 10,000.
- The sharable memory used by the SQL statement exceeds 1M.
- The version count for the SQL statement exceeds 20.

When evaluating the snapshot's data and the performance report, keep in mind the SQL threshold parameter values are cumulative. A very efficient query, if executed enough times, will exceed 10,000 buffer gets. Compare the number of buffer gets and disk reads to the number of executions to determine the activity each time the query is executed.

To modify the default settings for the thresholds, use the MODIFY_STATSPACK_PARAMETER procedure in the STATSPACK package. Specify the snapshot level via the I_SNAP_LEVEL parameter, along with the parameters to change. Table 14-1 lists the available parameters for the

MODIFY_STATSPACK_PARAMETER procedure.

Parameter Name	Range of Values	Default	Description
I_SNAP_LEVEL	0, 5, 6, 7, 10	5	Snapshot level
I_UCOMMENT	Any text	Blank	Comment for the snapshot
I_EXECUTIONS_TH	Integer >= 0	100	Threshold for the cumulative number of executions
I_DISK_READS_TH	Integer >= 0	1000	Threshold for the cumulative number of disk reads (physical reads)
I_PARSE_CALLS_TH	Integer >= 0	1000	Threshold for the cumulative number of parse calls
I_BUFFER_GETS_TH	Integer >= 0	10000	Threshold for the cumulative number of buffer gets (logical reads)
I_SHARABLE_MEM_TH	Integer >= 0	1048576	Threshold for the amount of shareable memory allocated
I_VERSION_COUNT_TH	Integer >= 0	20	Threshold for the number of versions of the SQL statement
I_SEG_BUFF_BUSY_TH	Integer >= 0	100	Threshold for the number of buffer busy waits on a segment
I_SEG_ROWLOCK_W_TH	Integer >= 0	100	Threshold for the number of row lock waits on a segment
I_SEG_ITL_WAITS_TH	Integer >= 0	100	Threshold for the number of ITL waits on a segment
I_SEG_CR_BKS_SD_TH	Integer >= 0	1000	Threshold for the number of consistent read (CR) blocks served for a segment
I_SEG_CU_BKS_SD_TH	Integer >= 0	1000	Threshold for the number of current (CU) blocks served for a segment
I_SEG_PHY_READS_TH	Integer >= 0	1000	Threshold for the number of physical reads on a segment
I_SEG_LOG_READS_TH	Integer >= 0	10000	Threshold for the number of logical reads on a segment
I_SESSION_ID	Valid SID from V$SESSION	0	Session ID of an Oracle session, if you wish to gather session-level statistics
I_MODIFY_PARAMETER	True or False	False	Set to True if you wish to save your changes for future snapshots

TABLE 14-1. *Modification Parameters*

To increase the BUFFER_GETS threshold for a level 5 snapshot to 100,000, issue the following command ("-" indicates the command continues on the next line):

```
EXECUTE STATSPACK.MODIFY_STATSPACK_PARAMETER -
  (i_snap_level=>5, i_buffer_gets_th=>100000, -
   i_modify_parameter=>'true');
```

If you plan to run the SNAP procedure on a scheduled basis, you should pin the Statspack package following database startup. The following listing shows a trigger that is executed each time the database is started. The KEEP procedure of the DBMS_SHARED_POOL package pins the Statspack package in the shared pool. As an alternative to pinning, you can use the SHARED_POOL_RESERVED_SIZE initialization parameter to reserve shared pool area for large packages.

```
create or replace trigger PIN_ON_STARTUP
after startup on database
begin
   DBMS_SHARED_POOL.KEEP ('PERFSTAT.STATSPACK', 'P');
end;
/
```

TIP
Pin the Statspack package following database startup if you plan to run the SNAP procedure on a scheduled basis.

Running the Statistics Report

If you have generated more than one snapshot, you can report on the statistics for the period between the two snapshots. The database must not have been shut down between the times the two snapshots were taken. When you execute the report, you need to know the SNAP_ID values for the snapshots. If you run the report interactively, Oracle provides a list of the available snapshots and the times they were created.

To execute the report, go to the /rdbms/admin directory under the Oracle software home directory. Log in to SQL*Plus as the PERFSTAT user and run the `spreport.sql` file found there:

```
SQL> @$ORACLE_HOME/rdbms/admin/spreport
```

Oracle displays the database and instance identification information from V$INSTANCE and V$DATABASE and then calls a second SQL file, `sprepins.sql`.

The `sprepins.sql` script generates the report of the changes in the statistics during the snapshot time interval. The available snapshots are listed, and you will be prompted to enter beginning and ending snapshot IDs. Unless you specify otherwise, the output is written to a file named `sp_`*beginning_ending*`.lst` (for example, `sp_1_2.lst` for a report between SNAP_ID values of 1 and 2—this will be exactly what you get when you run your first Statspack Report).

TIP
A second report, `sprepsql.sql`, can be used for additional research into the problem SQL statements identified via the `spreport.sql` report.

The Automatic Workload Repository (AWR) and the AWR Report

The AWR Report reports on the AWR stored data and is definitely the next generation of the Statspack Report. It does require additional licensing, so ensure that you are licensed to use it. The AWR collects database statistics every 60 minutes (on the hour) out of the box (this is configurable), and this data is maintained for a week and then purged. The statistics collected by the AWR are stored in the database. The AWR Report accesses the AWR to report statistical performance information similar to how Statspack has always done. Because the AWR schema was originally based on the Statspack schema, you will find much of what is included in Statspack in the AWR Report. Learning the AWR Report if you are familiar with Statspack is easy, *but* you will not find everything in Statspack that you find in the AWR Report. There are some newer/cooler parts of the AWR Report that Statspack users will definitely value.

The AWR data is stored separately from the Statspack data, so running both is a bit superfluous. If you choose to run *both*, ensure that you stagger AWR data collection from the Statspack collection—by at least 30 minutes—to avoid a performance hit as well as conflicts. You could also run both as you switch from one reporting tool to the other for overlap to ensure that you have coverage that shows comparison reports.

The Oracle database uses the AWR for problem detection and analysis as well as for self-tuning. A number of different statistics are collected by the AWR, including wait events, time model statistics, active session history statistics, various system- and session-level statistics, object usage statistics, and information on the most resource-intensive SQL statements. To properly collect database statistics, set the initialization parameter STATISTICS_LEVEL to TYPICAL (the default) or ALL. Other Oracle Database 12*c* features use the AWR, such as Automatic Database Diagnostic Monitor (ADDM) and other Enterprise Manager Cloud Control features as discussed in Chapter 5.

If you want to explore the AWR, feel free to do so. The AWR consists of a number of tables owned by the SYS schema and typically stored in the SYSAUX tablespace (currently no method exists that I know of to move these objects to another tablespace). All AWR table names start with the identifier "WR." AWR tables come with three different type designations:

- Metadata (WRM$)
- Historical/convertible data (WRH$, WRR$, and WRI$)
- AWR tables related to advisor functions (WRI$)

Most of the AWR table names are pretty self-explanatory, such as WRM$_SNAPSHOT or WRH$_ACTIVE_SESSION_HISTORY (a very valuable view to check out). Also, Oracle Database 12*c* offers several DBA views that allow you to query the AWR repository. The views start with DBA_HIST and are followed by a name that describes the view. These include views such as DBA_HIST_FILESTATS, DBA_HIST_DATAFILE, and DBA_HIST_SNAPSHOT.

TIP
If you choose to run both Statspack and the AWR, ensure that you stagger the AWR data collection from Statspack collection by at least 30 minutes to avoid a performance hit as well as conflicts. If you are running the AWR Report, you should not also need to run Statspack.

Manually Managing the AWR

Although the AWR is meant to be automatic (Oracle is capturing this information "out of the box"), provisions for manual operations impacting the AWR are available. You can manually modify the snapshot collection interval and retention criteria, create snapshots, and remove snapshots from the AWR. I will describe these processes in more detail in the next few sections, but please refer to the Oracle documentation for full coverage of the AWR.

You can modify the snapshot collection interval using the DBMS_WORKLOAD_REPOSITORY package. The procedure DBMS_WORKLOAD_REPOSITORY.MODIFY_SNAPSHOT_SETTINGS is used in this example to modify the snapshot collection so it occurs every 15 minutes and retention of snapshot data is fixed at 20,160 minutes (exactly 14 days):

```
-- This causes the repository to refresh every 15 minutes
-- and retain all data for 2 weeks.
exec dbms_workload_repository.modify_snapshot_settings -
(retention=>20160, interval=> 15);
```

Setting the interval parameter to 0 disables all statistics collection.

To view the current retention and interval settings for the AWR, use the DBA_HIST_WR_CONTROL view. There are two new columns in the 12*c* view: CON_ID (Container ID) and View Location. Here is an example of how to use this view:

```
select *
from   dba_hist_wr_control;

      DBID SNAP_INTERVAL        RETENTION            TOPNSQL CON_ID VIEW_LOCATION
---------- -------------------- -------------------- ------- ------ -------------
1434524921 +00000 01:00:00.0    +00008 00:00:00.0    DEFAULT      0             0
```

In the preceding example, you see that the snapshot interval is every hour (the default), and the retention is set for eight days.

You can use the DBMS_WORKLOAD_REPOSITORY package to create or remove snapshots. The DBMS_WORKLOAD_REPOSITORY.CREATE_SNAPSHOT procedure creates a manual snapshot in the AWR, as seen in this example:

```
exec dbms_workload_repository.create_snapshot;
```

You can see what snapshots are currently in the AWR by using the DBA_HIST_SNAPSHOT view, as seen in this example:

```
select snap_id, begin_interval_time, end_interval_time
from   dba_hist_snapshot
order  by 1;

   SNAP_ID BEGIN_INTERVAL_TIME       END_INTERVAL_TIME
---------- ------------------------- -------------------------
       375 11-MAY-16 11.00.37.796 PM 13-MAY-11 01.16.48.897 PM
       376 13-MAY-16 01.16.48.897 PM 13-MAY-11 02.00.29.909 PM
       377 13-MAY-16 02.00.29.909 PM 13-MAY-11 03.00.42.797 PM
       378 13-MAY-16 03.00.42.797 PM 13-MAY-11 04.00.55.608 PM
```

Each snapshot is assigned a unique snapshot ID that is reflected in the SNAP_ID column. If you have two snapshots, the earlier snapshot always has a smaller SNAP_ID than the later snapshot. The END_INTERVAL_TIME column displays the time that the actual snapshot was taken.

Sometimes you might want to drop snapshots manually. The DBMS_WORKLOAD_REPOSITORY.DROP_SNAPSHOT_RANGE procedure can be used to remove a range of snapshots from the AWR. This procedure takes two parameters, LOW_SNAP_ID and HIGH_SNAP_ID, as seen in this example:

```
exec dbms_workload_repository.drop_snapshot_range -
(low_snap_id=>1107, high_snap_id=>1108);
```

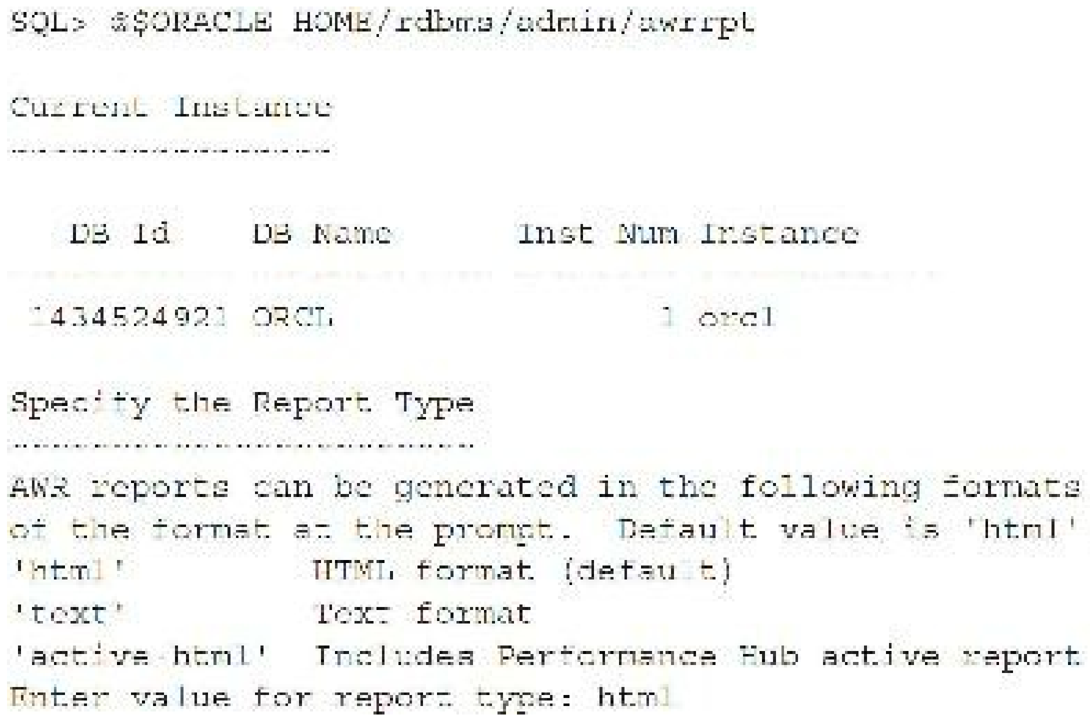
AWR Automated Snapshots

Oracle automatically gathers statistics for the AWR, and does so as long as the STATISTICS_LEVEL initialization parameter is set to TYPICAL or ALL (the default is TYPICAL). Setting the STATISTICS_LEVEL to BASIC disables many Oracle features including the AWR. To check your STATISTICS_LEVEL run the following:

```
SQL> show parameter statistics_level
NAME                                 TYPE        VALUE
------------------------------------ ----------- ------------------------------
statistics_level                     string      TYPICAL
```

AWR Snapshot Reports

Oracle provides reports that you can run to analyze the data in the AWR. These reports are much like the Statspack Reports. The AWR has two reports: `awrrpt.sql`, which is the main AWR Report, and `awrrpti.sql`. Both reports are available in the $ORACLE_HOME/rdbms/admin directory. The output of these reports (run from SQL*Plus) is essentially the same, except that `awrrpti.sql` allows you to define a specific instance to report on. The reports are much like the Statspack Reports of old, in that you define beginning and ending snapshot IDs, along with the report's output filename. Additionally, you can opt to produce the report in either text format or HTML format. As you will see when you run `awrrpt.sql`, the following simple example shows how similar this is to Statspack, other than the text itself (Statspack-looking output), or HTML (the screenshots in this chapter are both the text and the HTML) output:



```
SQL> @$ORACLE_HOME/rdbms/admin/awrrpt

Current Instance
~~~~~~~~~~~~~~~~

   DB Id    DB Name      Inst Num Instance
----------- ------------ -------- ------------
 1434524921 ORCL                1 orcl

Specify the Report Type
~~~~~~~~~~~~~~~~~~~~~~~
AWR reports can be generated in the following formats.  Please enter the name
of the format at the prompt.  Default value is 'html'.
'html'          HTML format (default)
'text'          Text format
'active-html'   Includes Performance Hub active report
Enter value for report_type: html
```

TIP
With the new 12cR2 AWR Report, you can choose to get text (similar to Statspack output), HTML, or the new Active HTML format (which summons OEM at the end of the report if desired) when you run `awrrpt.sql`. The HTML format is much better than text, as you can click various links within the report to navigate among sections easily. You can also run the AWR Report within OEM.

As when using Statspack, creating a baseline in the AWR is a good idea. A *baseline* is defined as a range of snapshots that you can use to compare with other pairs of snapshots. The Oracle database server will exempt the snapshots assigned to a specific baseline from the automated purge routine. The main purpose of a baseline is, therefore, to preserve typical runtime statistics in the AWR repository, allowing you to run the AWR snapshot reports on the preserved baseline snapshots at any time and compare them to recent snapshots contained in the AWR. This way you can compare current performance (and configuration) to established baseline performance, which can help you determine database performance problems.

You can use the CREATE_BASELINE procedure contained in the DBMS_WORKLOAD_REPOSITORY stored PL/SQL package to create a baseline, as seen in this example (you could also create a snapshot when nobody is on the system as a comparison):

```
exec dbms_workload_repository.create_baseline -
(start_snap_id=>1109, end_snap_id=>1111, -
baseline_name=>'EOM Baseline');
```

Baselines can be seen using the DBA_HIST_BASELINE view, as seen in the following example:

```
select baseline_id, baseline_name, start_snap_id, end_snap_id
from   dba_hist_baseline;

BASELINE_ID BASELINE_NAME   START_SNAP_ID END_SNAP_ID
----------- --------------- ------------- -----------
          1 EOM Baseline             1109        1111
```

In this case, the column BASELINE_ID identifies each individual baseline that has been defined. The name assigned to the baseline is listed, as are the beginning and ending snapshot IDs.

You can remove a baseline using the DBMS_WORKLOAD_REPOSITORY.DROP_BASELINE procedure, as seen in this example, which drops the EOM Baseline that I just created:

```
EXEC dbms_workload_repository.drop_baseline -
(baseline_name=>'EOM Baseline', Cascade=>FALSE);
```

NOTE
The CASCADE parameter causes all associated snapshots to be removed if it is set to TRUE; otherwise, the snapshots are cleaned up automatically by the AWR automated processes.

Run the AWR Report in Oracle Enterprise Manager Cloud Control

Although, as I have demonstrated, you can use the DBMS_WORKLOAD_REPOSITORY package to manage the AWR repository, you can also manage the AWR from Oracle Enterprise Manager. Enterprise Manager is covered in detail in Chapter 5, but some of the AWR Report screens are covered in this chapter. Enterprise Manager provides a nice interface into the management of the AWR and also provides an easy method for creating the AWR Report. Navigate to the database you wish to report on, then go to the Performance tab as seen in Figure 14-1. You can then click AWR.

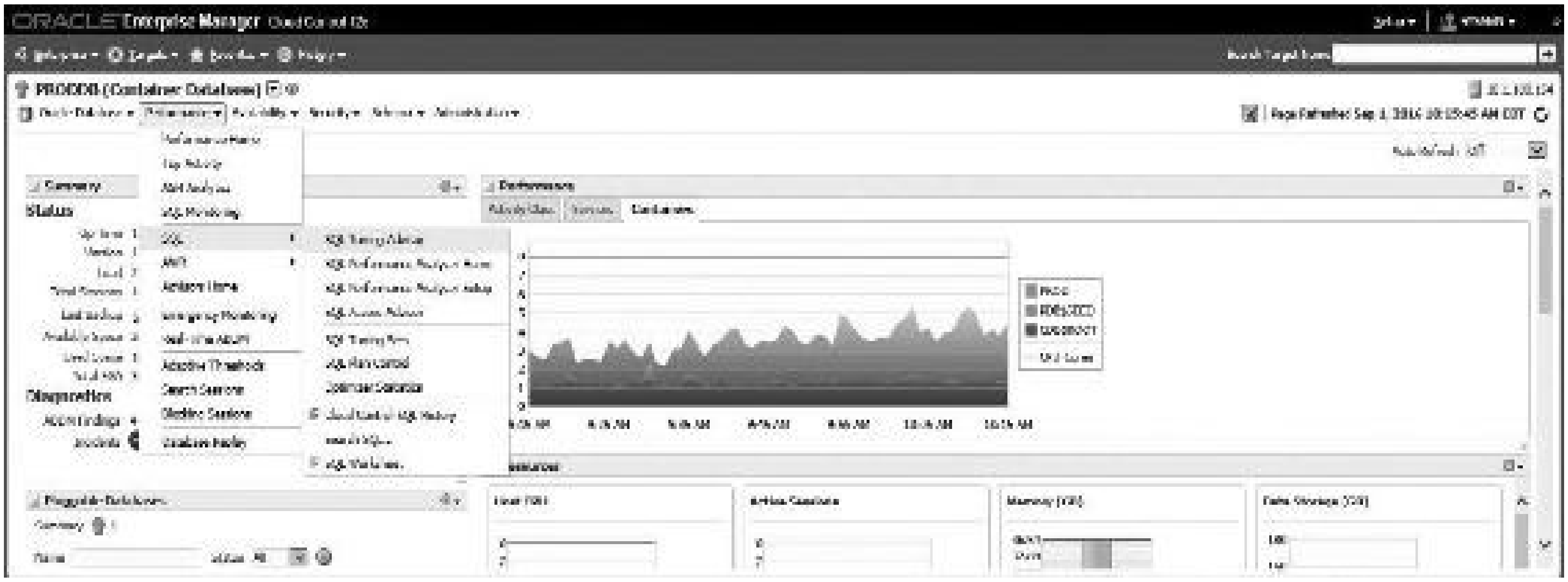
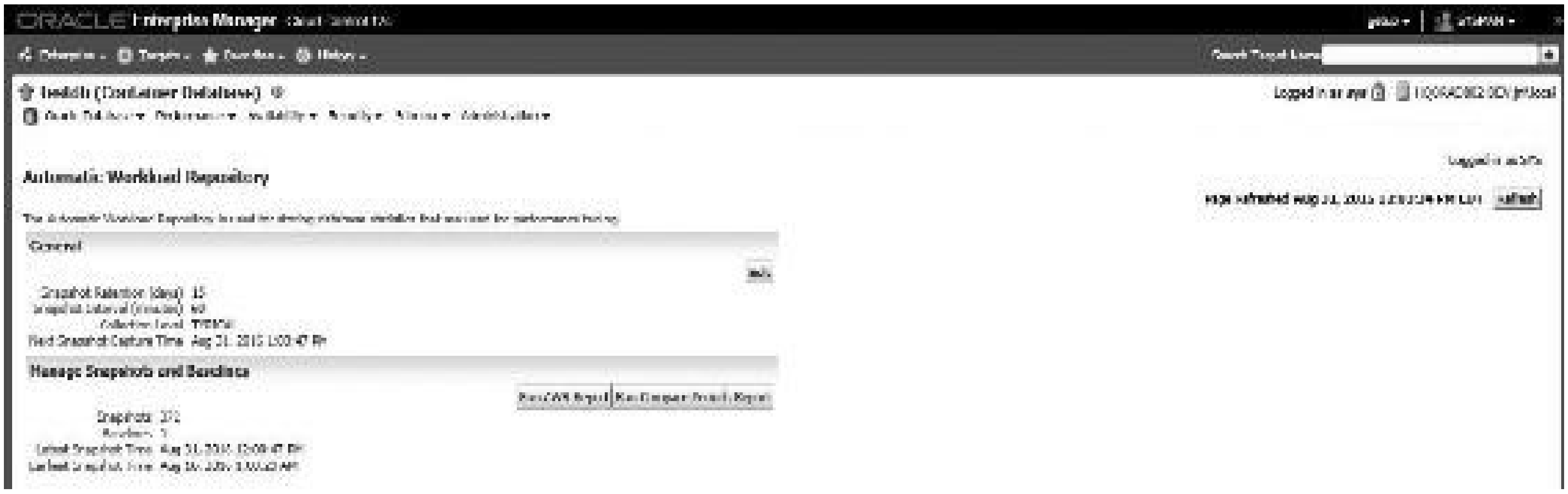


FIGURE 14-1. *AWR is located on the Performance drop-down tab.*

The next AWR screen (Figure 14-2) provides a summary of the current AWR settings and gives you an option to modify them and has a button to Run AWR Report. You can also review details about the snapshots in the AWR and create baseline AWR snapshots (called *preserved snapshot sets* in Enterprise Manager). Some of the important things you'll see on the edit page include snapshot retention, how often snapshots are collected (or if collection is turned off), and the collection level.



Automatic Workload Repository

General

Snapshot Retention (days) 15
Snapshot Interval (minutes) 60
Collection Level TYPICAL
Next Snapshot Capture Time Aug 31, 2015 1:00:47 PM

Manage Snapshots and Baselines

Snapshots 372
Baselines 1
Latest Snapshot Time Aug 31, 2015 12:00:47 PM
Earliest Snapshot Time Aug 16, 2015 1:00:42 AM

FIGURE 14-2. *AWR collection settings, snapshots and Run AWR Report button*

If you click the Edit button to the right of snapshot retention, the Edit Settings page displays information regarding snapshot retention and snapshot intervals that can be changed. You can also click on the Run Compare Periods Report button in Figure 14-2 to compare two sets of snapshot pairs. Clicking on this button displays the screen we see in Figure 14-3. Here you can enter starting and ending snapshots for the AWR Report. As long as the snapshots exist, you can run a report starting with any snapshot and ending with any snapshot. If you take snapshots every hour, you can either run a report for an hour or run a report spanning 24 hours (as long as the instance is not shut down at any time between snapshots). If you are running Real Application Clusters (RAC), you must run the report for each instance individually. Comparing snapshots allows you to determine if differences exist between a baseline snapshot and a recent set of snapshots. Using the report generated from this action, you can determine if the current system performance is diverging from the baseline performance in some way.

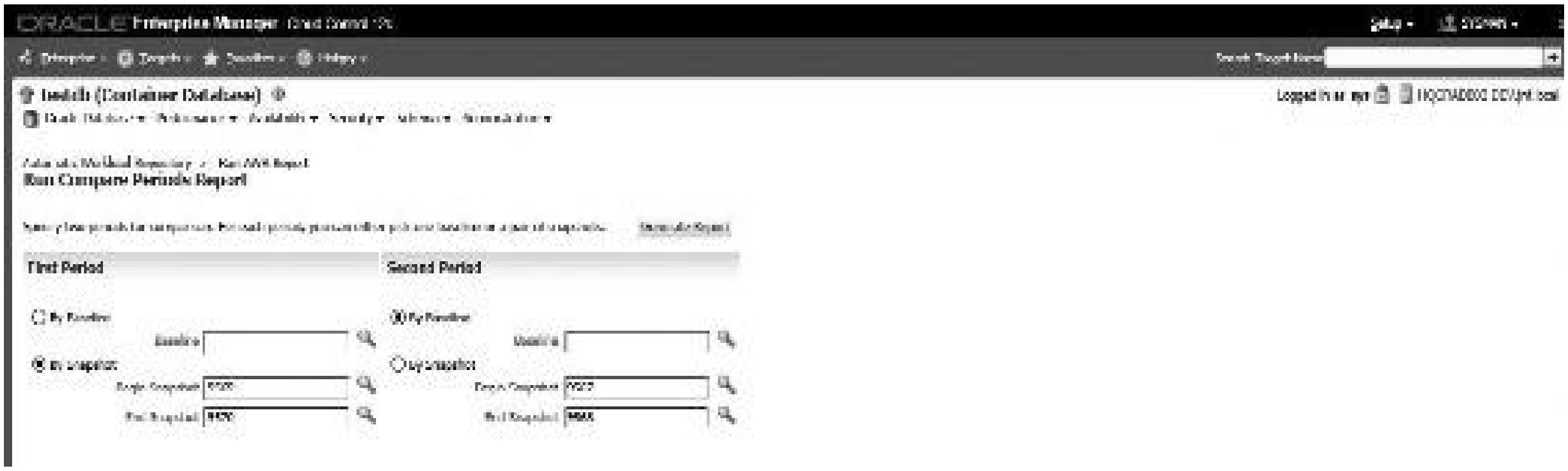


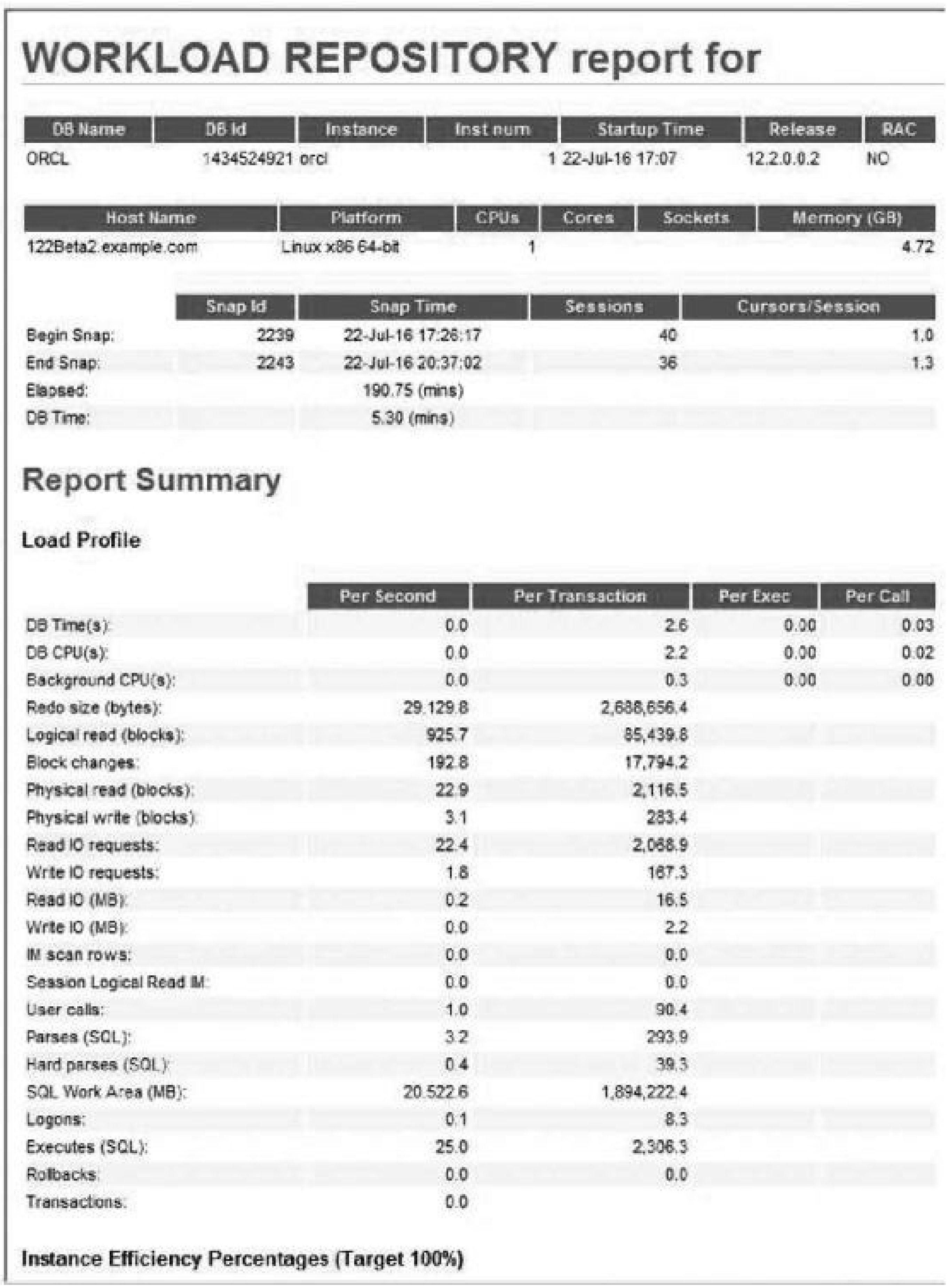
FIGURE 14-3. *Running the Compare Periods Report using the AWR*

You might investigate the following Oracle scripts for more information: `awrginp.sql`, `awrgrpt.sql`, and `awrgrpti.sql`. When you click on the Run AWR Report button in Figure 14-2, you just need to choose beginning and ending snapshot IDs (like you did in the Run Compare Periods Report) and click Generate Report as you did in Figure 14-3. Also, the AWR and ADDM support RAC and the In-Memory column store in 12*c*R2.

TIP

If you use Oracle Enterprise Manager (OEM), you can run the AWR Report directly from Cloud Control or Database Control from multiple versions of OEM.

When you generate an AWR Report, you will probably see a little clock (this screen is not displayed here), which tells you that the report is being generated. Then you will see the actual report (shown in Figure 14-4) as it is displayed in Enterprise Manager. You can also generate the report (`awr_report_425_431.html` in my case) in a file that can be viewed at any time by clicking Save To File. Many of the AWR Report screenshots in this chapter come from this report, but I also show a higher-volume example at times. You can see from Figure 14-4 and (in the next section) Figure 14-5 that the beginning of the AWR Report looks similar to the beginning of the Statspack Report (this one is for snaps 2239 to 2243 on 12.2.0.0.2). We'll see shortly that the AWR Reports and Statspack Reports vary in structure and what's included. Notably missing in the Statspack Report in 12.2 is the In-Memory information, which is seen in the AWR Report in Figure 14-5.



WORKLOAD REPOSITORY report for

DB Name	DB Id	Instance	Inst num	Startup Time	Release	RAC
ORCL	1434524921	orcl	1	22-Jul-16 17:07	12.2.0.0.2	NO

Host Name	Platform	CPUs	Cores	Sockets	Memory (GB)
122Beta2.example.com	Linux x86 64-bit	1			4.72

	Snap Id	Snap Time	Sessions	Cursors/Session
Begin Snap:	2239	22-Jul-16 17:26:17	40	1.0
End Snap:	2243	22-Jul-16 20:37:02	36	1.3
Elapsed:		190.75 (mins)		
DB Time:		5.30 (mins)		

Report Summary

Load Profile

	Per Second	Per Transaction	Per Exec	Per Call
DB Time(s):	0.0	2.6	0.00	0.03
DB CPU(s):	0.0	2.2	0.00	0.02
Background CPU(s):	0.0	0.3	0.00	0.00
Redo size (bytes):	29,129.8	2,688,656.4		
Logical read (blocks):	925.7	85,439.8		
Block changes:	192.8	17,794.2		
Physical read (blocks):	22.9	2,116.5		
Physical write (blocks):	3.1	283.4		
Read IO requests:	22.4	2,068.9		
Write IO requests:	1.8	167.3		
Read IO (MB):	0.2	16.5		
Write IO (MB):	0.0	2.2		
IM scan rows:	0.0	0.0		
Session Logical Read IM:	0.0	0.0		
User calls:	1.0	90.4		
Parses (SQL):	3.2	293.9		
Hard parses (SQL):	0.4	39.3		
SQL Work Area (MB):	20,522.6	1,894,222.4		
Logons:	0.1	8.3		
Executes (SQL):	25.0	2,306.3		
Rollbacks:	0.0	0.0		
Transactions:	0.0			

Instance Efficiency Percentages (Target 100%)

FIGURE 14-4. *The actual AWR Report is browsable or savable to a file.*

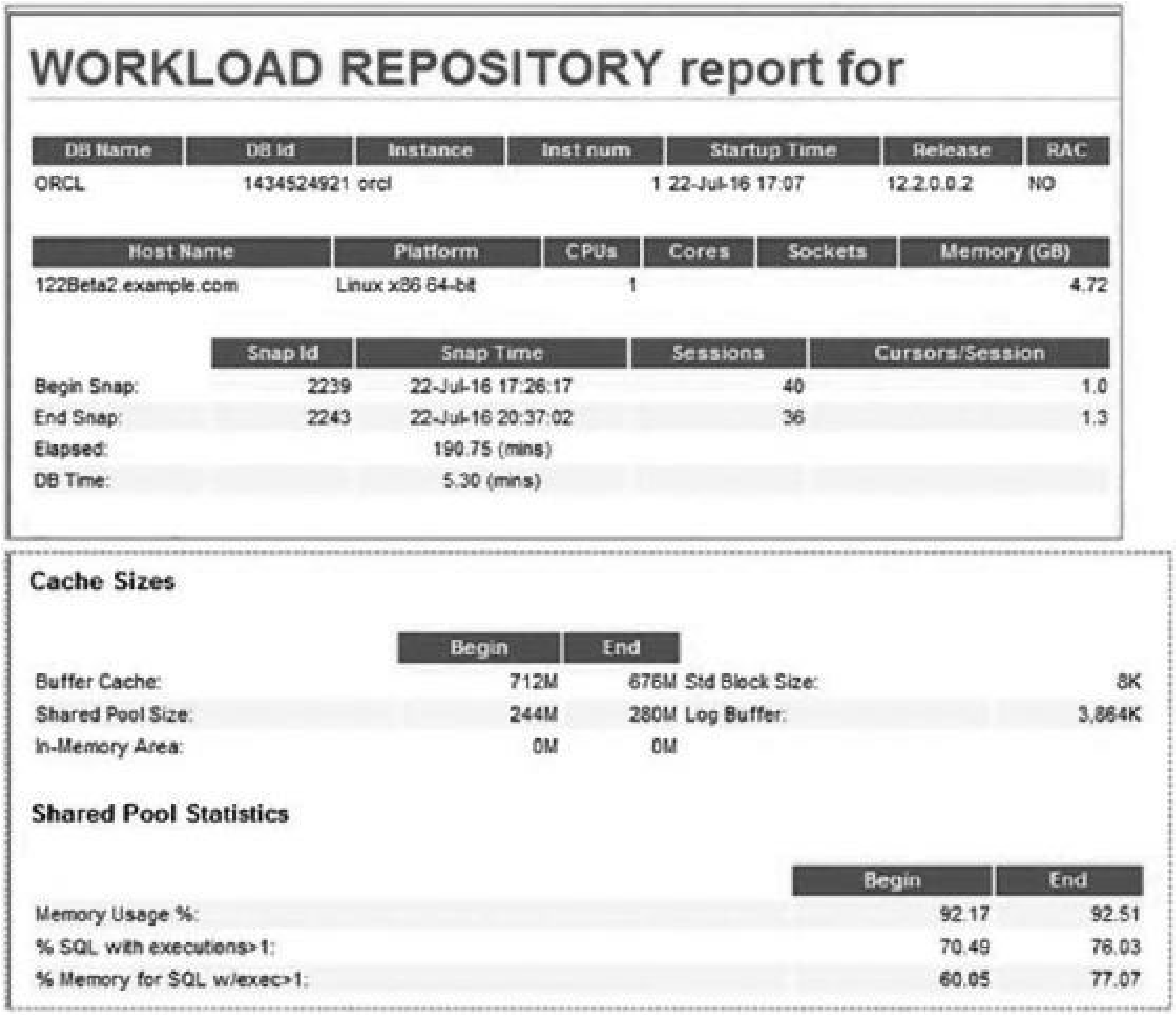
Interpreting the Statspack and AWR Report Output

Several sections are included in both the Statspack and AWR Reports. I cover each of the main sections, along with information on what to look for and how to use information that appears to be problematic. Most information must be combined with additional research to solve an issue, leading to an optimized system.

The Header Information and Cache Sizes

The first section of both the AWR Report and Statspack Report contains information about the database itself, including information on the database name, ID, release number, and host. Following this information is information on when the snapshot was started and ended and how many sessions were active. Always check to ensure the snapshot interval is what you were trying to measure, and make sure that it's a long enough interval to make it representative. If your interval is five minutes, that is almost always not long enough unless you are measuring something very short in duration. If your interval is five days, then you will have all kinds of peaks and valleys that average out, so it may be too long. But having one-day, one-hour (at peak), and one-hour (at non-peak) Statspack Reports handy is great to compare to a problem Statspack Report for any given day when an anomaly occurs on your system. Generally, a Statspack Report should cover at least an hour of time and should be strategically timed to measure problematic periods of time. You may also want to look at an entire day so you can compare days over a period of time.

The first section of the Statspack Report is Cache Sizes. Prior to 12*c*, this was also the first section in the AWR Report, but it has been moved down a few sections in 12*c* (the Load Profile section is now first, as you saw in Figure 14-4). An example of the Statspack header information and Cache Sizes section is displayed next. The equivalent information in the AWR Report is displayed in Figure 14-5 (with the Cache Sizes section cut and pasted from its new, later location for easy comparison). The notable difference between the Cache Sizes section in the two reports is that the 12*c*R2 Statspack Report does not include the In-Memory Area. Both reports include Buffer Cache (DB_CACHE_SIZE), Shared Pool Size (SHARED_POOL_SIZE), Std Block Size (DB_BLOCK_SIZE), and Log Buffer (LOG_BUFFER).



WORKLOAD REPOSITORY report for

DB Name	DB Id	Instance	Inst num	Startup Time	Release	RAC
ORCL	1434524921	orcl	1	22-Jul-16 17:07	12.2.0.0.2	NO

Host Name	Platform	CPUs	Cores	Sockets	Memory (GB)
122Beta2.example.com	Linux x86 64-bit	1			4.72

	Snap Id	Snap Time	Sessions	Cursors/Session
Begin Snap:	2239	22-Jul-16 17:26:17	40	1.0
End Snap:	2243	22-Jul-16 20:37:02	36	1.3
Elapsed:		190.75 (mins)		
DB Time:		5.30 (mins)		

Cache Sizes

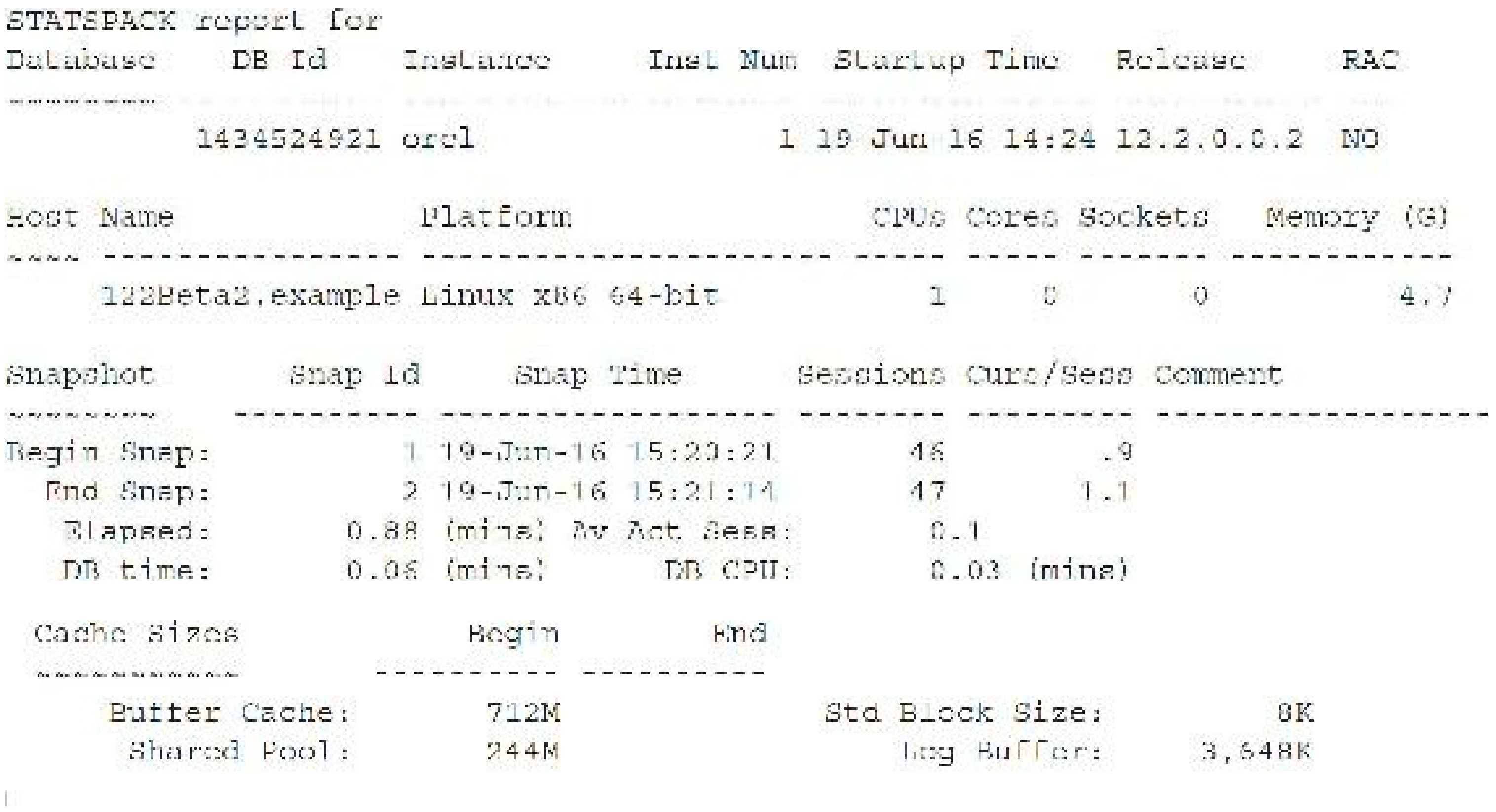
	Begin	End		
Buffer Cache:	712M	676M	Std Block Size:	8K
Shared Pool Size:	244M	280M	Log Buffer:	3,864K
In-Memory Area:	0M	0M		

Shared Pool Statistics

	Begin	End
Memory Usage %:	92.17	92.51
% SQL with executions>1:	70.49	76.03
% Memory for SQL w/exec>1:	60.05	77.07

FIGURE 14-5. *The AWR Report header information and Cache Sizes section (moved up for comparison)*

We'll see that the In-Memory information is also absent in places like the Load Profile and other areas of the Statspack Report. If you are using In-Memory, the Statspack Report *will not* be sufficient —use the AWR Report!



```
STATSPACK report for
Database    DB Id    Instance     Inst Num  Startup Time    Release     RAC
~~~~~~~~ ----------- ------------ -------- --------------- ----------- ---
          1434524921 orcl                1 19 Jun 16 14:24 12.2.0.0.2  NO

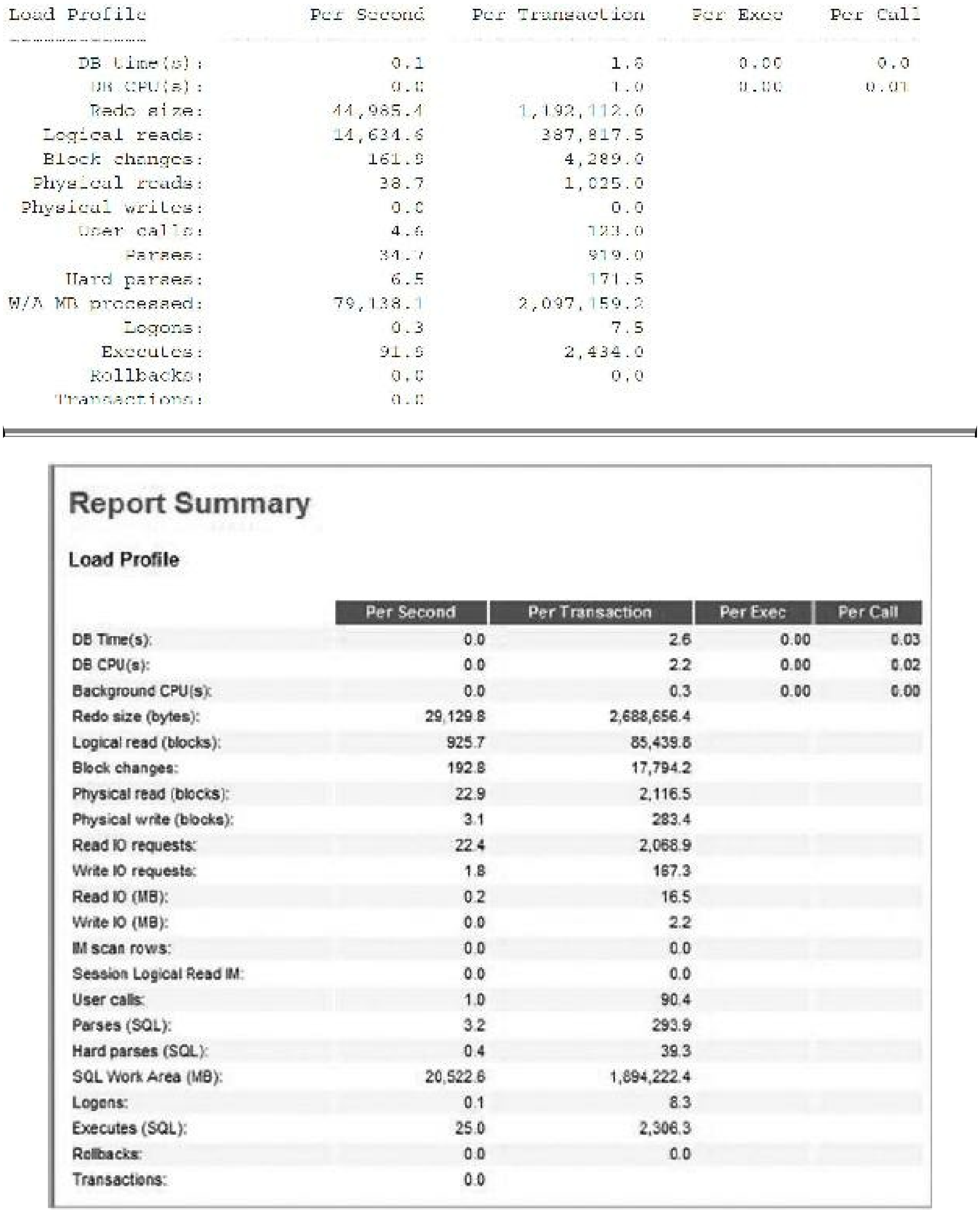
Host Name              Platform                CPUs Cores Sockets   Memory (G)
~~~~ ---------------- ---------------------- ----- ----- ------- ------------
     122Beta2.example Linux x86 64-bit           1     0       0          4.7

Snapshot       Snap Id     Snap Time      Sessions Curs/Sess Comment
~~~~~~~~    ---------- ------------------ -------- --------- ------------------
Begin Snap:          1 19-Jun-16 15:20:21       46        .9
  End Snap:          2 19-Jun-16 15:21:14       47       1.1
   Elapsed:       0.88 (mins) Av Act Sess:       0.1
   DB time:       0.06 (mins)      DB CPU:       0.03 (mins)

 Cache Sizes            Begin        End
 ~~~~~~~~~~~       ---------- ----------
     Buffer Cache:       712M              Std Block Size:         8K
      Shared Pool:       244M                  Log Buffer:     3,648K
```

The Load Profile

The next portion of the Statspack Report output, following the basic information, provides per-second and per-transaction statistics for the Load Profile. As previously indicated, the corresponding section in the AWR Report in 12*c* now appears first. Figure 14-6 shows the equivalent AWR Report information. The Load Profile section is excellent for monitoring throughput and load variations on your system. As the load on the system increases, you will see larger numbers per second. As you tune the system for maximum efficiency, you will usually see lower numbers for the per-transaction statistic. This is a great section to see if the load is changing day to day. The following listing shows sample output for the Statspack Load Profile section. The notable differences in the AWR Report in 12*c* are that it includes "IM scan rows" for the In-Memory (IM) column store and several Read/Write IO statistics. (The IM scan rows data in Figure 14-6 shows you that IM is working!)



```
Load Profile                    Per Second    Per Transaction    Per Exec    Per Call
~~~~~~~~~~~~~~~           ---------------    ---------------  ----------  ----------
      DB time(s):                     0.1                1.8        0.00         0.0
       DB CPU(s):                     0.0                1.0        0.00        0.01
       Redo size:                44,985.4        1,192,112.0
   Logical reads:                14,634.6          387,817.5
   Block changes:                   161.9            4,289.0
  Physical reads:                    38.7            1,025.0
 Physical writes:                     0.0                0.0
      User calls:                     4.6              123.0
          Parses:                    34.7              919.0
     Hard parses:                     6.5              171.5
W/A MB processed:                79,138.1        2,097,159.2
          Logons:                     0.3                7.5
        Executes:                    91.9            2,434.0
       Rollbacks:                     0.0                0.0
    Transactions:                     0.0
```

Report Summary

Load Profile

	Per Second	Per Transaction	Per Exec	Per Call
DB Time(s):	0.0	2.6	0.00	0.03
DB CPU(s):	0.0	2.2	0.00	0.02
Background CPU(s):	0.0	0.3	0.00	0.00
Redo size (bytes):	29,129.8	2,688,656.4		
Logical read (blocks):	925.7	85,439.8		
Block changes:	192.8	17,794.2		
Physical read (blocks):	22.9	2,116.5		
Physical write (blocks):	3.1	283.4		
Read IO requests:	22.4	2,068.9		
Write IO requests:	1.8	167.3		
Read IO (MB):	0.2	16.5		
Write IO (MB):	0.0	2.2		
IM scan rows:	0.0	0.0		
Session Logical Read IM:	0.0	0.0		
User calls:	1.0	90.4		
Parses (SQL):	3.2	293.9		
Hard parses (SQL):	0.4	39.3		
SQL Work Area (MB):	20,522.6	1,894,222.4		
Logons:	0.1	8.3		
Executes (SQL):	25.0	2,306.3		
Rollbacks:	0.0	0.0		
Transactions:	0.0			

FIGURE 14-6. *The AWR Report Load Profile section*

The Load Profile helps to identify both the load and type of activity being performed. In both the Statspack example and AWR example, the activity recorded includes a large amount of both logical and physical activity, but especially redo activity (I performed a lot of INSERTs during this snapshot range).

Things to look for include the following:

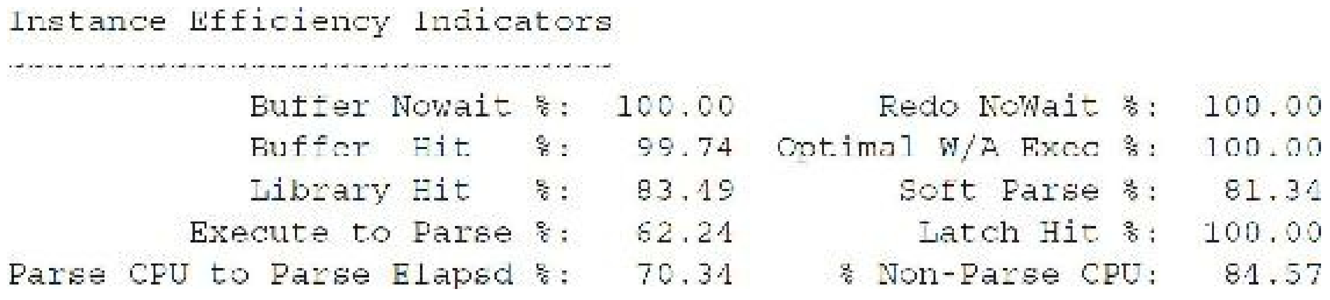
- A large increase in Logical reads or Physical reads compared to a normal load for this period.
- An increase in Redo size and Block changes indicate increased DML (INSERT/UPDATE/DELETE) activity.
- A hard parse occurs when a SQL statement is executed and is *not* currently in the shared pool. A hard parse rate greater than 100 per second could indicate that bind variables are not being used effectively; the CURSOR_SHARING initialization parameter should be used; or you have a shared pool–sizing problem. (See Chapter 4 on sizing the shared pool and a detailed discussion related to this.)
- A soft parse occurs when a SQL statement is executed and it is currently in the shared pool. A very high soft parse rate could indicate program inefficiencies that need to be examined in greater detail to see if there is a problem that needs to be fixed.

TIP
Get to know your system by reviewing and understanding your system's regular Load Profile. Significant changes to the Load Profile during what should be similar workloads or common times during the day may warrant further investigation.

Instance Efficiency

The Instance Efficiency section continues to grow and shows information for many of the common hit ratios. In 12*c*, the AWR Report has added Flash Cache Hit %. Great DBAs generally keep an eye on this section so they can be alerted to significant changes in system behavior when compared historically (you have to know your system for this to be helpful). Hit ratios are a great alert mechanism for general potential problems or specific potential problems, such as bad SQL that has been introduced recently into the system. This can give you the opportunity to find the issue and address it before it has a serious/noticeable effect on the system. Waits (covered in depth later in this chapter) are another excellent way to find major problems, but waits usually show up after the problem becomes a larger issue. Unfortunately, by that time, the business users will often raise it as a problem.

Monitoring hit ratios as an alert is just one piece among the thousands of pieces of your tuning arsenal. The reason that so many tuning tips are provided in this book is that in writing about tuning, I am writing about all of the turns that the optimizer will make and how to be alerted to a problem or compensate for any issues. Although I don't believe you could capture everything in a book (you'd be *un*-writing the hardest part of Oracle—the optimizer), I do believe this compilation helps solve many of them. Some DBAs (usually those trying to sell you a tuning product or DBAs who don't know the system well) minimize the importance of hit ratios (*proactive tuning*) and focus completely on waits (*reactive tuning*), since focusing on waits is a great way to solve the current burning problems quickly (also covered in this book). By monitoring the Instance Efficiency section and Load Profile section (and using all of Statspack and Enterprise Manager), the DBA combines reactive and proactive tuning and will discover some problems before the users scream or wait events hit the Top 5 or Top 10 list. The listing that follows shows how well this Statspack section shows you all of the common hit ratios at once.



```
Instance Efficiency Indicators
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
            Buffer Nowait %:  100.00       Redo NoWait %:  100.00
            Buffer  Hit   %:   99.74  Optimal W/A Exec %:  100.00
            Library Hit   %:   83.19        Soft Parse %:   81.34
         Execute to Parse %:   62.24         Latch Hit %:  100.00
Parse CPU to Parse Elapsd %:   70.34     % Non-Parse CPU:   84.57
```

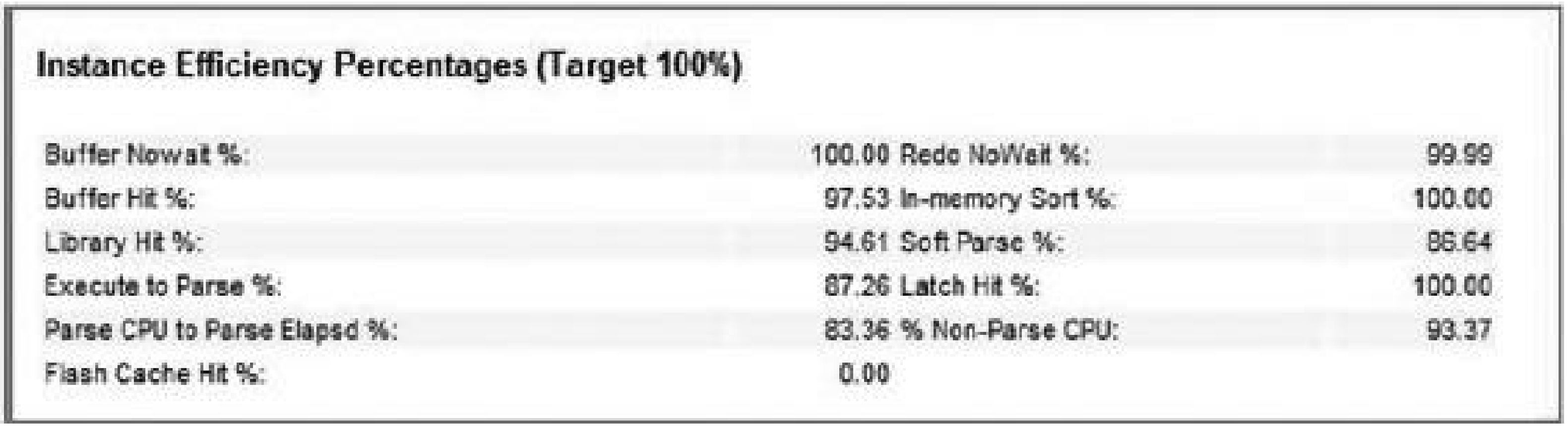
Things to look for include the following:

- A Buffer Nowait % of less than 99 percent. This value is the ratio of hits on a request for a specific buffer where the buffer was immediately available in memory. If the ratio is low, then there are (hot) blocks being contended for that should be found in the Buffer Wait section.
- A Buffer Hit % of less than 95 percent. This value is the ratio of hits on a request for a specific buffer when the buffer was in memory and no physical I/O was needed. While originally one of the few methods of measuring memory efficiency, it still is an excellent method for showing how often you need to do a physical I/O, which merits further investigation as to the cause. Unfortunately, if you have unselective indexes that are frequently accessed, that will drive your hit ratio higher, which can be a misleading indication of good performance to some DBAs. When you effectively tune your SQL and have effective indexes on your entire system, this issue is not encountered as frequently and the hit ratio is a better performance indicator. A high hit ratio is not a measure of good performance, but a low hit ratio is often a sign of performance that can be improved or should at least be looked into.
- A hit ratio that is steadily at 95 percent and then one day goes to 99 percent should be checked for bad SQL or a bad index that is causing a surge of logical reads (check the load profile and top buffer gets SQL).
- A hit ratio that is steadily at 95 percent and then drops to 45 percent should be checked for bad SQL or a dropped index (check the top physical reads SQL) causing a surge in physical reads that are not using an index or an index that has been dropped (I've seen this more often than you can imagine).
- A Library Hit % of less than 95 percent. A lower library hit ratio usually indicates that SQL is being pushed out of the shared pool early (could be due to a shared pool that is too small). A

lower ratio could also indicate that bind variables are not used or some other issue is causing SQL not to be reused (in which case, a smaller shared pool may only be a bandage that potentially fixes a resulting library latch problem). Despite the rants about lowering your shared pool all the time to fix library cache and shared pool latching issues, most multiterabyte systems I've seen with heavy usage have shared pools in the gigabytes without any issues because they've fixed the SQL issues. You must fix the problem (use bind variables or CURSOR_SHARING) and then appropriately size the shared pool. I'll discuss this further when I get to latch issues.

- An In-memory Sort % of less than 95 percent in OLTP. In an OLTP system, you really don't want to do disk sorts. Setting the MEMORY_TARGET or PGA_AGGREGATE_TARGET (or SORT_AREA_SIZE in previous versions) initialization parameter effectively eliminates this problem. Note that In-memory Sort % appears only in the AWR Report (as in 11*g*), not in the Statspack Report.
- A Soft Parse % of less than 95 percent. As covered in the Load Profile section (last section), a soft parse ratio that is less than 80 percent indicates that SQL is not being reused and needs to be investigated.
- A Latch Hit % of less than 99 percent is usually a big problem. Finding the specific latch will lead you to solving this issue. I cover this in detail in the "Latch Free" section later in the chapter.
- A Flash Cache Hit % (only appears in the AWR Report on 12*c*) of less than 90 percent could be a problem if you have a large amount of Flash Cache (system dependent). If you are using Exadata, Chapter 11 provides some queries to help tune this problem if you're not appropriately using your Flash Cache.

Figure 14-7 shows how the Instance Efficiency section looks in the AWR Report (no longer the same as Statspack).


Instance Efficiency Percentages (Target 100%)

Buffer Nowait %:	100.00	Redo NoWait %:	99.99
Buffer Hit %:	97.53	In-memory Sort %:	100.00
Library Hit %:	94.61	Soft Parse %:	86.64
Execute to Parse %:	87.26	Latch Hit %:	100.00
Parse CPU to Parse Elapsd %:	83.36	% Non-Parse CPU:	93.37
Flash Cache Hit %:	0.00		

FIGURE 14-7. *The AWR Report Instance Efficiency Percentages section*

If you regularly run the AWR Report or Statspack, comparing hit ratios from one day to another can be a great barometer as to whether something drastic has changed. If an index was dropped on a frequently accessed column, the buffer hit ratio could drop dramatically, giving you something to investigate. If an index was added to a table, it could cause the buffer hit ratio to soar if it causes a table join to occur in the wrong order, causing massive numbers of buffers to be read, but by using poor indexes. A library hit ratio that rises or falls greatly from one day to the next indicates changing SQL patterns. Latch hit ratio changes can indicate contention issues that you need to investigate more.

Hit ratios can be a very proactive tool for a DBA who regularly monitors and understands a given production system, whereas many of the other tuning tools are reactive to problems that have already occurred.

TIP
Hit ratios are a great barometer of the health of your system. A large increase or drop from day to day is an indicator of a major change that needs to be investigated. Investigating waits is like investigating an accident that has already occurred, whereas investigating a change in hit ratios is like looking into the intersection with a changing traffic pattern that may cause an accident in the future if something is not adjusted. Generally, buffer and library cache hit ratios should be greater than 95 percent for OLTP, but they could be less for a data warehouse that performs many full table scans.

Remember also that a system with very high ratios in this section of the report may still have performance problems. As described previously, a poorly written query can cause volumes of index searches to join to other indexes, causing a high hit ratio (with lots of buffer gets), which is not good in this case. The database is doing most of its work in memory, but it shouldn't be doing so much work. Good hit ratios don't show the whole picture either. There are always cases where the database is working very efficiently, but performance is still bad; this report only shows the database operations, not the application operations, server actions, or networking issues that also impact the performance of the application.

Shared Pool Statistics

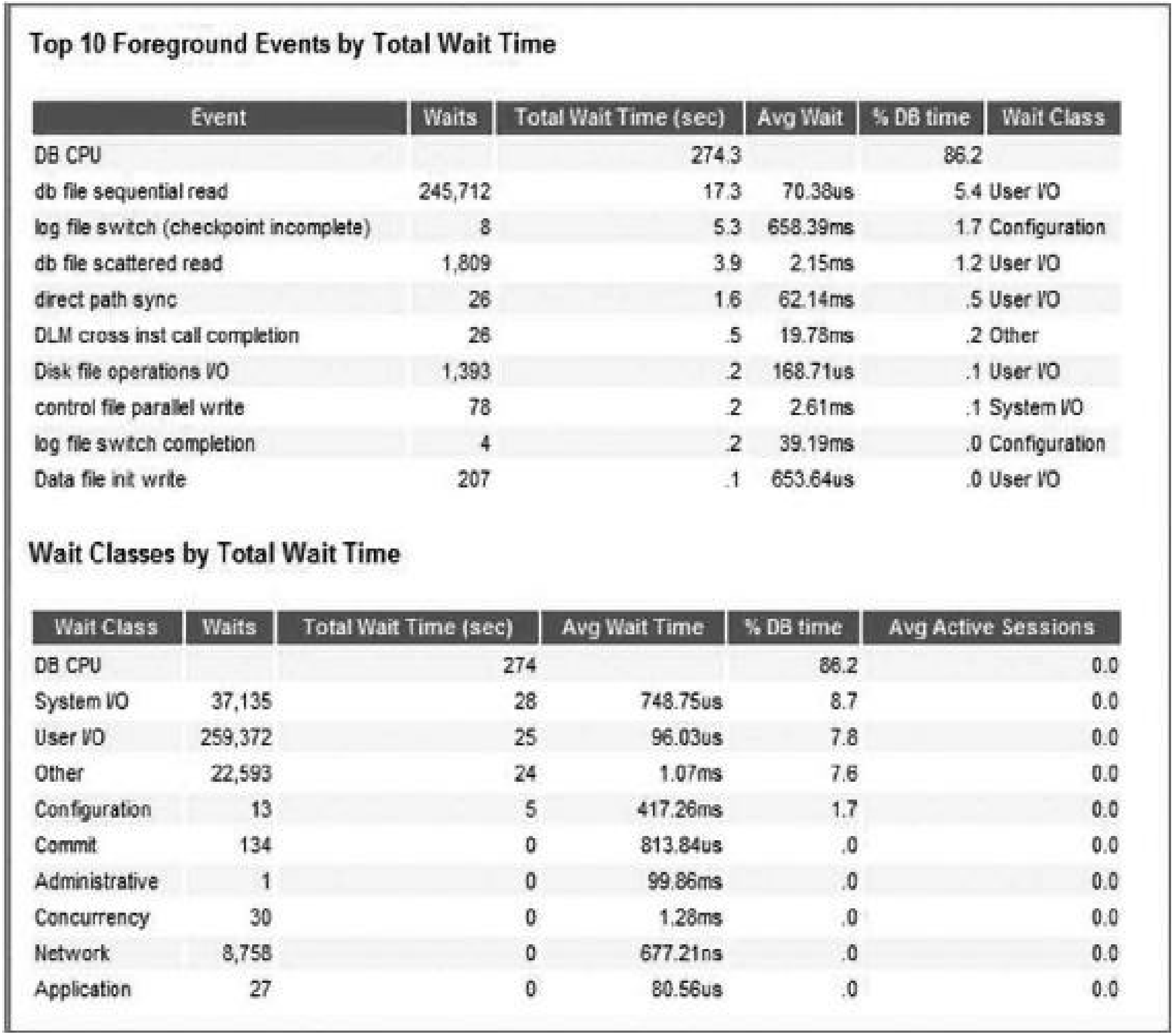
The Shared Pool Statistics section that follows the Instance Efficiency section (both in the AWR Report and Statspack) shows the percentage of the shared pool in use and the percentage of SQL statements that have been executed multiple times (as desired). Combining this data with the library, parse, and latch data helps you to size the shared pool. The following listing shows sample shared pool statistics from the Statspack Report (Figure 14-5 showed this for the AWR):

```
Shared Pool Statistics        Begin    End
                              ------   -----
             Memory Usage %:   76.33   76.74
    % SQL with executions>1:   61.03   61.89
  % Memory for SQL w/exec>1:   75.89   76.57
```

As shown by the data in the preceding listing, at the time of the second snapshot, 76.74 percent of the shared pool's memory was in use. Of the statements in the shared pool, only 61.89 percent had been executed more than once, indicating a potential need to improve cursor sharing in the application. Adjusting the shared pool settings is covered in detail in Chapter 4.

Top Wait Events

The Top Wait Events section of Statspack is probably the most revealing section in the entire report when you are trying to eliminate bottlenecks quickly on your system. This section of the report shows the Top 5 Wait Events. The 12*c* AWR Report, as shown in Figure 14-8, now has Top 10 Foreground Events by Total Wait Time followed by Wait Classes by Total Wait Time instead of the Top 5 Timed Events that Statspack has in it.



Top 10 Foreground Events by Total Wait Time

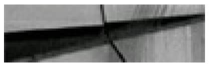
Event	Waits	Total Wait Time (sec)	Avg Wait	% DB time	Wait Class
DB CPU		274.3		86.2	
db file sequential read	245,712	17.3	70.38us	5.4	User I/O
log file switch (checkpoint incomplete)	8	5.3	658.39ms	1.7	Configuration
db file scattered read	1,809	3.9	2.15ms	1.2	User I/O
direct path sync	26	1.6	62.14ms	.5	User I/O
DLM cross inst call completion	26	.5	19.78ms	.2	Other
Disk file operations I/O	1,393	.2	168.71us	.1	User I/O
control file parallel write	78	.2	2.61ms	.1	System I/O
log file switch completion	4	.2	39.19ms	.0	Configuration
Data file init write	207	.1	653.64us	.0	User I/O

Wait Classes by Total Wait Time

Wait Class	Waits	Total Wait Time (sec)	Avg Wait Time	% DB time	Avg Active Sessions
DB CPU		274		86.2	0.0
System I/O	37,135	28	748.75us	8.7	0.0
User I/O	259,372	25	96.03us	7.8	0.0
Other	22,593	24	1.07ms	7.6	0.0
Configuration	13	5	417.26ms	1.7	0.0
Commit	134	0	813.84us	.0	0.0
Administrative	1	0	99.86ms	.0	0.0
Concurrency	30	0	1.28ms	.0	0.0
Network	8,758	0	677.21ns	.0	0.0
Application	27	0	80.56us	.0	0.0

FIGURE 14-8. *The AWR Report Top 10 Foreground Events and Wait Classes by Total Wait Time*

In Statspack, we get the Top 5 Waits followed by the full list of Wait Events, and the Background Wait Events. Identifying major wait events helps to target your tuning efforts to the most burning issues on your system. If TIMED_STATISTICS is TRUE, then the events are ordered in time waited; if FALSE, then the events are ordered by the number of waits (in testing Microsoft Windows, this still was ordered by wait time). For example, the following listing shows the Top 5 Timed Events for a report interval:



```
Top 5 Timed Events
~~~~~~~~~~~~~~~~~~                                                 % Total
Event                                     Waits    Time (s) Ela Time
-------------------------- ------------ ----------- --------
db file sequential read      399,394,399   2,562,115    52.26
CPU time                                    960,825    19.60
buffer busy waits            122,302,412     540,757    11.03
PL/SQL lock timer                  4,077     243,056     4.96
log file switch                  188,701     187,648     3.83
(checkpoint incomplete)
```

In the preceding example, the db file sequential read waits show an incredible number of waits (almost 400,000,000, which, assuming a 8K block size, is 3.2T of data read) and an incredible amount of time spent waiting on db file sequential reads. For this report, this wait event was due to a badly written SQL statement using too many indexes and reading many more blocks than it should have. Slow disk access contributed to the slow performance because of the large number of blocks needing to be read (heavy I/O can lead to high SPU as well), but the real issue was the SQL itself (as usual). After tuning the code for only a single day, over 90% of all disk reads were eliminated. Well over 5T of reads were eliminated (over 3T just in the SQL statement causing these reads alone) in a 24-hour period.

Here is another example, showing the Top 5 Wait Events for a system:

```
Top 5 Wait Events
~~~~~~~~~~~~~~~~~                                             Wait     % Total
Event                                            Waits  Time (cs)   Wt Time
-------------------------------------------- ------------ ------------ -------
db file sequential read                       18,977,104   22,379,571   82.29
latch free                                     4,016,773    2,598,496    9.55
log file sync                                  1,057,224      733,490    2.70
log file parallel write                        1,054,006      503,695    1.85
db file parallel write                         1,221,755      404,230    1.49
```

In the preceding listing, you see a large number of waits related to reading a single block (db file sequential read) and also waits for latches (latch free). You also see some pretty high waits for some of the writing to both datafiles and log files, as well as other potential issues with log file contention. To solve these issues (and to identify which ones are truly major issues), you must narrow them down by investigating the granular reports within other sections of Statspack or the AWR Report.

The following is a sample listing of waits on this very intense system (not as bad as the preceding one, though). Note that all waits were in one section.

```
                                                                   Avg
                                                     Total Wait   wait  Waits
Event                               Waits   Timeouts  Time (cs)   (ms)   /txn
---------------------------- ------------ ---------- ----------- ------ ------
db file sequential read        18,977,104          0  22,379,571     12   17.4
latch free                      4,016,773  2,454,622   2,598,496      6    3.7
log file sync                   1,057,224         10     733,490      7    1.0
enqueue                            90,140      1,723      67,611      8    0.1
library cache pin                   3,062          0      29,272     96    0.0
db file scattered read             21,110          0      26,313     12    0.0
buffer busy waits                  29,640          2      22,739      8    0.0
log file sequential read           31,061          0      18,372      6    0.0
row cache lock                     22,402          0       3,250      1    0.0
LGWR wait for redo copy             4,436         45         183      0    0.0
SQL*Net more data to client        15,937          0         156      0    0.0
file identify                         125          0          12      1    0.0
wait for inquiry response              76          0          10      1    0.0
SQL*Net message to client      35,427,781          0       6,599      0   32.5
```

Statspack and the AWR Reports have sections on Foreground Wait Events, Background Wait Events, and Wait Events (fg and bg). A partial listing of these three sections is displayed next. Although only a partial listing, I've tried to include many of the most common problems. After the listing, I will discuss some of the common events that cause problems.

```
Foreground Wait Events  DB/Inst: ORCL/orcl  Snaps: 1 2
-> Only events with Total Wait Time (s) >= .001 are shown
-> ordered by Total Wait Time desc, Waits desc (idle events last)

                                                                Avg          %Total
                                             %Tim Total Wait   wait   Waits    Call
Event                                 Waits   out   Time (s)   (ms)    /txn    Time
---------------------------------- -------- ----- ---------- ------ ------- -------
direct path read                        648     0          6      9     3.8     8.9
enq: KO - fast object checkp              1     0          4   4108     0.0     6.0
direct path write                       243     0          4     16     1.4     5.5
db file scattered read                   62     0          3     45     0.4     4.0
control file sequential read          2,608     0          0      0    15.4      .4
log file switch completion                2     0          0    127     0.0      .4
log file sync                            65     0          0      3     0.4      .2
db file sequential read                   6     0          0      9     0.0      .1

Background Wait Events  DB/Inst: ORCL/orcl  Snaps: 1-2
```

```
-> Only events with Total Wait Time (s) >= .001 are shown
-> ordered by Total Wait Time desc, Waits desc (idle events last)

                                                             Avg                %Total
                                        %Tim Total Wait    wait     Waits    Call
Event                           Waits    out   Time (s)    (ms)      /txn    Time
---------------------------- ------------ ---- ---------- ------ -------- ------
db file parallel write               686    0         13     18      4.1   18.4
log file parallel write              910    0          4      4      5.4    5.6
control file parallel write          359    0          2      5      2.1    2.6
control file sequential read         934    0          1      1      5.5     .8
os thread startup                     35    0          0      7      0.2     .4
direct path read                       4    0          0     21      0.0     .1

Wait Events (fg and bg) DB/Inst: ORCL/orcl  Snaps: 1-2
-> s - second, cs - centisecond,  ms - millisecond, us - microsecond
-> %Timeouts:  value of 0 indicates value was < .5%.  Value of null is truly 0
-> Only events with Total Wait Time (s) >= .001 are shown
-> ordered by Total Wait Time desc, Waits desc (idle events last)

                                                             Avg                %Total
                                        %Tim Total Wait    wait     Waits    Call
Event                           Waits    out   Time (s)    (ms)      /txn    Time
---------------------------- ------------ ---- ---------- ------ -------- ------
db file parallel write               686    0         13     18      4.1   18.4
direct path read                     652    0          6     10      3.9    9.0
enq: KO - fast object checkp           1    0          4   4109      0.0    6.0
log file parallel write              910    0          4      4      5.4    5.6
direct path write                    246    0          4     15      1.5    5.5
db file scattered read                62    0          3     45      0.4    4.0
control file parallel write          359    0          2      5      2.1    2.6
control file sequential read       3,542    0          1      0     21.0    1.2
log file switch completion             2    0          0    127      0.0     .4
os thread startup                     35    0          0      7      0.2     .4
log file sync                         65    0          0      3      0.4     .2
db file sequential read                6    0          0      9      0.0     .1
```

Next are some of the most common problems; explanations and potential solutions are given as well. These sections are very important and worth their weight in gold!

DB File Scattered Read

The db file scattered read wait event generally indicates waits related to full table scans or fast full index scans. With the speed of disks and added Flash Cache, less indexing is certainly a wave of the future (especially on Exadata and Exalogic), but not yet. As full table scans are pulled into memory, they are scattered throughout the buffer cache since it is generally unlikely that they fall into contiguous buffers. A large number of db file scattered read waits indicates that there may be missing or suppressed indexes. This could also be preferred because performing a full table scan may be more efficient than an index scan. Check to ensure full table scans are necessary when you see these waits. Try to cache small tables to avoid reading them into memory over and over again. Locate the data on disk systems that have either more disk caching or are buffered by the OS file system cache. DB_FILE_MULTIBLOCK_READ_COUNT (default is 128 for Windows or Linux) can make full scans faster (but it could also influence Oracle to do more of them). You can also partition tables and indexes so only a portion of the entire table or index is scanned. Slow file I/O (slow disks) can cause these waits. Correlated to each of the waits are the values for P1,P2,P3=file, block, blocks.

DB File Sequential Read

The db file sequential read event generally indicates a single block read (an index read, for example). A large number of db file sequential reads can indicate poor table joining orders or unselective indexing. This number will certainly be large (normally) for a high-transaction, well-tuned system. You should correlate this wait with other known issues within the Statspack or AWR Report such as inefficient SQL. Check to ensure index scans are necessary and check join orders for multiple table joins. The DB_CACHE_SIZE parameter also determines how often these waits show up; hash-area joins causing problems should show up in the PGA memory but similarly are memory hogs that can cause high wait numbers for sequential reads or can also show up as direct path read/write waits. Range scans can read a lot of blocks if the data is spread over many different blocks (density within blocks could cause issues with range scans, and reverse key indexes could be problematic with range scans). Loading data in a sorted manner can help range scans and reduce the number of blocks read. Partitioning can help, as it can eliminate some blocks. Look for unselective indexes that are causing a lot of db file sequential reads. Locate the data on disk systems that either have more disk caching and/or are buffered by OS file system cache. Correlated to the waits are the values for P1,P2,P3=file, block, blocks.

Buffer Busy Waits IDs and Meanings

A buffer busy wait is a wait for a buffer that is being used in an unsharable way. Buffer busy waits should not be greater than 1 percent. Check the buffer wait statistics section (or V$WAITSTAT) to find out where the wait is. Follow the solution in this section for buffer busy waits associated with segment header, UNDO header, UNDO block, data block, and index block. Correlated to the waits are the values for P1,P2,P3=file, block, id (see the list in the following table from My Oracle Support). Some people argue that buffer busy waits can be helped by adding more ITL slots (*initrans*), but the information shown in the table should make it evident that initrans can help in the appropriate situation (based on the correlated TX enqueue wait).

Reason Code (ID) (Block Class)			
<=8.0.6	**8.1.6–9.2**	**>=10.1**	**Reason**
1003	100	n/a	You want to NEW the block, but the block is currently being read by another session (most likely for undo).
1007	200	n/a	You want to NEW the block, but someone else is using the current copy so you have to wait for them to finish.
1010	230	n/a	Trying to get a buffer in CR/CRX mode, but a modification has started on the buffer that has not yet been completed.

1012	–	n/a	A modification is happening on a SCUR or XCUR buffer, but has not yet completed.
1012 (duplicate)	231	n/a	CR/CRX scan found the CURRENT block, but a modification has started on the buffer that has not yet been completed.
1013	130	n/a	Block is being read by another session and no other suitable block image was found, e.g., CR version, so you have to wait until the read is completed. This wait may also occur after a buffer cache assumed deadlock. The kernel can't get a buffer in a certain amount of time and assumes a deadlock. Therefore, it reads the CR version of the block. This should not have a negative impact on performance, and basically replaces a read from disk with a wait for another process to read it from disk, as the block needs to be read one way or another.
1014	110	n/a	You want the CURRENT block either shared or exclusive but the block is being read into cache by another session, so you have to wait until its read() is completed.
1014 (duplicate)	120	n/a	You want to get the block in current mode, but someone else is currently reading it into the cache. Wait for them to complete the read. This occurs during buffer lookup.
1016	210	n/a	The session wants the block in SCUR or XCUR mode. If this is a buffer exchange or the session is in discrete TX mode, the session waits for the first time and the second time escalates the block as a deadlock and so does not show up as waiting very long. In this case, the statistic "exchange deadlocks" is incremented, and you yield the CPU for the "buffer deadlock" wait event.
1016 (duplicate)	220	n/a	During buffer lookup for a CURRENT copy of a buffer, you have found the buffer but someone holds it in an incompatible mode so you have to wait.

Buffer Busy/Segment Header

If the wait is on a segment header, you can increase the free lists or freelist groups (this can even help single instances) or increase the PCTUSED-to-PCTFREE gap. Use Automatic Segment Space Management (ASSM). If you are using ASSM, Oracle does this for you by using bitmap free lists. ASSM also removes the need to set PCTUSED.

Buffer Busy/UNDO Header

If the wait is on an UNDO header, you can address this by adding rollback segments or increasing the size of the UNDO area.

Buffer Busy/UNDO Block

If the wait is on an UNDO block, you should try to commit more often (but not too often, or you'll get "log file sync" waits) or use larger rollback segments or UNDO areas. You may need to reduce the data density on the table driving this consistent read or increase the DB_CACHE_SIZE. Sizing initialization parameters is covered in Chapter 4.

Buffer Busy/Data Block

If the wait is on a data block, you can move "hot" data to another block to avoid this hot block or use smaller blocks (to reduce the number of rows per block, making it less "hot"). Check for scanning unselective data, and fix queries that are causing this or partition the table to eliminate unnecessary data scans. You can also increase initrans for a hot block (where users are simultaneously accessing the same block). Don't set initrans too high, as this takes 24 bytes per ITL slot, and you only need enough for the number of users accessing the *exact* same block for DML at the same time (usually something like 6 is more than enough). When a DML (INSERT/UPDATE/DELETE) occurs on a block, the lock byte is set in the block and any user accessing the record(s) being changed must check the ITL for information related to building the before image of the block. Oracle Database writes information into the block, including all users who are "interested" in the state of the block, in the interested transaction list (ITL). To decrease waits in this area, you increase the initrans, which creates the space in the block to allow multiple ITL slots (for multiple DML user access). The default is two ITL slots per index or data block. You can also increase the PCTFREE value on the table where this block exists (Oracle uses space in PCTFREE to add ITL slots up to the number specified by MAXTRANS when there are not enough slots prebuilt with the specified initrans). The value for MAXTRANS defaults to 255. Check for correlated TX4 enqueue waits as well. Each ITL slot takes about 24 bytes of space, so don't just set initrans to 255, or you may unnecessarily waste space.

Buffer Busy/Index Block

Use reverse key indexes and/or smaller blocks (to reduce the number of rows per block). Note that reverse key indexes can slow down range scans where you want the data to be sequentially located in the same block. Check for scanning unselective indexes (bad code/bad indexes). You may want to rebuild the index or partition the index to decrease the number of accesses to it. Increase initrans for a hot block (not too high, as this takes 24 bytes per slot) where multiple users are accessing the same block for DML (see "Tuning and Viewing at the Block Level" later in the chapter for more information on ITL). Check for correlated TX4 enqueue waits as well.

Latch Free

Latches are low-level queuing mechanisms (they're accurately referred to as *mutual exclusion mechanisms*) used to protect shared memory structures in the System Global Area (SGA). Latches are like locks on memory that are very quickly obtained and released. Latches are used to prevent concurrent access to a shared memory structure. If the latch is not available, a latch free miss is recorded. Most latch problems (waits, misses, and sleeps) are related to the failure to use bind variables (library cache mutex and shared pool latch), REDO generation issues (redo allocation latch), buffer cache contention issues (cache buffers lru chain), and hot blocks in the buffer cache (cache buffers chains). The library cache pin (protects cursors/SQL) and library cache latch (protects the library cache) are both replaced by *mutexes* (program objects that negotiate mutual exclusion among threads). There are also latch and mutex waits related to bugs; check My Oracle Support (Metalink) for bug reports if you suspect this is the case. If the latch miss ratio is greater than 0.5 percent, you should investigate the issue. If the latch miss ratio is greater than 2 percent and there are a large number of them, you may have a serious problem.

TIP
The library cache pin (protects cursors/SQL) and library cache latch (protects the library cache) are both replaced by mutexes (program objects that negotiate mutual exclusion among threads).

Cursor: pin S

The library cache pin (protects cursors/SQL) is replaced with a library cache mutex. The cursor: pin S wait event happens because one session is waiting on another to increment (or decrement) the *reference count* (an exclusive atomic update to the mutex structure itself) to keep track of its use. SQL with high execution counts can cause this. You can modify a statement and insert a comment into it so several statements do the same thing but are slightly different (this is the reverse of using bind variables where you're trying to use only one statement). Also, see the upcoming "Oracle Bugs" section for bugs related to this wait event. No blockers exist for this type of wait event. Correlated to each of the waits are the values for P1,P2,P3=idn, value, where. From value, you can get the session ID holding the mutex along with the reference count, and from where, you can locate where in the code the mutex was requested from; this value is helpful to Oracle Support.

Cursor: pin S wait on X

This wait event is more likely to occur than the cursor: pin S wait. If you are not reusing SQL, you may see many cursor: pin S wait on X waits. A session wants a mutex in S (share mode) on a cursor (SQL statement), but another session is holding that mutex in X (exclusive) mode. The session in S mode is usually waiting on a hard parse of a cursor by the other session, which is holding the mutex in exclusive X mode. You'll also see the reverse of this: cursor: pin X wait on S. Consider setting CURSOR_SHARING as described in Chapter 4. This may also occur if the shared pool is under a heavy load or undersized. Correlated to each of the waits are the values for P1,P2,P3=idn, value, where. From value, you can get the session ID holding the mutex along with the reference count, and from where, you can locate where in the code the mutex was requested from; this value is helpful to Oracle Support.

Library cache: mutex X

As of 11*g* (and continuing into 12*c*), the library cache latches are replaced by mutexes. Because there are *many* more of these structures now, the wait events become much more specific. The library cache mutex is generally used when you are pinning or unpinning code into the library cache. Limiting this behavior is key; this often includes using CURSOR_SHARING and appropriately sizing the shared pool. Under heavy loads, this wait event can exacerbate an already overloaded CPU. Correlated to each of the waits are the values for P1,P2,P3=idn, value, where. From value, you can get the session ID holding the mutex, and from where, you can locate where in the code the mutex was requested from; this value is helpful to Oracle Support.

Enqueue

An *enqueue* is a lock that protects a shared resource. Locks protect shared resources such as data in a record to prevent two people from updating the same data at the same time. Locks include a queuing mechanism, which is FIFO (first in, first out). Note that Oracle's latching mechanism is not FIFO. Enqueue waits usually point to the *ST* enqueue, the *HW* enqueue, and the *TX4* enqueue. The ST enqueue is used for space management and allocation for dictionary-managed tablespaces. Use locally managed tablespaces (LMTs), or try to preallocate extents or at least make the next extent larger for problematic dictionary-managed tablespaces. HW enqueues are used with the high-water mark of a segment; manually allocating the extents can circumvent this wait. TX4 is one of the most common enqueue waits.

TX4 enqueue waits are usually the result of one of three issues. The first issue involves duplicates in a unique index; you need to roll back to free the enqueue. The second concerns multiple updates to the same bitmap index fragment. Because a single bitmap fragment may contain multiple ROWIDs, you need to issue a commit or a rollback to free the enqueue when multiple users are trying to update the same fragment. The third and most likely issue arises when multiple users are updating the same block. If there are no free ITL slots when multiple users want to perform DML on a different row of the same block, a block-level lock could occur. You can easily avoid this scenario by increasing the initrans to create multiple ITL slots and/or by increasing the PCTFREE on the table (so Oracle can create the ITL slots as needed). You could also use a smaller block size so there are fewer rows in the block and thus greater concurrency on the data is allowed. Two other TX4 waits are also less prevalent: waiting for a prepared statement and inserting a row into an index where another transaction is splitting the index block. When users want to change the exact same record in a block, a TX6 lock results. Lastly, while you no longer get long-lasting TM locks, which are table locks when you don't index foreign keys, be sure to consider indexing foreign keys to avoid performance issues. Correlated to the transaction waits are the values for P1,P2,P3=lock type and mode, lockid1, lockid2 (a p2raw and a p3raw will also appear as p2/p3 in hex).

Log File Switch

If you see the log file switch wait event, then all commit requests are waiting for “logfile switch (archiving needed)” or “logfile switch (chkpt.Incomplete).” Ensure that the archive disk is not full or slow. DBWR may be too slow due to I/O. You may need to add more or larger REDO logs, and you may also need to add database writers if the DBWR is the problem.

Log Buffer Space

When a change is made, the change is copied to the log buffer. If the log buffer doesn’t get written fast enough to the redo logs, it can cause log buffer space issues (things get backed up). Space issues can also be a problem when you commit a very large amount of data at once (make the log buffer larger for these types of transactions). This wait usually occurs because you are writing to the log buffer faster than LGWR can write the buffer contents out to the redo logs, or because log switches are too slow, but *usually* not because the log buffer is too small (although this is also the case at times). To address this problem, increase the size of the log files, or get faster disks to write to, but, as a last resort, increase the size of the log buffer (in very large systems, it is not uncommon to see a log buffer in the tens of megabytes). You might even consider using solid-state disks or flash disks for their high speed for redo logs.

Log File Sync

When a user changes data in a record, the block the record is contained in is copied to the log buffer (many records/rows are contained in a block). When a commit or rollback is issued, the log buffer is flushed (copied) to the redo logs by the LGWR (Log Writer). The process of writing the changed data from the log buffer to the redo log and getting a confirmation that the write successfully occurred is called a *log file sync*. To reduce log file sync waits, try to commit more records at once (try to commit a batch of 50 instead of one at a time if possible). If you commit 50 records one at a time, 50 log file syncs need to occur. Put redo logs on a faster disk or alternate redo logs on different physical disk arrays to reduce the archiving effect on the LGWR (or use solid-state disks or flash disks). Don’t use RAID 5 because it is very slow for applications that write a lot; potentially consider using filesystem direct I/O or raw devices, which are very fast at writing information. Correlated to the waits are the values for P1,P2,P3=buffer#, unused, unused.

Global Cache CR Request

When using multiple instances (RAC/Grid/Cloud), a global cache cr request wait occurs when one instance is waiting for blocks from another instance’s cache (sent via the interconnect). This wait says that the current instance can’t find a consistent read (cr) version of a block in the local cache. If the block is not in the remote cache, then a db file sequential read wait will also follow this one. Tune the SQL that is causing large amounts of reads that get moved from node to node. Try to put users who are using the same blocks on the same instance so the blocks are not moved from instance to instance. Some non-Oracle application servers move the same process from node to node looking for the fastest node (unaware they are moving the same blocks from node to node). Pin these long processes to the same node. Potentially increase the size of the local cache if slow I/O combined with a small cache is the problem. Monitor V$CR_BLOCK_SERVER to see if an issue like reading UNDO segments has occurred. Correlated to the waits are the values for P1,P2,P3=file, block, lenum (look in V$LOCK_ELEMENT for the row where LOCK_ELEMENT_ADDR has the same value as lenum).

Log File Parallel Write

Put redo logs on fast disks (or use solid-state disks or flash disks) and don't use RAID 5. Separate redo logs from other data that might slow them down and ensure tablespaces are not left in hot backup mode. Correlated to the waits are the values for P1,P2,P3=files written to, blocks, requests.

DB File Parallel Write

Fix or speed up the operating system I/O and file system I/O by doing the database writing to database files. Correlated to the waits are the values for P1,P2,P3=files, blocks, requests/timeouts.

Direct Path Read

Oracle usually does direct path reads to read blocks directly into the PGA. Direct path reads are used for things such as sorting, parallel querying, and read-aheads. The time here does not always reflect the true wait time. This is usually an issue with the file I/O (see if any disks are I/O bound using OS utilities, as described in Chapter 16). Check for sorting on disk instead of in memory (located in the Instance Statistics section of the report, discussed later in the chapter). Using async I/O could reduce the elapsed time, although it may not reduce the wait time. Correlated to the waits are the values for P1,P2,P3=file, start block, number of blocks.

Direct Path Write

Direct path writes are used for such things as direct load operations, parallel DML, and writes to uncached LOBs (Large Objects). The time here does not always reflect the true wait time. This wait usually reflects an issue with the file I/O (see if any disks are I/O bound using OS utilities, as described in Chapter 16). Check for sorting on disk (located in the Instance Statistics section of the report). Using async I/O could reduce the elapsed time, although it may not reduce the wait time. Correlated to the waits are the values for P1,P2,P3=file, start block, number of blocks.

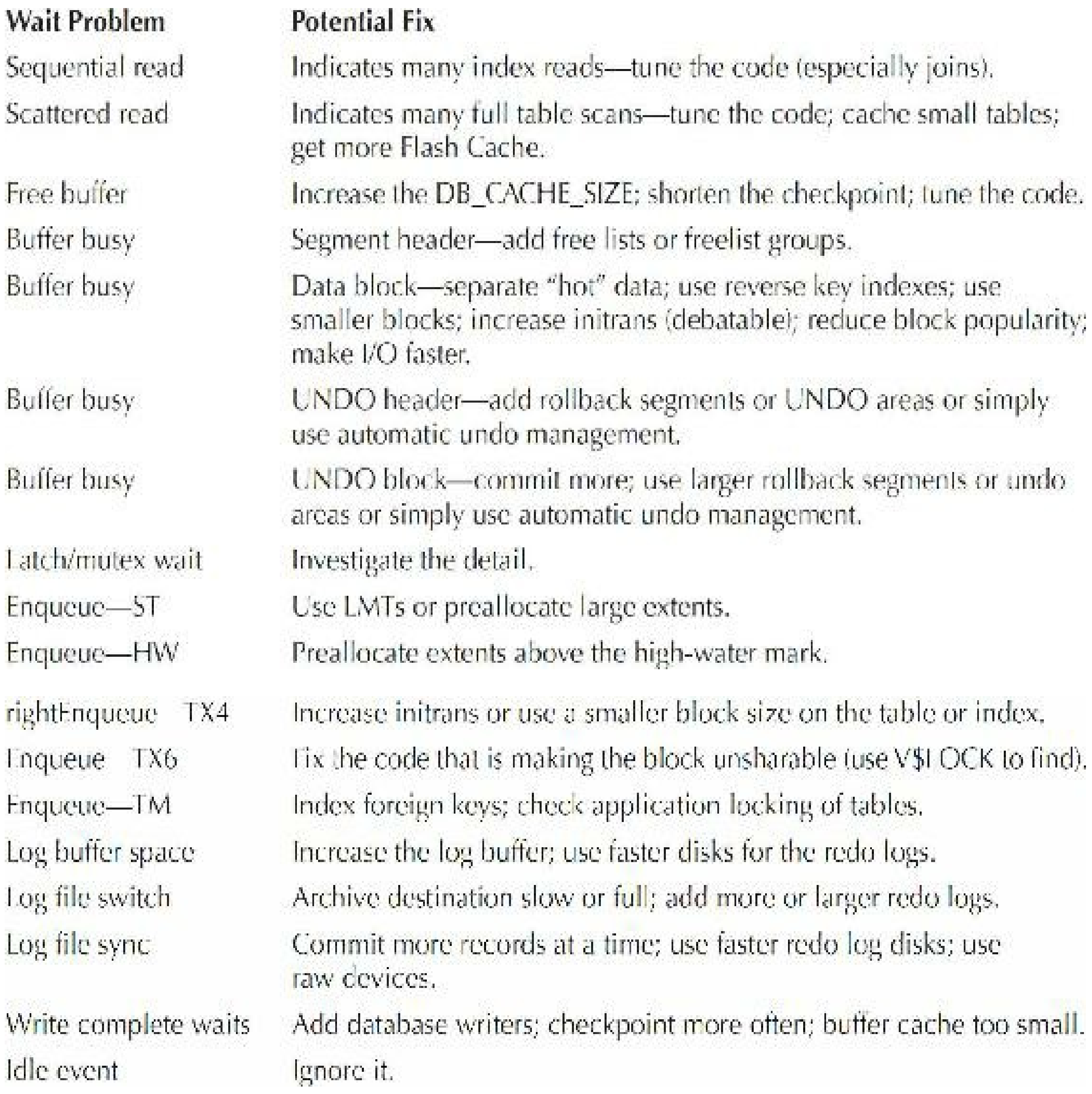
Async Disk I/O

Oracle is waiting for the completion of an async write or for an async slave to write. The problem could arise from I/O issues with the DBWR (Database Writer), the LGWR (Log Writer), the ARCH (Archiver), and the CKPT (checkpoint process), but is usually some file I/O issue.

Idle Events

Several idle wait events are listed after the output that can be ignored. Idle events are generally listed at the bottom of each section and include things like SQL*Net messages to or from the client and other background-related timings. Idle events are listed in the STATS$IDLE_EVENT table. In 12*c*R1, there were several idle events that were listed in the Top Waits, but that issue has been corrected in 12*c*R2.

Some of the most common wait problems and potential solutions are outlined here:



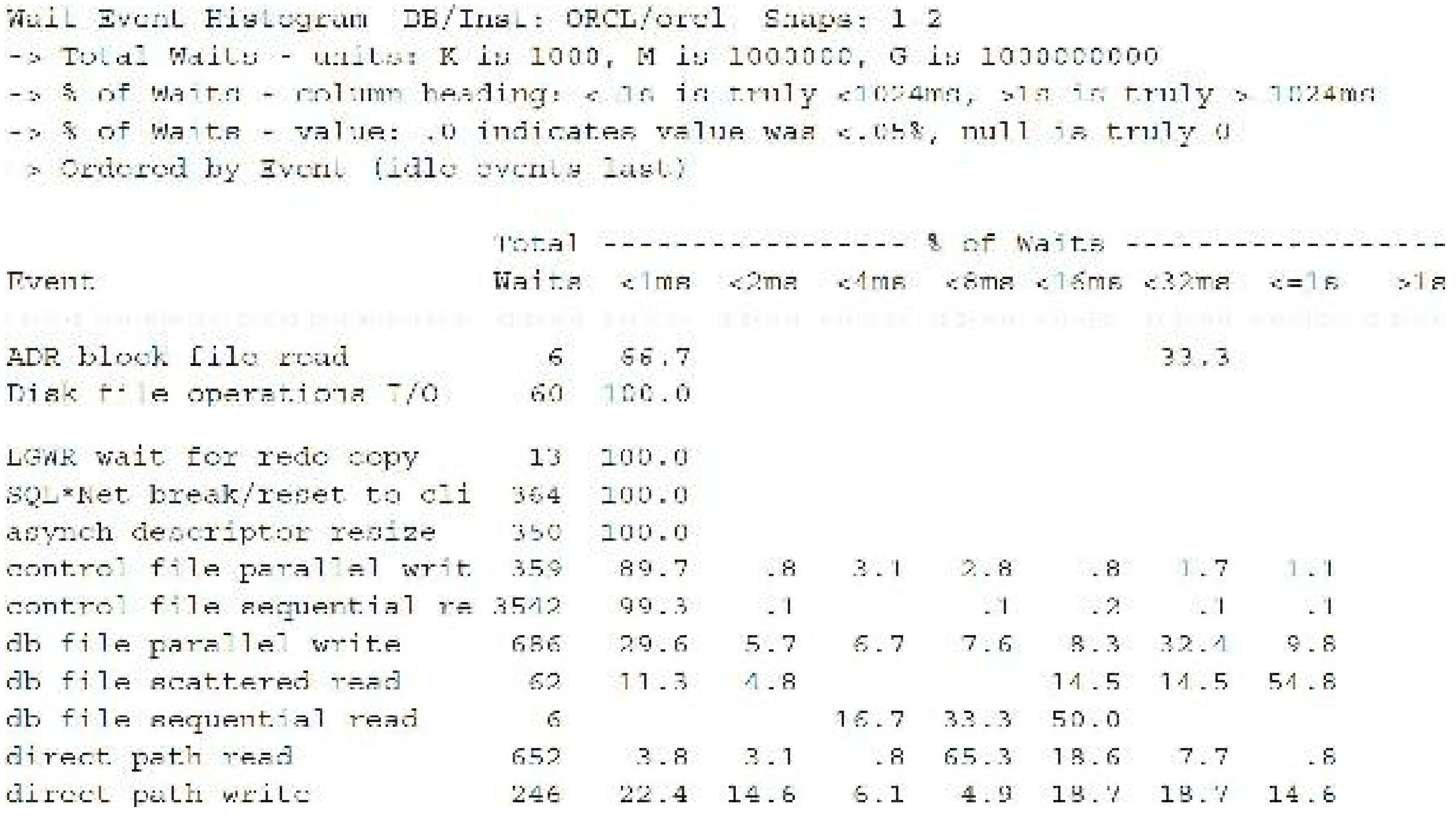
Wait Problem	Potential Fix
Sequential read	Indicates many index reads—tune the code (especially joins).
Scattered read	Indicates many full table scans—tune the code; cache small tables; get more Flash Cache.
Free buffer	Increase the DB_CACHE_SIZE; shorten the checkpoint; tune the code.
Buffer busy	Segment header—add free lists or freelist groups.
Buffer busy	Data block—separate "hot" data; use reverse key indexes; use smaller blocks; increase initrans (debatable); reduce block popularity; make I/O faster.
Buffer busy	UNDO header—add rollback segments or UNDO areas or simply use automatic undo management.
Buffer busy	UNDO block—commit more; use larger rollback segments or undo areas or simply use automatic undo management.
Latch/mutex wait	Investigate the detail.
Enqueue—ST	Use LMTs or preallocate large extents.
Enqueue—HW	Preallocate extents above the high-water mark.
rightEnqueue TX4	Increase initrans or use a smaller block size on the table or index.
Enqueue TX6	Fix the code that is making the block unsharable (use V$LOCK to find).
Enqueue—TM	Index foreign keys; check application locking of tables.
Log buffer space	Increase the log buffer; use faster disks for the redo logs.
Log file switch	Archive destination slow or full; add more or larger redo logs.
Log file sync	Commit more records at a time; use faster redo log disks; use raw devices.
Write complete waits	Add database writers; checkpoint more often; buffer cache too small.
Idle event	Ignore it.

Following are some common idle events (by type of idle event):

- Dispatcher timer (shared server idle event)
- Lock manager wait for remote message (RAC idle event)

- Pipe get (user process idle event)
- Pmon timer (background process idle event)
- PX idle wait (parallel query idle event)
- PX deq credit: need buffer (parallel query idle event)
- PX deq: execution msg (parallel query idle event)
- Rdbms ipc message (background process idle event)
- Smon timer (background process idle event)
- SQL*Net message from client (user process idle event)
- Virtual circuit status (shared server idle event)

Oracle 12*c* Statspack Report also has a Wait Event Histogram that shows how many of the waits fall into various buckets. The 12*c* AWR Report also shows three histogram sections (1 to 64 microseconds, 512 microseconds to 32 ms, 32 ms to 2 sec+), all the way down to 1 microsecond. This type of histogram is also provided for file I/O by tablespace to show if you are waiting on mostly short waits with a few very long waits or many medium-length waits. A partial listing for this is below:

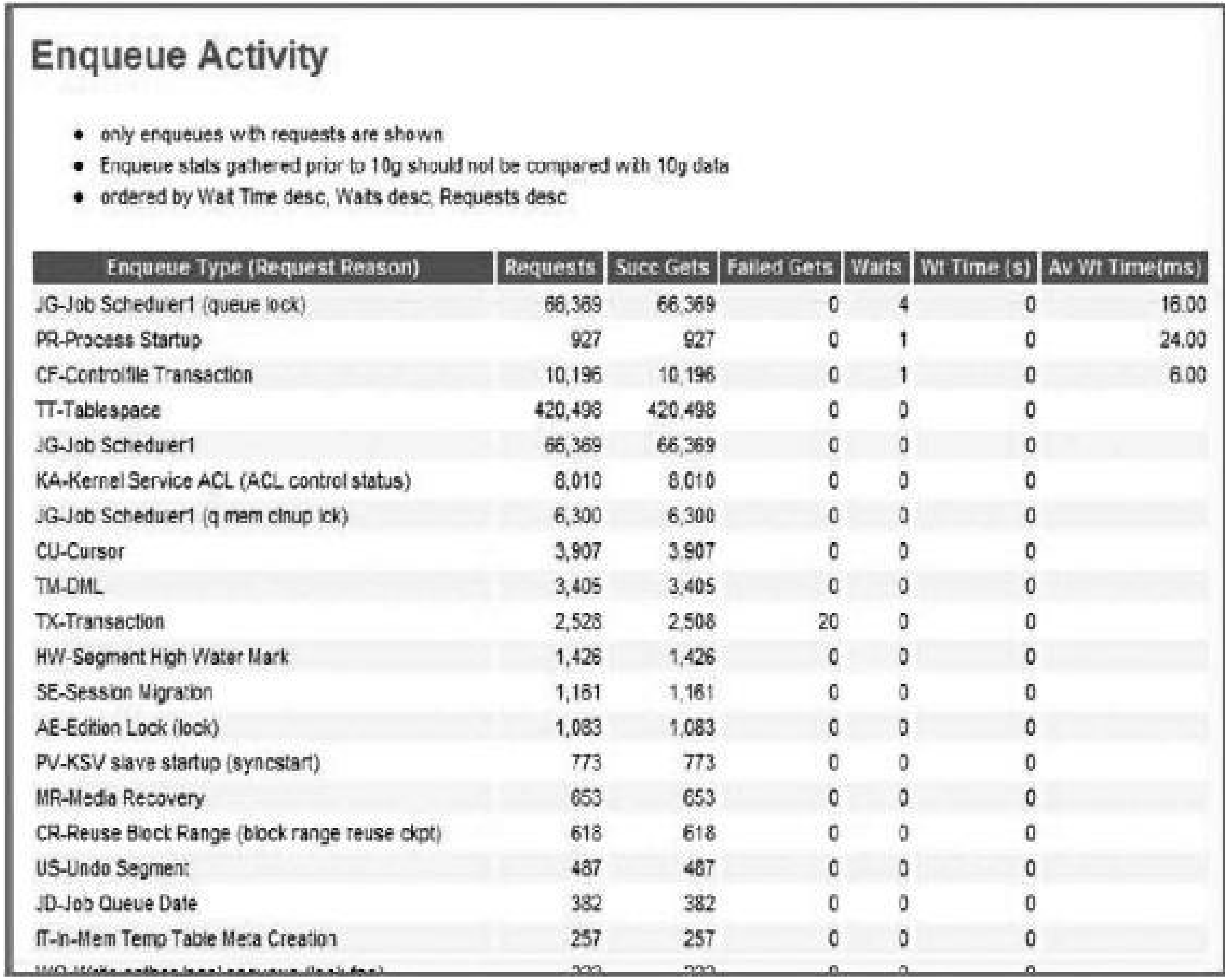


```
Wait Event Histogram  DB/Inst: ORCL/orcl  Snaps: 1 2
-> Total Waits - units: K is 1000, M is 1000000, G is 1000000000
-> % of Waits - column heading: <=1s is truly <1024ms, >1s is truly > 1024ms
-> % of Waits - value: .0 indicates value was <.05%, null is truly 0
-> Ordered by Event (idle events last)

                           Total ----------------- % of Waits ------------------
Event                      Waits  <1ms  <2ms  <4ms  <8ms <16ms <32ms  <=1s   >1s
-------------------------- ----- ----- ----- ----- ----- ----- ----- ----- -----
ADR block file read            6  66.7                               33.3
Disk file operations I/O      60 100.0

LGWR wait for redo copy       13 100.0
SQL*Net break/reset to cli   364 100.0
asynch descriptor resize     350 100.0
control file parallel writ   359  89.7    .8   3.1   2.8    .8   1.7   1.1
control file sequential re  3542  99.3    .1          .1    .2    .1    .1
db file parallel write       686  29.6   5.7   6.7   7.6   8.3  32.4   9.8
db file scattered read        62  11.3   4.8              14.5  14.5  54.8
db file sequential read        6              16.7  33.3  50.0
direct path read             652   3.8   3.1    .8  65.3  18.6   7.7    .8
direct path write            246  22.4  14.6   6.1   4.9  18.7  18.7  14.6
```

The Enqueue Activity section actually spells out the type of enqueue. For instance, if it is a TX Enqueue, it will now say TX Transaction or TM for DML. If that isn't good enough, it goes one step further and even tells you the type of transaction and then it gives the Requests, Gets, Waits, and a few other bits of helpful information. See Figure 14-9 for a look at this section in the AWR Report.



Enqueue Activity

- only enqueues with requests are shown
- Enqueue stats gathered prior to 10g should not be compared with 10g data
- ordered by Wait Time desc, Waits desc, Requests desc

Enqueue Type (Request Reason)	Requests	Succ Gets	Failed Gets	Waits	Wt Time (s)	Av Wt Time(ms)
JG-Job Scheduler1 (queue lock)	66,369	66,369	0	4	0	16.00
PR-Process Startup	927	927	0	1	0	24.00
CF-Controlfile Transaction	10,196	10,196	0	1	0	6.00
TT-Tablespace	420,498	420,498	0	0	0	
JG-Job Scheduler1	66,369	66,369	0	0	0	
KA-Kernel Service ACL (ACL control status)	8,010	8,010	0	0	0	
JG-Job Scheduler1 (q mem clnup lck)	6,300	6,300	0	0	0	
CU-Cursor	3,907	3,907	0	0	0	
TM-DML	3,405	3,405	0	0	0	
TX-Transaction	2,528	2,508	20	0	0	
HW-Segment High Water Mark	1,426	1,426	0	0	0	
SE-Session Migration	1,161	1,161	0	0	0	
AE-Edition Lock (lock)	1,083	1,083	0	0	0	
PV-KSV slave startup (syncstart)	773	773	0	0	0	
MR-Media Recovery	653	653	0	0	0	
CR-Reuse Block Range (block range reuse ckpt)	618	618	0	0	0	
US-Undo Segment	487	487	0	0	0	
JD-Job Queue Date	382	382	0	0	0	
IT-In-Mem Temp Table Meta Creation	257	257	0	0	0	

FIGURE 14-9. *The AWR Report Enqueue Activity section*

TIP
Tuning by wait events is one of the best possible reactive tuning methods.

Oracle Bugs

There are also Oracle bugs (Oracle used to call bugs *undocumented features*) to watch for that can cause a large number of wait events. Several bugs are related to the new mutex wait events. The first diagnostic step to resolve these issues is to apply the latest patchset available in your platform. Most of the buffer cache issues related to bugs can be avoided by applying these patchsets listed in the appropriate bug note. The following table summarizes the most common bugs related to Library Cache problems, possible workarounds, and the patchset that fixes the problem (it will be listed in the bug note when you go to it; thanks to My Oracle Support for these listings).

The following are "cursor: pin S" waits that are related to bugs and fixed in 11*g*/12*c*:

Bug	Fixed	Description
14380605	12.2	High "library cache lock," "cursor: pin S wait on X," and "library cache: mutex X" waits (affects 12.1, 11.2).
22500027	12.2	Database hang on 12cR1 with "cursor: pin S wait on X," "row cache lock," and "library cache load lock."
9499302	11.1.0.7.7, 11.2.0.2, 12.1.0.0	Improve concurrent mutex request handling.
9591812	11.2.0.2.2, 12.1.0.0	Wrong wait events in 11.2 ("cursor: mutex S" instead of "cursor: mutex X").

The following are "library cache: mutex X"–related bugs and fixed in 11*g*/12*c* (note that one is also solved above in 12.2):

8431767	12.2	High "library cache: mutex X" when using Application Context.
21759047	12.2	High "library cache: mutex X" when many sessions executing against a partitioned table.
8860198	11.2.0.2, 12.1.0.0	High "library cache: mutex X" waits using XMLType.
10417716	12.1.0.0, 11.2.0.2 Exadata	Mutex X waits in 11g on an instance with heavy Java usage.
11818335	11.2.0.2.2, 12.1.0.0	Additional support for bug 10411618 to allow dynamic mutex wait scheme changes.
10204505	12.1.0.0	SGA autotune can cause row cache misses, Library Cache reloads, and parsing.

10632113	12.1.0.0	OLS calls cause mutex contention even with low number of concurrent users.
9530750	12.1.0.0	High waits for "library cache: mutex X" for cursor build lock.
10086843	12.1.0.0	Recursive SQL cursors not reused; PMON crashes instance with ORA-600 [kglLockOwnersListDelete].
7352775	11.2.0.2, 12.1.0.0	Many child cursors when PARALLEL_INSTANCE_GROUP set incorrectly.
9239863	11.2.0.2, 12.1.0.0	Excessive "library cache: mutex X" contention on hot objects.
7317117	11.2.0.1	Unnecessary "library cache: mutex X" waits on LOB operations.

The Life of an Oracle Shadow Process

Here is a breakdown of the life of an Oracle shadow process and where it might be waiting as it lives. This table is adapted from Oracle Doc ID 61998.1 and shows what's happening in less than one second within Oracle.

State	Notes
IDLE	Waits for "SQL*Net message from client" (waiting for the user). Receives the SQL*Net packet requesting PARSE/EXECUTE of a statement.
ON CPU	Decodes the SQL*Net packet.
WAITING	Waits for "latch free" to obtain the library cache mutex. Gets the library cache mutex.
ON CPU	Scans the shared pool for the SQL statement, finds match, frees mutex (if the statement, cursor, is already in memory, it does—"cursor: pin S"), sets up links to the shared cursor, etc., and begins to execute.
WAITING	Waits for "db file sequential read"; you need a block not in the cache (waits for I/O).
ON CPU	Block read from disk complete. Execution continues. Construct SQL*Net packet with first row of data to send to client and sends.
WAITING	Waits on "SQL*Net message from client" for acknowledgment packet received.
IDLE	Waits for next SQL*Net message from client.

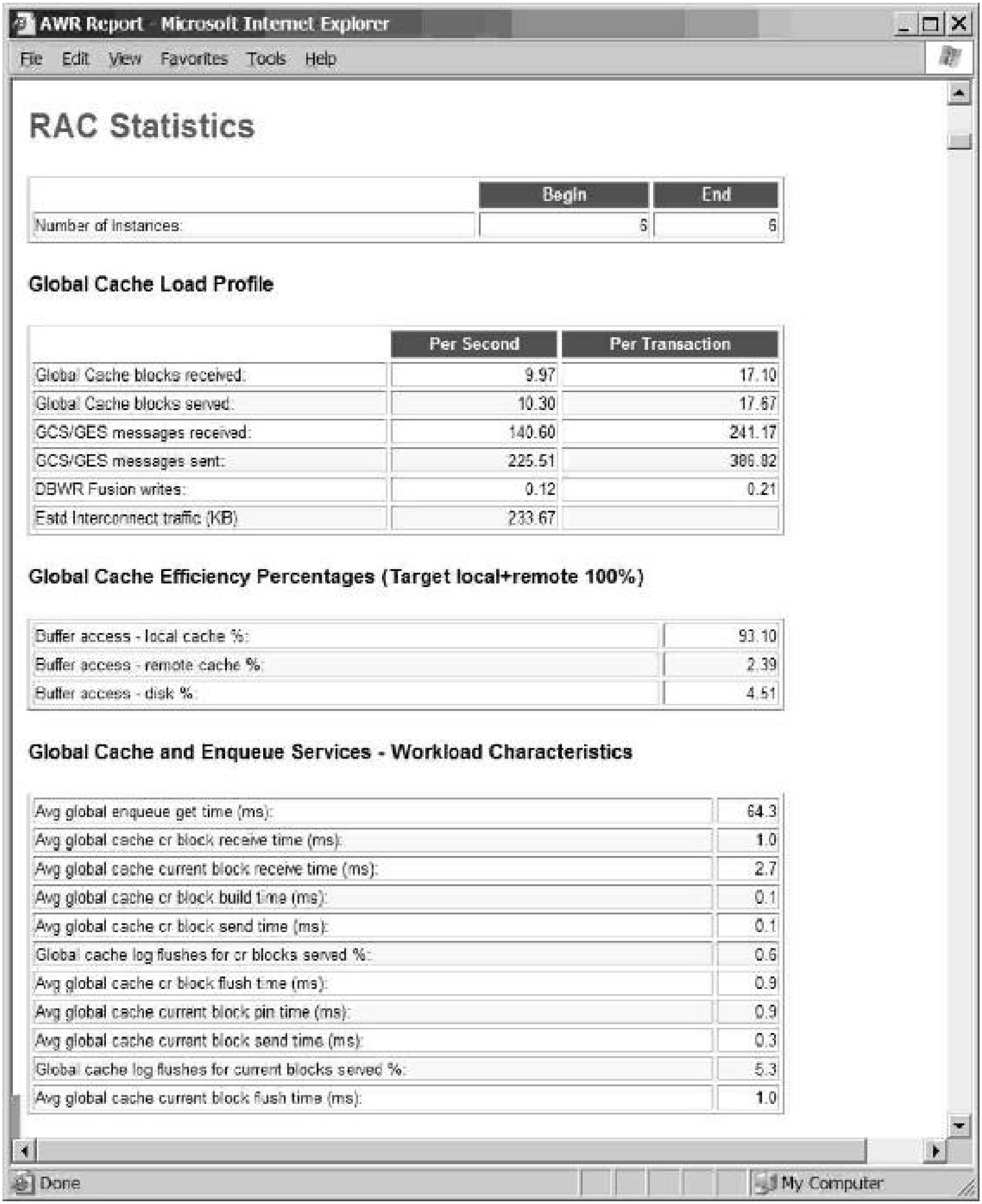
RAC Wait Events and Interconnect Statistics

The RAC events are listed next in the report if you are running RAC (multiple instances). As stated earlier, you need to run Statspack or the AWR Report for *each* instance that you have. For Statspack, you run the `statspack.snap` procedure and `spreport.sql` script on each node you want to monitor to compare to other instances. The greatest comparison report is one from another node that accesses the same database. I cover more on tuning RAC in Chapter 11 and will not repeat that information here. It's very important to remember that single-instance tuning should be performed before attempting to tune the processes that communicate via the cluster interconnect. In other words, tune the system as a single instance before you move it to RAC. For the AWR on RAC, you can run `awrgdrpt.sql` to get a global report. However, according to `spdoc.txt`, section 4.2, for Statspack, it works only for a single database instance.

Some of the top wait events that you may encounter are listed briefly next and covered in more detail in Chapter 11. The top global cache (gc) waits to look for include the following:

- **gc (global cache) current block busy** Happens when an instance requests a CURR data block (wants to do some DML) and the block to be transferred is in use.
- **gc (global cache) buffer busy** A wait event that occurs whenever a session has to wait for an ongoing operation on the resource to complete because the block is in use.
- **gc (global cache) cr request** Happens when an instance requests a CR data block and the block to be transferred hasn't arrived at the requesting instance. This is the one I see the most, and it's usually because the SQL is poorly tuned and *many* index blocks are being moved back and forth between instances.

Figure 14-10 shows the AWR Report RAC Statistics section. You can see that there are six instances (nodes) in this cluster. You can also see things like the number of blocks sent/received as well as how many of the blocks are being accessed in the local cache (93.1 percent) as opposed to on the disk or in another instance. As you would guess, accessing blocks in the local cache is faster, but accessing one of the remote caches on one of the other nodes is almost always faster (given a fast enough interconnect and no saturation of the interconnect) than going to disk (more on this in Chapter 11).


AWR Report - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Done
My Computer

RAC Statistics

	Begin	End
Number of Instances:	6	6

Global Cache Load Profile

	Per Second	Per Transaction
Global Cache blocks received:	9.97	17.10
Global Cache blocks served:	10.30	17.67
GCS/GES messages received:	140.60	241.17
GCS/GES messages sent:	225.51	386.82
DBWR Fusion writes:	0.12	0.21
Estd Interconnect traffic (KB)	233.67	

Global Cache Efficiency Percentages (Target local+remote 100%)

Buffer access - local cache %:	93.10
Buffer access - remote cache %:	2.39
Buffer access - disk %:	4.51

Global Cache and Enqueue Services - Workload Characteristics

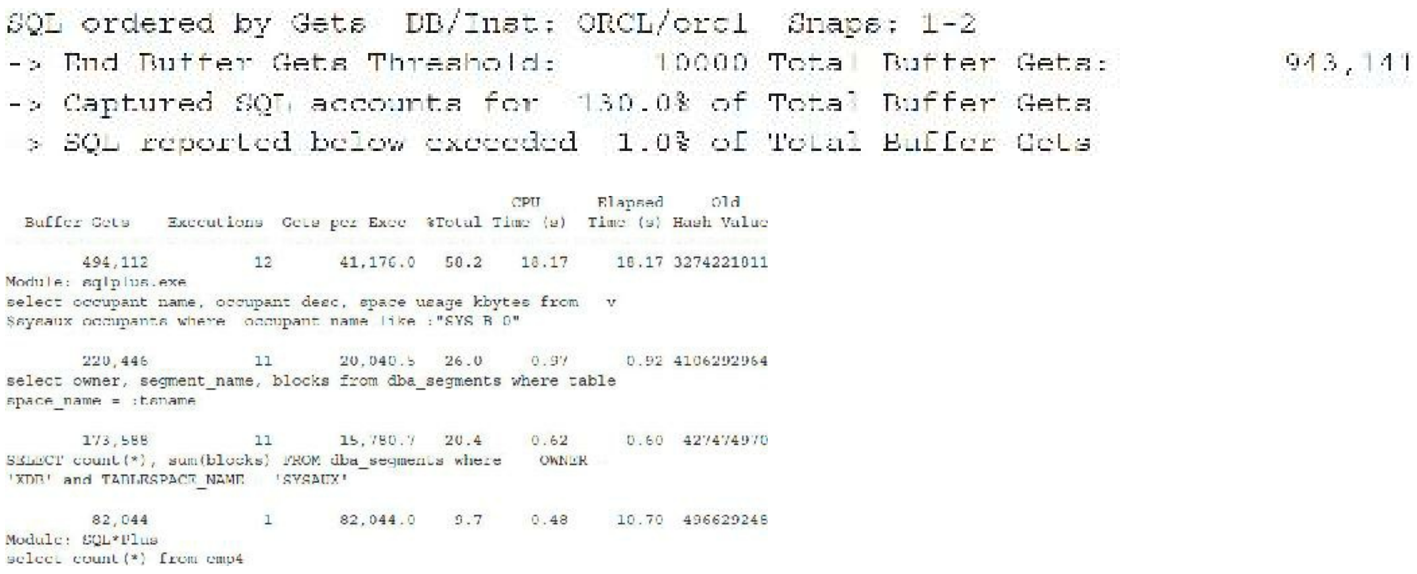
Avg global enqueue get time (ms):	64.3
Avg global cache cr block receive time (ms):	1.0
Avg global cache current block receive time (ms):	2.7
Avg global cache cr block build time (ms):	0.1
Avg global cache cr block send time (ms):	0.1
Global cache log flushes for cr blocks served %:	0.6
Avg global cache cr block flush time (ms):	0.9
Avg global cache current block pin time (ms):	0.9
Avg global cache current block send time (ms):	0.3
Global cache log flushes for current blocks served %:	5.3
Avg global cache current block flush time (ms):	1.0

FIGURE 14-10. *The AWR Report RAC Statistics section*

Top SQL Statements

The most resource-intensive SQL statements in the database are listed next, in descending order of CPU, Elapsed Time, Buffer Gets (or Gets), Disk Reads (or Reads), Executions, Parse Calls, Sharable Memory, and Version Count. Depending on where the problem is, you have plenty of places to investigate. If you saw many buffer gets as the top wait event (db file sequential reads), then you would investigate the statements in the descending order of buffer gets (focusing on the worst ones that are at the top of the list). Because the buffer gets statistic is cumulative, the query with the most buffer gets may not be the worst-performing query in the database; it may just have been executed enough times to earn the highest ranking. Compare the cumulative number of buffer gets to the cumulative number of disk reads for the queries; if the numbers are close, then you should evaluate the EXPLAIN PLAN for the query to find out why it is performing so many disk reads. Near the end of the 12*c*R2 AWR Report (discussed later in the chapter), Oracle has even provided Top SQL with Top Events (correlating the two).

If the disk reads are not high but the buffer gets are high and the executions are low, then the query is either using a bad index or performing a join in the wrong order. This is also a system problem, as you are using a lot of your memory unnecessarily. Here is an example of this listing:



```
SQL ordered by Gets  DB/Inst: ORCL/orcl  Snaps: 1-2
-> End Buffer Gets Threshold:     10000 Total Buffer Gets:         943,141
-> Captured SQL accounts for  130.0% of Total Buffer Gets
-> SQL reported below exceeded  1.0% of Total Buffer Gets

                                                     CPU      Elapsed     Old
  Buffer Gets    Executions  Gets per Exec  %Total Time (s)  Time (s) Hash Value

       494,112           12       41,176.0   50.2    18.17      18.17 3274221011
Module: sqlplus.exe
select occupant name, occupant desc, space usage kbytes from   v
$sysaux occupants where  occupant name like :"SYS B 0"

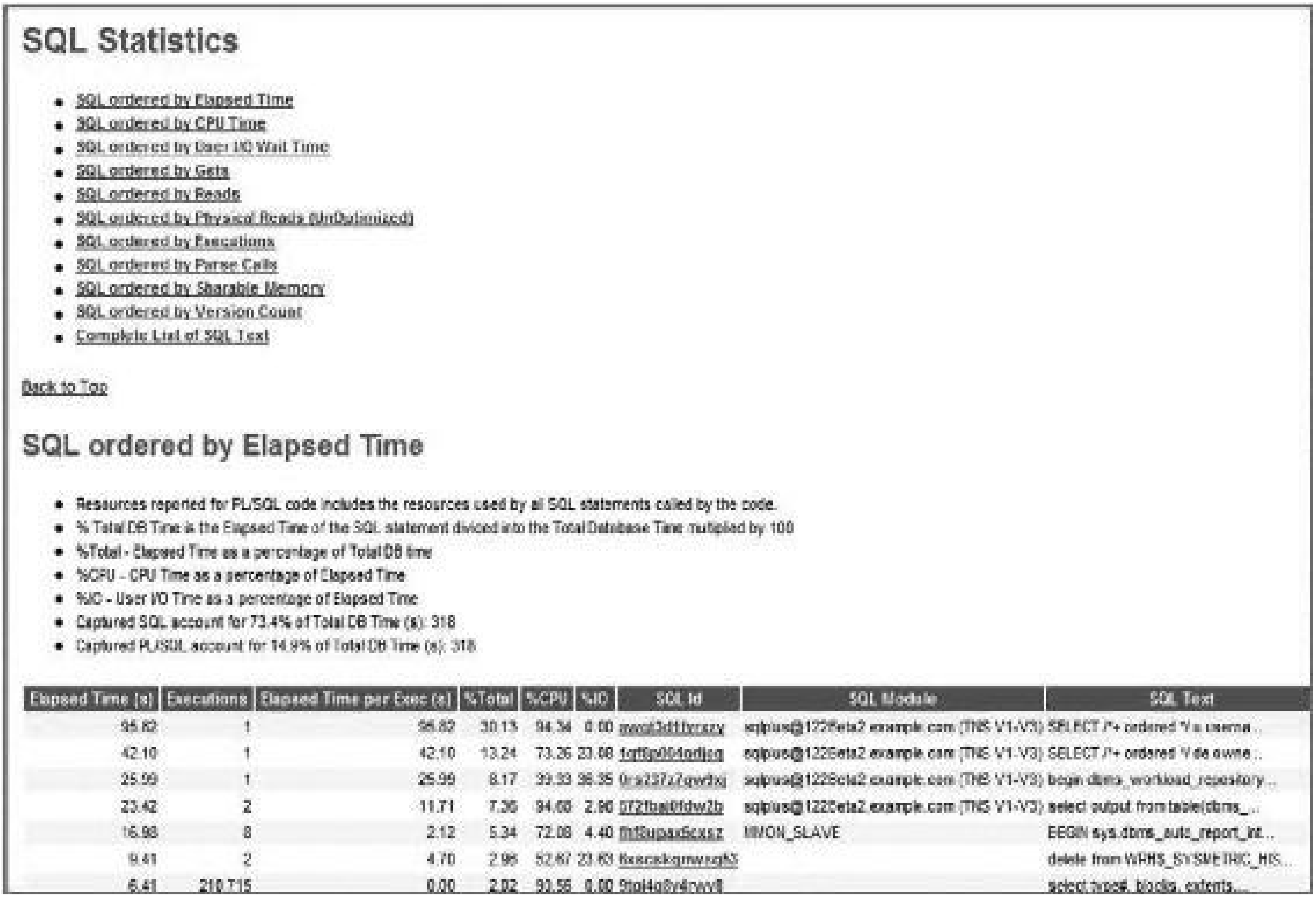
       220,446           11       20,040.5   26.0     0.97       0.92 4106292964
select owner, segment_name, blocks from dba_segments where table
space_name = :tsname

       173,588           11       15,780.7   20.4     0.62       0.60  427474970
SELECT count(*), sum(blocks) FROM dba_segments where    OWNER
'XDB' and TABLESPACE_NAME   'SYSAUX'

        82,044            1       82,044.0    9.7     0.48      10.70  496629248
Module: SQL*Plus
select count(*) from emp4
```

You may also see the internal Oracle data dictionary operations listed as part of these sections. Your application commands commonly account for the great majority of the buffer gets and disk reads performed by the database. If the shared pool is flushed between the execution times of the two snapshots, the SQL portion of the output report will not necessarily contain the most resource-intensive SQL executed during the period. V$SQL shows SQL for multiple users with the same statement, and it shows child cursors; V$SQL_PLAN_STATISTICS shows the execution stats for each cached cursor; and V$SQL_PLAN_STATISTICS_ALL shows the joins plan and stats and many other performance-related statistics.

The AWR Report has many Top SQL sections. Oracle now shows how many of the Physical Reads (or Reads) need to be optimized; see the SQL ordered by Physical Reads (UnOptimized) section. An example of the SQL Statistics section is shown in Figure 14-11. It includes the following subsections:



SQL Statistics

- SQL ordered by Elapsed Time
- SQL ordered by CPU Time
- SQL ordered by User I/O Wait Time
- SQL ordered by Gets
- SQL ordered by Reads
- SQL ordered by Physical Reads (UnOptimized)
- SQL ordered by Executions
- SQL ordered by Parse Calls
- SQL ordered by Sharable Memory
- SQL ordered by Version Count
- Complete List of SQL Text

Back to Top

SQL ordered by Elapsed Time

- Resources reported for PL/SQL code includes the resources used by all SQL statements called by the code.
- % Total DB Time is the Elapsed Time of the SQL statement divided into the Total Database Time multiplied by 100
- %Total - Elapsed Time as a percentage of Total DB time
- %CPU - CPU Time as a percentage of Elapsed Time
- %IO - User I/O Time as a percentage of Elapsed Time
- Captured SQL account for 73.4% of Total DB Time (s): 318
- Captured PL/SQL account for 14.9% of Total DB Time (s): 318

Elapsed Time (s)	Executions	Elapsed Time per Exec (s)	%Total	%CPU	%IO	SQL Id	SQL Module	SQL Text
95.82	1	95.82	30.13	94.34	0.00	mwgt3d1fyrxzy	sqlplus@122Beta2.example.com (TNS V1-V3)	SELECT /*+ ordered */ u.userna...
42.10	1	42.10	13.24	73.26	23.08	fqff6p084adjsq	sqlplus@122Beta2.example.com (TNS V1-V3)	SELECT /*+ ordered */ do.owne...
25.99	1	25.99	8.17	39.33	36.35	0rs237z7qwdxq	sqlplus@122Beta2.example.com (TNS V1-V3)	begin dbms_workload_repository...
23.42	2	11.71	7.36	94.68	2.96	072fbal0fdw2b	sqlplus@122Beta2.example.com (TNS V1-V3)	select output from table(dbms_...
16.98	8	2.12	5.34	72.08	4.40	fhf8upax6cxsz	MMON_SLAVE	BEGIN sys.dbms_auto_report_int...
9.41	2	4.70	2.96	52.67	23.63	6xxcskqmwsqh3		delete from WRH$_SYSMETRIC_HIS...
6.41	210,715	0.00	2.02	90.56	0.00	9tgl4g8y4rwy8		select type#, blocks, extents,...

FIGURE 14-11. *The AWR Report SQL Statistics section*

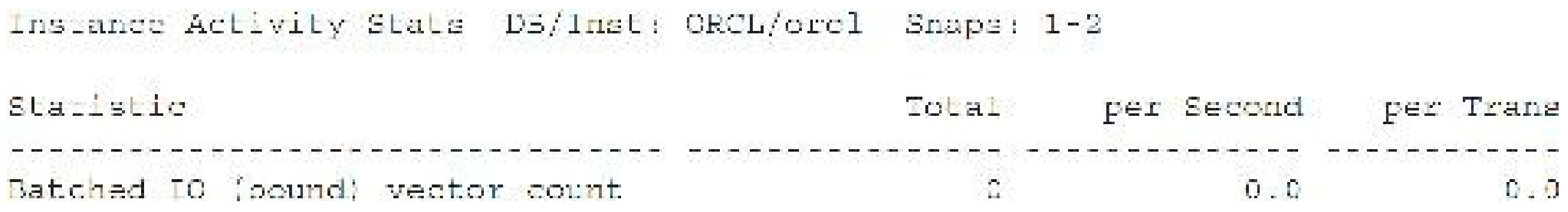
- SQL ordered by Elapsed Time
- SQL ordered by CPU Time
- SQL ordered by User I/O Wait Time
- SQL ordered by Gets (buffer gets—usually index reads)
- SQL ordered by Reads (physical reads)
- SQL ordered by Physical Reads (UnOptimized)
- SQL ordered by Executions
- SQL ordered by Parse Calls
- SQL ordered by Sharable Memory
- SQL ordered by Version Count
- Complete List of SQL Text (huge!)

TIP

Tuning the top 25 buffer get and top 25 physical get queries can yield system performance gains of anywhere from 5 percent to 5000+ percent. The SQL section of the Statspack Report tells you which queries to consider tuning first. The top 10 SQL statements should not be substantially more than 10 percent of all of your buffer gets or disk reads. Near the end of the new 12c AWR Report, the Top SQL is connected with the Top Events to help you even more!

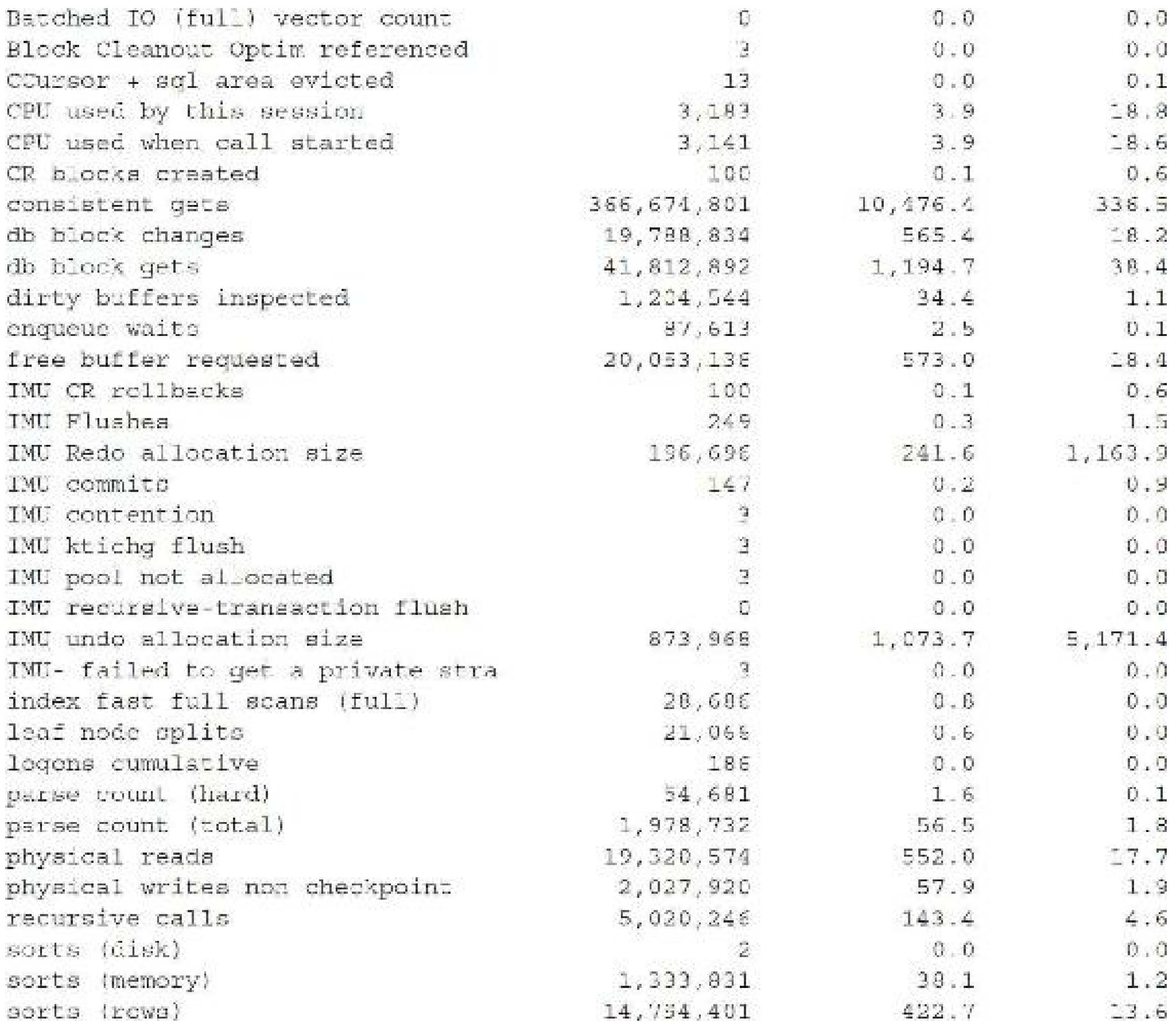
Instance Activity Statistics

Following the SQL statement listing, you will see the list of changes to statistics from V$SYSSTAT. Entitled “Instance Activity Stats,” the V$SYSSTAT statistics are useful for identifying performance issues not shown in the prior sections. Here is a partial Statspack listing with some of the key sections listed. Note the excellent IMU (in memory undo) statistics; IMUs are covered in “Tuning and Viewing at the Block Level,” later in this chapter.



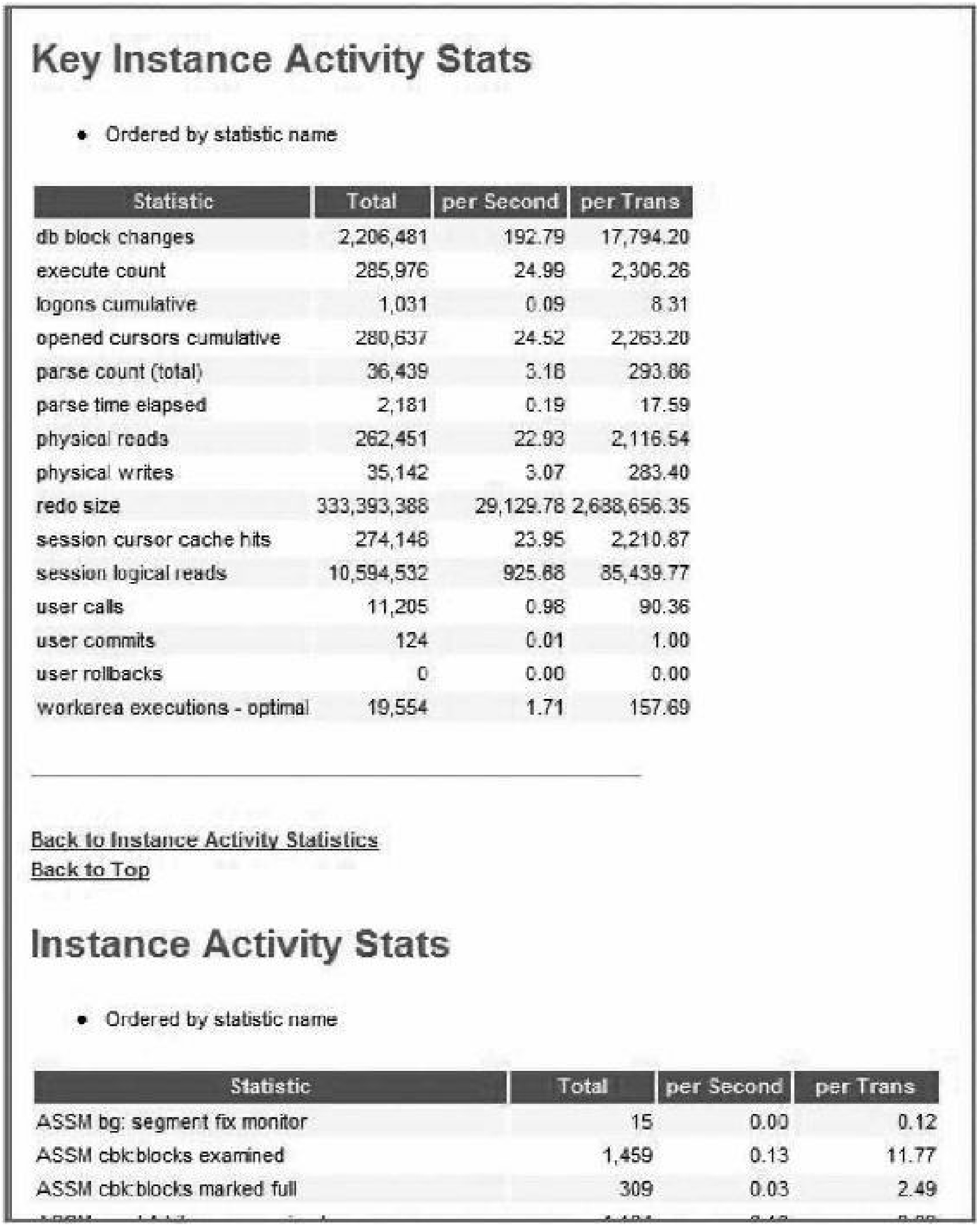
```
Instance Activity Stats  DB/Inst: ORCL/orcl  Snaps: 1-2

Statistic                                      Total     per Second    per Trans
--------------------------------- ------------------ -------------- ------------
Batched IO (bound) vector count                    2            0.0          0.0
```



```
Batched IO (full) vector count                     0          0.0          0.0
Block Cleanout Optim referenced                    3          0.0          0.0
CCursor + sql area evicted                        13          0.0          0.1
CPU used by this session                       3,183          3.9         18.8
CPU used when call started                     3,141          3.9         18.6
CR blocks created                                100          0.1          0.6
consistent gets                          366,674,801     10,476.4        336.5
db block changes                          19,788,834        565.4         18.2
db block gets                             41,812,892      1,194.7         38.4
dirty buffers inspected                    1,204,544         34.4          1.1
enqueue waits                                 87,613          2.5          0.1
free buffer requested                     20,053,136        573.0         18.4
IMU CR rollbacks                                 100          0.1          0.6
IMU Flushes                                      249          0.3          1.5
IMU Redo allocation size                     196,696        241.6      1,163.9
IMU commits                                      147          0.2          0.9
IMU contention                                     3          0.0          0.0
IMU ktichg flush                                   3          0.0          0.0
IMU pool not allocated                             2          0.0          0.0
IMU recursive-transaction flush                    0          0.0          0.0
IMU undo allocation size                     873,968      1,073.7      5,171.4
IMU- failed to get a private stra                  3          0.0          0.0
index fast full scans (full)                  28,686          0.8          0.0
leaf node splits                              21,066          0.6          0.0
logons cumulative                                186          0.0          0.0
parse count (hard)                            54,681          1.6          0.1
parse count (total)                        1,978,732         56.5          1.8
physical reads                            19,320,574        552.0         17.7
physical writes non checkpoint             2,027,920         57.9          1.9
recursive calls                            5,020,246        143.4          4.6
sorts (disk)                                       2          0.0          0.0
sorts (memory)                             1,333,831         38.1          1.2
sorts (rows)                              14,794,401        422.7         13.6
```

These statistics can also be found in the AWR Report. In Figure 14-12, you can see that in 12*c*R2 the AWR Report now presents a helpful Key Instance Activity Stats section before the full list of stats in the Instance Activity Stats section.



Key Instance Activity Stats

- Ordered by statistic name

Statistic	Total	per Second	per Trans
db block changes	2,206,481	192.79	17,794.20
execute count	285,976	24.99	2,306.26
logons cumulative	1,031	0.09	8.31
opened cursors cumulative	280,637	24.52	2,263.20
parse count (total)	36,439	3.18	293.86
parse time elapsed	2,181	0.19	17.59
physical reads	262,451	22.93	2,116.54
physical writes	35,142	3.07	283.40
redo size	333,393,388	29,129.78	2,688,656.35
session cursor cache hits	274,148	23.95	2,210.87
session logical reads	10,594,532	925.68	85,439.77
user calls	11,205	0.98	90.36
user commits	124	0.01	1.00
user rollbacks	0	0.00	0.00
workarea executions - optimal	19,554	1.71	157.69

Back to Instance Activity Statistics
Back to Top

Instance Activity Stats

- Ordered by statistic name

Statistic	Total	per Second	per Trans
ASSM bg: segment fix monitor	15	0.00	0.12
ASSM cbk:blocks examined	1,459	0.13	11.77
ASSM cbk:blocks marked full	309	0.03	2.49

FIGURE 14-12. *The AWR Report Key Instance Activity Stats and Instance Activity Stats (all)*

Things to Look for in the Instance Statistics Section

Compare the number of sorts performed on disk to the number performed in memory; increase the MEMORY_TARGET (if used and if needed to be increased) and the minimum PGA_AGGREGATE_TARGET (or SORT_AREA_SIZE for earlier versions) or maximum PGA_AGGREGATE_LIMIT (in 12*c*R2) to reduce disk sorts (see Chapter 4 for more information). If physical reads are high, you are probably performing full table scans. If there is a significant number of full table scans of large tables, evaluate the most-used queries and try to reduce this inefficiency by using indexes. A large number for consistent gets signals potentially over-indexed or nonselective index use. If dirty buffers inspected is high (over 5 percent) relative to free buffer requested, the memory parameters for the SGA may be too small (see Chapter 4 for additional use of these parameters and settings), or you may not be checkpointing often enough. If leaf node splits are high, consider rebuilding indexes that have grown and become fragmented if they are causing a performance degradation. The following sections look at a few of these scenarios.

The following listing shows the applicable rows from this section of the report:

```
Statistic                                        Total     per Second     per Trans
-------------------------------- ------------------ -------------- -------------
sorts (disk)                                         2            0.0           0.0
sorts (memory)                                   3,062            3.8          18.1
sorts (rows)                                   134,855          165.7         798.0
table scan rows gotten                      30,089,991       36,965.6     178,047.3
table scans (direct read)                            1            0.0           0.0
table scans (long tables)                            5            0.0           0.0
table scans (short tables)                       1,285            1.6           7.6
```

In the preceding example, the database performed almost all sorts in memory during the reporting interval. Of the table scans performed, most were of very small tables. The table scans (short tables) are tables that are smaller than 2 percent of the buffer cache in Oracle 12*c*.

TIP

If many sorts are being performed to disk (greater than 1–5 percent of the total number of rows being sorted), you may need to increase the initialization parameters associated with sorting. See Chapter 4 for more information on these.

Key Areas to Consider

A few key areas to consider are explained in this section:

- **Consistent gets** The number of blocks read from the buffer cache for queries without the SELECT FOR UPDATE clause. The value for this statistic plus the value of the "db block gets" statistic constitute what is referred to as *logical reads* (all reads cached in memory). These are usually the CURRENT version of the block, but can also be a Consistent Read (CR) version.
- **DB block gets** The number of blocks read in the buffer cache that were accessed for INSERT, UPDATE, DELETE, or SELECT FOR UPDATE statements. These are CURRENT versions of the block. When these are changed, they are reflected in the "db block changes" value.
- **Physical reads** The number of data blocks that were not read from the buffer cache. This could

be reads from disks, OS cache, or disk cache to satisfy a SELECT, SELECT FOR UPDATE, INSERT, UPDATE, or DELETE statement.

By adding the "consistent gets" and "db block gets," you get the number of logical reads (memory reads). Using the following equation, you can calculate the buffer (data) cache hit ratio:

```
Hit Ratio = (Logical Reads - Physical Reads) / Logical Reads
```

TIP

The buffer cache hit ratio should be greater than 95 percent. If it is less than 95 percent, you should consider increasing the size of the data cache by increasing the MEMORY_TARGET (if used) or increasing the minimum setting for the DB_CACHE_SIZE initialization parameter (given that physical memory is available to do this).

- **Dirty buffers inspected** The number of dirty (modified) data buffers that were aged out on the least recently used (LRU) list. A value here indicates that the DBWR is not keeping up. You may benefit by adding more DBWRs.

TIP

If "dirty buffers inspected" is greater than 1–2 percent of "free buffer requested," consider increasing the database writers as detailed in Chapter 3.

- **Enqueue waits (timeouts)** The number of times that an enqueue (lock) was requested and the specific one that was requested was not available. If this statistic is greater than 0, investigate the locking issues.
- **Free buffer inspected** Includes buffers that were skipped because they were dirty, pinned, or busy. If you subtract those values ("dirty buffers inspected" and "buffer is pinned count") from this statistic, it leaves the buffers that could not be reused due to latch contention. A large number would be a good indicator of a too-small buffer cache. There is also a "free buffer requested" section that you can compare to this.
- **Parse count** The number of times a SQL statement was parsed (total count). You can also check the version count of the SQL section to correlate with this one.
- **Recursive calls** The number of recursive calls to the database. This type of call occurs for a few reasons—misses in the Dictionary Cache, dynamic storage extension, and when PL/SQL statements are executed. Generally, if the number of recursive calls is more than four per process, you should check the Dictionary Cache hit ratio, and see if there are tables or indexes with a large number of extents. Unless you have PL/SQL, the ratio of recursive calls to user calls should be 10 percent or less.

- **REDO size** The size in bytes of the amount of REDO information that was written to the redo logs. This information can be used to help size the redo logs. Additional information on REDO sizing is in Chapter 3.
- **Sorts (disk)** The number of sorts that were unable to be performed in memory and, therefore, required the creation of a TEMP segment in the temporary tablespace. This statistic divided by the sorts (memory) should not be greater than 5 percent. If it is, you should increase the SORT_AREA_SIZE (if used) or PGA_AGGREGATE_TARGET (note that you may need to increase MEMORY_TARGET if you don't set a minimum value for PGA_AGGREGATE_TARGET or you may need to increase MEMORY_TARGET if you increase the PGA_AGGREGATE_TARGET) parameter in the `init.ora` file.
- **Sorts (memory)** The number of sorts that were performed in memory.
- **Sorts (rows)** The total number of rows that were sorted.

TIP
The "sorts (disk)" statistic divided by the "sorts (memory)" statistic should not be greater than 1–5 percent. If it is, you should increase the PGA_AGGREGATE_TARGET/PGA_AGGREGATE_LIMIT (or SORT_AREA_SIZE and/or MEMORY_TARGET) parameter in the initialization file (if physical memory is available to do this). Remember that the memory allocated for SORT_AREA_SIZE is a per-user value and PGA_AGGREGATE_TARGET is across all sessions. See Chapter 4 for more information.

- **Table fetch by rowid** The number of rows that were accessed by using a ROWID. This ROWID came from either an index or a "WHERE ROWID = …" statement. A high number *usually* indicates a well-tuned application as far as fetching the data goes.
- **Table fetch continued row** The number of rows that were fetched that were chained or migrated.

TIP
If chained rows are indicated, the problem needs to be fixed as soon as possible if performance degradation is evident. Chained rows can cause severe degradation of performance if a large number of rows are chained. See Chapter 3 for tips on eliminating chaining.

- **Table scans (long tables)** A *long table* is one that is larger than _SMALL_TABLE_THRESHOLD (which is a hidden/undocumented parameter) with no CACHE clause. The default value of _SMALL_TABLE_THRESHOLD is 2 percent of the buffer cache in Oracle 12*c* and since 10*g*. _SMALL_TABLE_THRESHOLD is a dangerous parameter to modify without careful benchmarking of the effects. As this affects all tables accessing it, increasing this parameter significantly, if at all, is unwise, as it can cause blocks to age more quickly and reduce your hit ratio. In Oracle, this parameter is the number of db blocks up to which the table is considered small. This threshold is used to determine the cutover point for direct-read operations. Any object that is smaller than the value of _SMALL_TABLE_THRESHOLD will not be worth performing direct reads for and thus will be read through the buffer cache. If the number of table scans per transaction is greater than 0, you may wish to review the application SQL statements and try to increase the use of indexes. Oracle does not want a large table to overrun the buffer cache; that's the reason this parameter ensures that every table larger than 2 percent of the buffer cache is considered a long table.

TIP

If full table scans are being performed, serious performance issues may result and data hit ratios will be distorted. These tables need to be identified so the appropriate indexes are created or used. See Chapters 8 and 9 on query tuning for more information.

- **Table scans (short tables)** A *short table* is one that is less than 2 percent of the buffer cache. Full table scans on short tables are preferred by Oracle.

Tablespace and File I/O Statistics

The next section of the Statspack Report provides the I/O statistics. Prior to the Tablespace IO Stats and File IO Stats sections, there is a section that shows the I/O stats grouped by function, including the types of reads that are occurring (see the listing):

```
IO Stat by Function   summary  DB/Inst: ORCL/orcl  Snaps: 1 2
->Data Volume values suffixed with   M,G,T,P are in multiples of 1024,
  other values suffixed with       K,M,G,T,P are in multiples of 1000
->ordered by Data Volume (Read+Write) desc

                ---------- Read --------- --------- Write -------- --- Wait ----
                 Data  Requests     Data  Data  Requests     Data          Avg
Function        Volume     /sec  Vol/sec Volume     /sec  Vol/sec  Count Tm(ms)
--------------- ------ -------- -------- ------ -------- -------- ------ ------
Direct Reads      641M       .8      .8M                .0                 0.0

Others             55M      4.4      .1M    72M      1.1      .1M   3888    0.0
LGWR                         .1             57M      1.3      .1M     65    0.0
Buffer Cache Re    46M       .1      .1M                                68    0.0
```

If the I/O activity is not properly distributed among your files, you may encounter performance bottlenecks during periods of high activity. As a rule of thumb, you don't want more than 100 I/Os per second per 10,000 RPM disk (even with a RAID array). If the Av Rd(ms) column (Average Reads per millisecond) is higher than 14 ms (given a fair amount of reading is being done), you may want to investigate, since most disks should provide at least this much performance. If rows in this column show 1,000 ms or more in the Av Rd(ms) column or in the Av Buf Wt(ms) column (Average Buffer Writes per millisecond), you probably have some type of I/O problem, and if it shows ###### (meaning it couldn't fit the value in the size of the field), then you have a serious I/O problem of some kind (this can also be a formatting problem, but anything greater than 1,000 is a problem when a fair number of reads are being done).

I have seen I/O issues that are related to other problems, yet show up as an I/O problem. For disks with a lot of memory cached on the disk, the I/O time is often less than 1 ms for a disk where heavy reading is being done. You should use this section of the report to identify such bottlenecks and to measure how effectively you have resolved those problems. If you have the choice between 15K RPM 600G SAS drives and 7.2K RPM 2T SATA disks—*always* choose the SAS drives unless it's for archived information that will almost never be accessed.

Set the DB_FILE_MULTIBLOCK_READ_COUNT parameter in the initialization file (SPFILE or `init.ora`) to help improve the read time. This parameter controls the number of blocks that can be read in one I/O when a full table scan is being performed. In 12*c*, the default is set to 128, so it should be sufficient. Setting it can reduce the number of I/Os needed to scan a table, thus improving the performance of the full table scan. Unfortunately, the optimizer might do more full table scans as a result of setting DB_FILE_MULTIBLOCK_READ_COUNT (you don't want this behavior), so you may also need to set the OPTIMIZER_INDEX_COST_ADJ to a number, such as 10, to eliminate this problem and drive the use of indexes (be careful with this parameter and see Chapter 4 and Appendix A before setting it). Here is an example listing from this section of the report:

```
Tablespace IO Stats for DB: ORA10  Instance: ora10  Snaps: 1 -2
->ordered by IO's (Reads + Writes) desc
Tablespace
------------------------------
                 Av      Av     Av                    Av        Buffer Av Buf
         Reads Reads/s Rd(ms) Blks/Rd       Writes Writes/s      Waits Wt(ms)
-------------- ------- ------ ------- ------------ -------- ---------- ------
TS_ORDERS
     1,108,981      32   12.1     1.0    1,006,453       29      6,445    4.9
TS_ORDER_SUM
       967,108      28   12.5     1.0      675,647       19         51    7.6
TS_ORDER_LINES
     1,389,292      40   10.1     1.0       22,930        1      1,753    3.9
```

Here are descriptions of some of the columns appearing in this output:

Column	Description
TABLESPACE	The name of the tablespace.
READS	The number of physical reads that were performed on the datafile to retrieve data.
AV BLKS/RD	The number of blocks per read that were read from the datafile to satisfy an average read.
WRITES	The number of writes to the data file.

Following the Tablespace IO Stats section, you'll see a File IO Stats section, as you can see here:

```
File IO Stats  DB/Inst: ORCL/orcl  Snaps: 1-2
->Mx Rd Bkt: Max bucket time for single block read
->ordered by Tablespace, File

Tablespace               Filename
------------------------ ----------------------------------------------------
                        Av   Mx                                             Av
                 Av     Rd   Rd    Av                    Av        Buffer BufWt
         Reads Reads/s (ms)  Bkt Blks/Rd       Writes Writes/s      Waits  (ms)
-------------- ------- ----- --- ------- ------------ -------- ---------- ------
EXAMPLE                  C:\APP\USER\ORADATA\ORCL\EXAMPLE01.DBF
             1       0   0.0         1.0            1        0          0

FLOW_1046531734508653    C:\APP\USER\ORADATA\ORCL\FLOW_1046531734508653.DBF
             1       0   0.0         1.0            1        0          0

FLOW_1064429114609071    C:\APP\USER\ORADATA\ORCL\FLOW_1064429114609071.DBF
             1       0   0.0         1.0            1        0          0

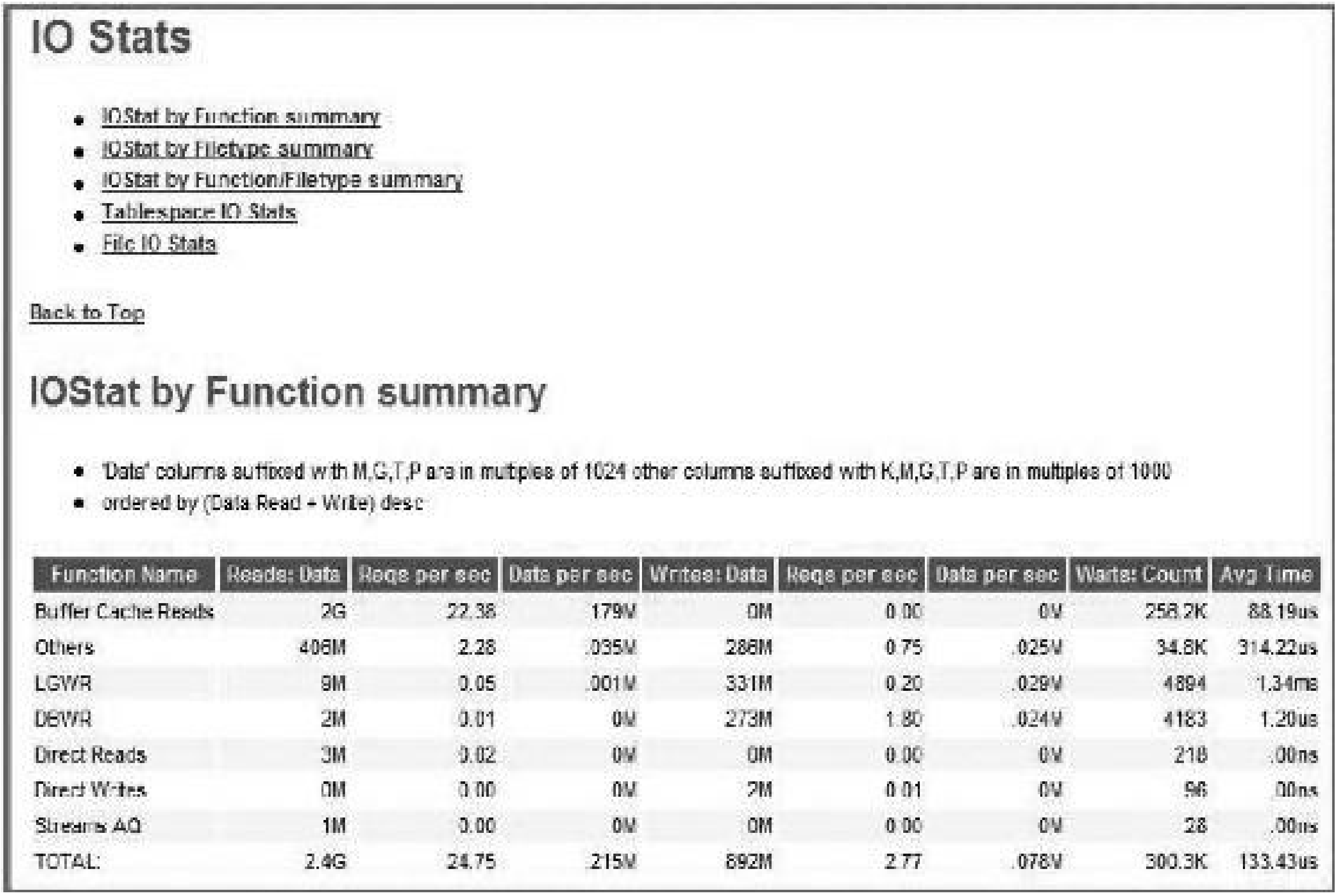
SYSAUX                   C:\APP\USER\ORADATA\ORCL\SYSAUX01.DBF
             3       0   6.7  16     1.0          110        0          0

SYSTEM                   C:\APP\USER\ORADATA\ORCL\SYSTEM01.DBF
             5       0   6.0  16     1.0          219        0          0

UNDOTBS1                 C:\APP\USER\ORADATA\ORCL\UNDOTBS01.DBF
             1       0   0.0         1.0           84        0          0

USERS                    C:\APP\USER\ORADATA\ORCL\USERS01.DBF
            79       0  10.3       107.0            5        0          0
                         C:\APP\USER\ORADATA\ORCL\USERS02.DBF
            32       0  32.2        82.3            1        0          0
                         C:\APP\USER\ORADATA\ORCL\USERS03.DBF
            79       0  11.6       120.9           11        0          0
                         C:\APP\USER\ORADATA\ORCL\USERS04
           529       1   0.0       127.2        4,935        6          0
```

An example of the AWR Report IO Stats section is displayed in Figure 14-13. You can also see from this figure that Oracle gives tablespace I/O and file I/O information as well in this section.



IO Stats

- IOStat by Function summary
- IOStat by Filetype summary
- IOStat by Function/Filetype summary
- Tablespace IO Stats
- File IO Stats

Back to Top

IOStat by Function summary

- 'Data' columns suffixed with M,G,T,P are in multiples of 1024 other columns suffixed with K,M,G,T,P are in multiples of 1000
- ordered by (Data Read + Write) desc

Function Name	Reads: Data	Reqs per sec	Data per sec	Writes: Data	Reqs per sec	Data per sec	Waits: Count	Avg Time
Buffer Cache Reads	2G	22.38	179M	0M	0.00	0M	258.2K	88.19us
Others	406M	2.28	.035M	286M	0.75	.025M	34.8K	314.22us
LGWR	9M	0.05	.001M	331M	0.20	.029M	4894	1.34ms
DBWR	2M	0.01	0M	273M	1.80	.024M	4183	1.20us
Direct Reads	3M	0.02	0M	0M	0.00	0M	218	.00ns
Direct Writes	0M	0.00	0M	2M	0.01	0M	96	.00ns
Streams AQ	1M	0.00	0M	0M	0.00	0M	28	.00ns
TOTAL:	2.4G	24.75	215M	892M	2.77	.078M	300.3K	133.43us

FIGURE 14-13. *AWR Report IO Stats section*

Following the tablespace I/O statistics is a file I/O section breakdown—a very granular look at how the I/O is being distributed across the datafiles. If one of the datafiles is getting a majority of the reads and writes, you may be able to improve performance by creating multiple datafiles on separate disks or by striping the datafile across multiple disks. Also, stay away from RAID 5 (Chapter 3 has more on this) or you'll get slower write times. In 12*c*, Oracle allows you to move "hotter" data to the fastest portion of the disk. I show you how to do this in Chapter 5 on Enterprise Manager.

TIP

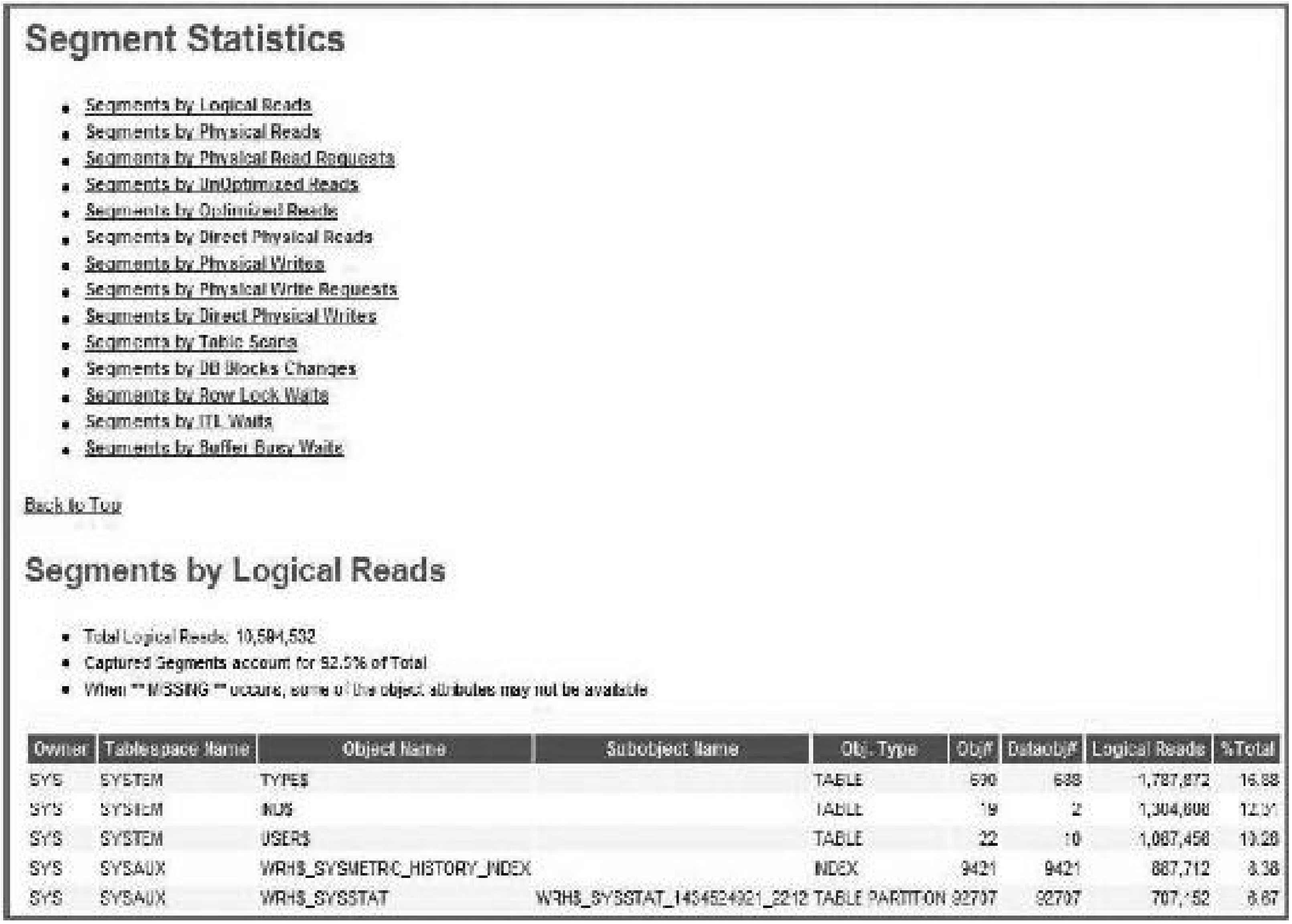
If the number of physical reads is heavier on one physical disk, balancing the data properly or using ASM correctly will probably improve performance. See Chapter 3 for tips on fixing I/O problems (and using ASM) with either datafiles or tablespaces.

Segment Statistics

One of the best data dictionary views that Oracle provides is V$SEGMENT_STATISTICS. This view quickly became a DBA favorite after its introduction in Oracle9*i*. Using this view, you can view Segment Statistics reports for everything you could ever need. Here are the sections that the AWR Report now shows:

- Segments by Logical Reads
- Segments by Physical Reads
- Segments by Physical Read Requests
- Segments by UnOptimized Reads
- Segments by Optimized Reads
- Segments by Direct Physical Reads
- Segments by Physical Writes
- Segments by Physical Write Requests
- Segments by Direct Physical Writes
- Segments by Table Scans
- Segments by DB Block Changes
- Segments by Row Lock Waits
- Segments by ITL Waits
- Segments by Buffer Busy Waits
- Segments by Global Cache Buffer Busy (RAC only)
- Segments by CR Blocks Received (RAC only)
- Segments by Current Blocks Received (RAC only)

Figure 14-14 shows the section of the AWR Report dedicated to segment statistics. This is particularly useful for finding what specific INDEX or DATA segment is causing a bottleneck of some kind. Finding specific ITL waits was also very difficult prior to Oracle providing this additional detail. Now, in the Segment Statistics section, you can see the exact number of ITL waits by owner, tablespace name, object name, and subobject name (such as an index partition subobject name).



Segment Statistics

- Segments by Logical Reads
- Segments by Physical Reads
- Segments by Physical Read Requests
- Segments by UnOptimized Reads
- Segments by Optimized Reads
- Segments by Direct Physical Reads
- Segments by Physical Writes
- Segments by Physical Write Requests
- Segments by Direct Physical Writes
- Segments by Table Scans
- Segments by DB Blocks Changes
- Segments by Row Lock Waits
- Segments by ITL Waits
- Segments by Buffer Busy Waits

Back to Top

Segments by Logical Reads

- Total Logical Reads: 10,594,532
- Captured Segments account for 92.5% of Total
- When ** MISSING ** occurs, some of the object attributes may not be available

Owner	Tablespace Name	Object Name	Subobject Name	Obj. Type	Obj#	Dataobj#	Logical Reads	%Total
SYS	SYSTEM	TYPE$		TABLE	690	688	1,787,872	16.88
SYS	SYSTEM	IND$		TABLE	19	2	1,304,608	12.31
SYS	SYSTEM	USER$		TABLE	22	10	1,087,456	10.28
SYS	SYSAUX	WRH$_SYSMETRIC_HISTORY_INDEX		INDEX	9421	9421	887,712	8.38
SYS	SYSAUX	WRH$_SYSSTAT	WRH$_SYSSTAT_1434524921_2212	TABLE PARTITION	92707	92707	707,152	6.67

FIGURE 14-14. *The AWR Report Segment Statistics section*

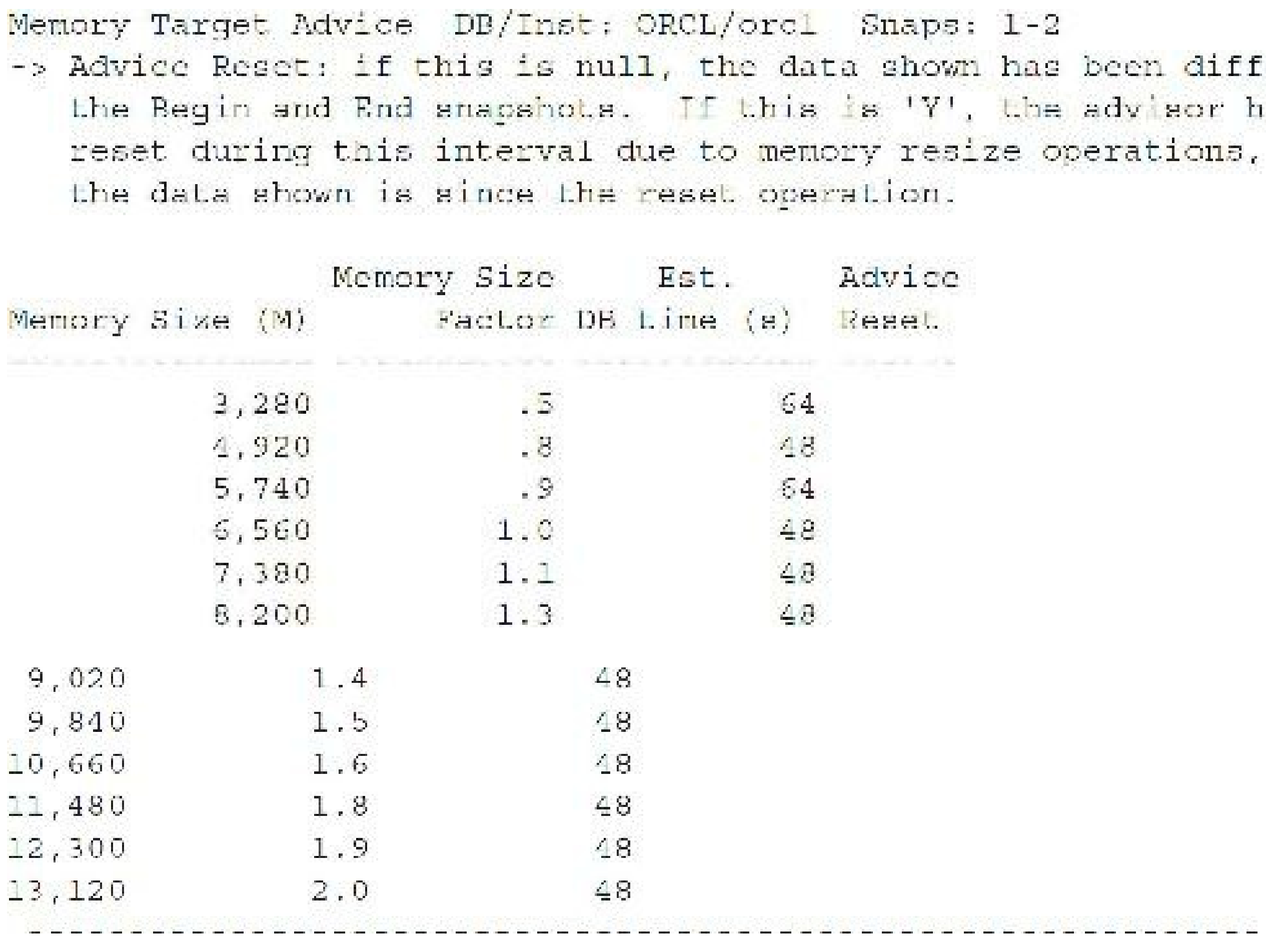
TIP

Segment statistics are a great way to pinpoint performance problems to a given table, index, or partition. Oracle provides many segment-level statistics in both the AWR Report and Statspack.

Additional Memory Statistics

Following the I/O statistics, both reports list many memory sections, including a section for sizing the MEMORY_TARGET (which includes the 12*c*R2 INMEMORY_SIZE area), a section on all of the dynamic components related to the MEMORY_TARGET, a buffer pool advisory (for sizing the DB_CACHE_SIZE), buffer cache statistics by pool (default, keep, and recycle), instance recovery statistics (the number of REDO blocks), shared pool sizing advisory, and the PGA memory statistics and advisory. I won’t be able to cover all of them here (initialization parameter sizing is covered in

Chapter 4), but I show a sample listing of several of these sections next. The MEMORY_TARGET advisor (first listing) shows that by setting this above the current setting (Size Factor = 1; MEMORY_TARGET = 6.56G), I will not get additional benefits given the current load at this time. If the load changes, these values will change as well.



```
Memory Target Advice  DB/Inst: ORCL/orcl  Snaps: 1-2
-> Advice Reset: if this is null, the data shown has been diffed between
   the Begin and End snapshots.  If this is 'Y', the advisor has been
   reset during this interval due to memory resize operations, and
   the data shown is since the reset operation.

                Memory Size      Est.     Advice
Memory Size (M)      Factor DB time (s)   Reset
--------------- ----------- ------------ ------
          3,280          .5           64
          4,920          .8           48
          5,740          .9           64
          6,560         1.0           48
          7,380         1.1           48
          8,200         1.3           48
  9,020         1.4           48
  9,840         1.5           48
 10,660         1.6           48
 11,480         1.8           48
 12,300         1.9           48
 13,120         2.0           48
  -------------------------------------------------------------
```

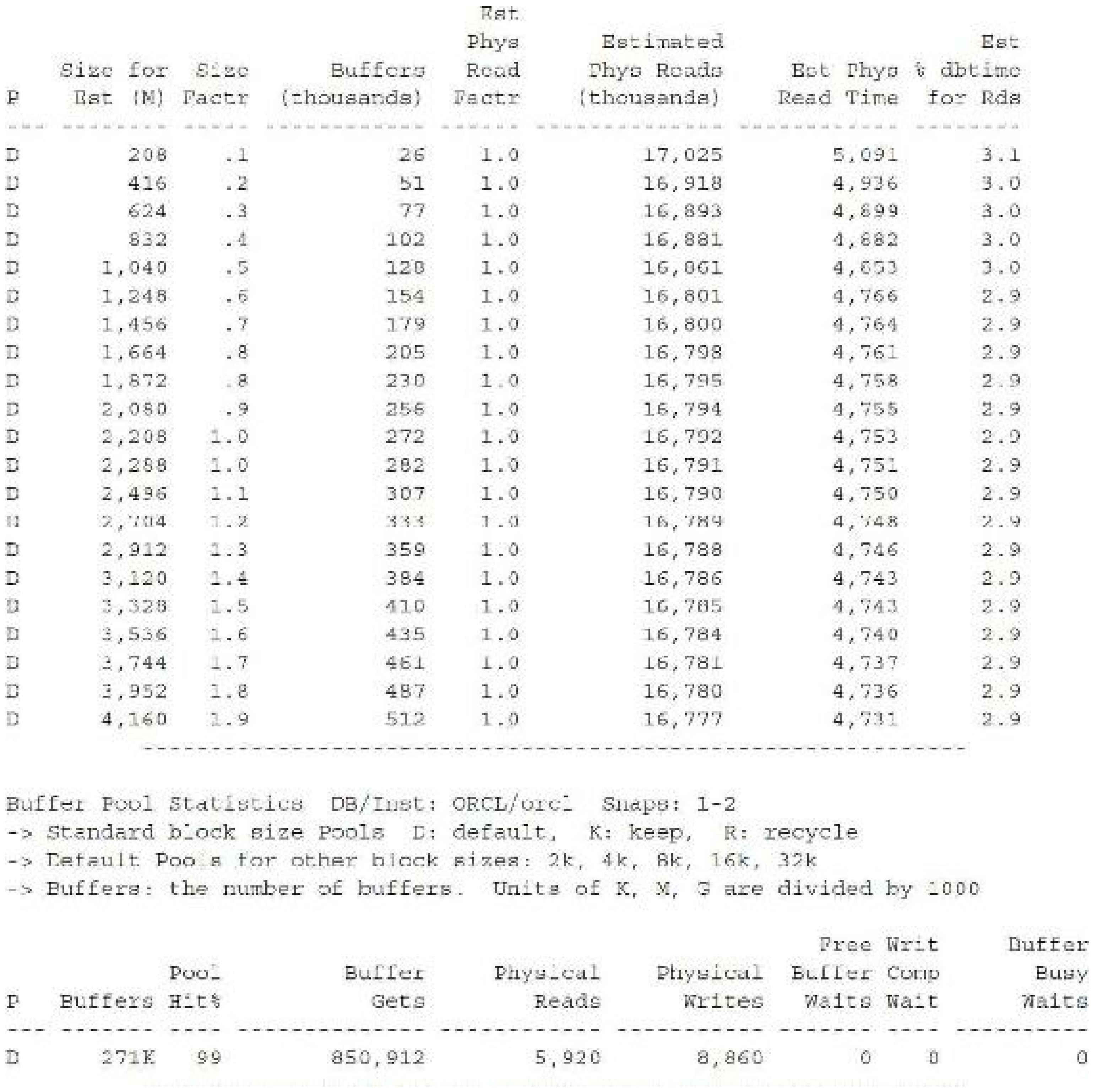
You can easily see, under Memory Dynamic Components (shown next), *exactly* where memory is currently being allocated. Here, you see the SGA_TARGET is 4.272G, the DB_CACHE_SIZE is 2.208G, the PGA_AGGREGATE_TARGET is 2.288G, and the shared pool is just under 1G. The Statspack Report does not list the In-Memory areas, whereas the AWR Report lists the In-Memory Area, In Memory RO Extension Area, and In Memory RW Extension Area in the 12*c*R2 Memory Dynamic Components section.

```
Memory Dynamic Components  DB/Inst: ORCL/orcl  Snaps: 1 2
->  Op - memory resize Operation
->  Cache:    D: Default,  K: Keep,  R:  Recycle
->   Mode:  DEF: DEFerred mode,  IMM: IMMediate mode

                         Begin Snap End Snap   Op    Last Op
Cache                      Size (M) Size (M)  Count  Type/Mode   Last Op Time
---------------------- ---------- -------- ------- ---------- ---------------
D:buffer cache              2,208                0 INITIAL
PGA Target                  2,288                0 STATIC
SGA Target                  4,272                0 STATIC
Shared IO Pool                928                0 STATIC
java pool                      16                0 STATIC
large pool                     32                0 STATIC
shared pool                 1,024                0 STATIC
streams pool                   16                0 STATIC
```

The next section is Buffer Pool Advisory. While much of this information is shown in other sections, the Buffer Pool Statistics section is very detailed in this part of the report. It shows individual buffer pools for the keep and recycle pools, if they are used (Chapter 4 includes more information on using these buffer pools). This section also shows information for the different block sizes if you use multiple block sizes. As with MEMORY_TARGET, I also have an advisor (see the following listing) that shows my current setting for the DB_CACHE_SIZE or memory allocated for data buffers (Size Factor = 1; DB_CACHE_SIZE = 2.208G). From this, you can see that I will not get many additional benefits, given the current load at this time, by increasing this value. If the load changes, these values will change as well. The hit ratio (99 percent) is shown in this listing.

```
Buffer Pool Advisory  DB/Inst: ORCL/orcl  End Snap: 2
-> Only rows with estimated physical reads >0 are displayed
-> ordered by Pool, Block Size, Buffers For Estimate
```

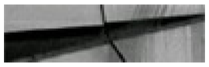


```
                                        Est
                                       Phys      Estimated                  Est
    Size for  Size        Buffers      Read     Phys Reads     Est Phys % dbtime
P    Est (M) Factr    (thousands)     Factr    (thousands)    Read Time  for Rds
--- -------- ----- -------------- ------- -------------- ----------- --------
D        208    .1             26      1.0         17,025        5,091      3.1
D        416    .2             51      1.0         16,918        4,936      3.0
D        624    .3             77      1.0         16,893        4,899      3.0
D        832    .4            102      1.0         16,881        4,882      3.0
D      1,040    .5            128      1.0         16,861        4,653      3.0
D      1,248    .6            154      1.0         16,801        4,766      2.9
D      1,456    .7            179      1.0         16,800        4,764      2.9
D      1,664    .8            205      1.0         16,798        4,761      2.9
D      1,872    .8            230      1.0         16,795        4,758      2.9
D      2,080    .9            256      1.0         16,794        4,756      2.9
D      2,208   1.0            272      1.0         16,792        4,753      2.9
D      2,288   1.0            282      1.0         16,791        4,751      2.9
D      2,496   1.1            307      1.0         16,790        4,750      2.9
D      2,704   1.2            333      1.0         16,789        4,748      2.9
D      2,912   1.3            359      1.0         16,788        4,746      2.9
D      3,120   1.4            384      1.0         16,786        4,743      2.9
D      3,328   1.5            410      1.0         16,785        4,743      2.9
D      3,536   1.6            435      1.0         16,784        4,740      2.9
D      3,744   1.7            461      1.0         16,781        4,737      2.9
D      3,952   1.8            487      1.0         16,780        4,736      2.9
D      4,160   1.9            512      1.0         16,777        4,731      2.9
          -------------------------------------------------------------

Buffer Pool Statistics  DB/Inst: ORCL/orcl  Snaps: 1-2
-> Standard block size Pools  D: default,  K: keep,  R: recycle
-> Default Pools for other block sizes: 2k, 4k, 8k, 16k, 32k
-> Buffers: the number of buffers.  Units of K, M, G are divided by 1000

                                                              Free Writ     Buffer
            Pool         Buffer      Physical      Physical  Buffer Comp       Busy
P   Buffers Hit%           Gets         Reads        Writes   Waits Wait      Waits
--- ------- ---- -------------- ------------ ----------- ------- ---- ----------
D      271K   99        850,912         5,920        8,860       0    0          0
```

The next couple of sections (not all displayed here) relate to the memory needed for PGA and sorting or the PGA_AGGREGATE_TARGET (which is now limited by the 12*c*R2 PGA_AGGREGATE_LIMIT parameter). There are also sections with shared pool statistics. The PGA_AGGREGATE_TARGET section is listed here (this value is sufficient with 100 percent of the hits being done in memory):



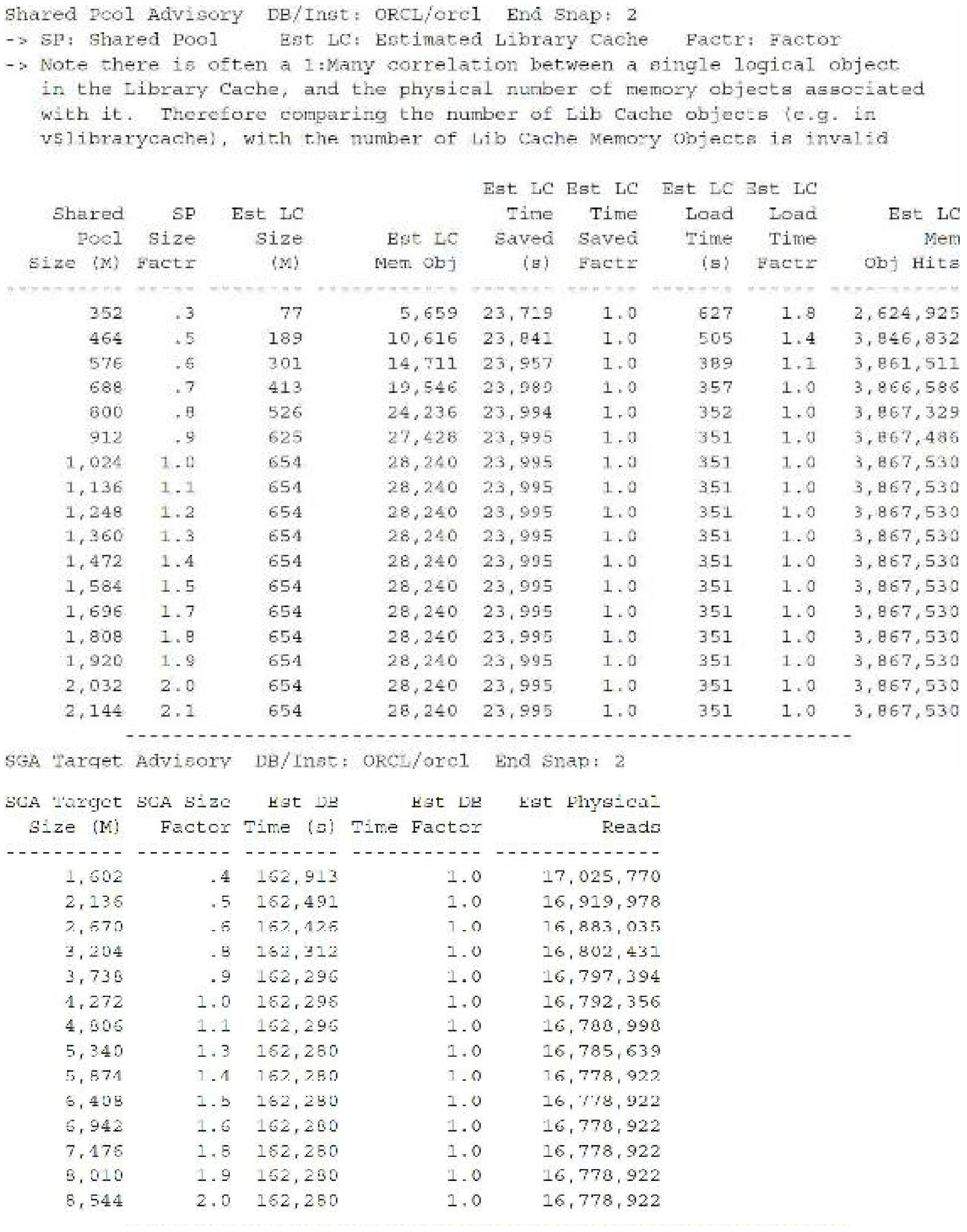
```
PGA Aggr Target Stats  DB/Inst: ORCL/orcl  Snaps: 1 2
-> B: Begin snap   E: End snap (rows identified with B or E contain data
   which is absolute i.e. not diffed over the interval)
-> PGA cache hit % - percentage of W/A (WorkArea) data processed only in-memory
-> Auto PGA Target - actual workarea memory target
-> W/A PGA Used    - amount of memory used for all WorkAreas (manual + auto)
-> %PGA W/A Mem    - percentage of PGA memory allocated to WorkAreas
-> %Auto W/A Mem   - percentage of WorkArea memory controlled by Auto Mem Mgmt
-> %Man W/A Mem    - percentage of WorkArea memory under Manual control

PGA Cache Hit % W/A MB Processed Extra W/A MB Read/Written
--------------- ---------------- -------------------------
          100.0              178                         0
```

The Instance Recovery Stats section is listed next:

```
Instance Recovery Stats for DB: ORA10  Instance: ora10  Snaps: 1 -2
-> B: Begin snapshot, E: End snapshot
  Targt Estd                                         Log File   Log Ckpt   Log Ckpt
  MTTR  MTTR   Recovery    Actual     Target         Size       Timeout    Interval
   (s)   (s)   Estd IO's  Redo Blks  Redo Blks  Redo Blks  Redo Blks  Redo Blks
- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
B    33    18       5898        706      13546     184320      13546 ##########
E    33    24       5898        717      14524     184320      14524 ##########
```

The Shared Pool Advisory and the SGA Target Advisory sections follow the Latch section (I've moved them here to present them with the other SGA components). Both of these are set sufficiently at the current load (a size factor greater than 1.0 yields no additional savings: SHARED_POOL_SIZE = 1G and SGA_TARGET = 4.272G). You may even consider decreasing them if this load is representative of your system during normal loads.

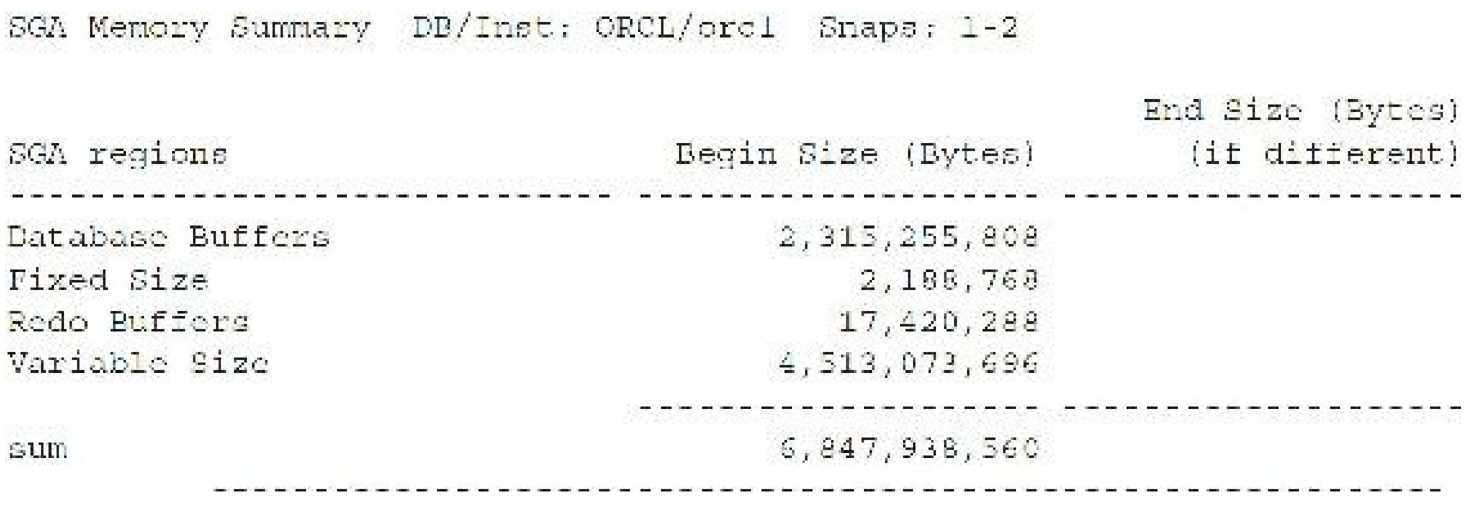


```
Shared Pool Advisory  DB/Inst: ORCL/orcl  End Snap: 2
-> SP: Shared Pool     Est LC: Estimated Library Cache   Factr: Factor
-> Note there is often a 1:Many correlation between a single logical object
   in the Library Cache, and the physical number of memory objects associated
   with it.  Therefore comparing the number of Lib Cache objects (e.g. in
   v$librarycache), with the number of Lib Cache Memory Objects is invalid

                                             Est LC Est LC  Est LC Est LC
  Shared    SP   Est LC                        Time   Time    Load   Load      Est LC
    Pool  Size     Size            Est LC     Saved  Saved    Time   Time         Mem
Size (M) Factr      (M)           Mem Obj       (s)  Factr     (s)  Factr    Obj Hits
---------- ----- -------- ------------ ------- ------ ------- ------ ------------
     352    .3       77          5,659  23,719    1.0     627    1.8    2,624,925
     464    .5      189         10,616  23,841    1.0     505    1.4    3,846,832
     576    .6      301         14,711  23,957    1.0     389    1.1    3,861,511
     688    .7      413         19,546  23,989    1.0     357    1.0    3,866,586
     800    .8      526         24,236  23,994    1.0     352    1.0    3,867,329
     912    .9      625         27,428  23,995    1.0     351    1.0    3,867,486
   1,024   1.0      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,136   1.1      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,248   1.2      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,360   1.3      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,472   1.4      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,584   1.5      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,696   1.7      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,808   1.8      654         28,240  23,995    1.0     351    1.0    3,867,530
   1,920   1.9      654         28,240  23,995    1.0     351    1.0    3,867,530
   2,032   2.0      654         28,240  23,995    1.0     351    1.0    3,867,530
   2,144   2.1      654         28,240  23,995    1.0     351    1.0    3,867,530
          -------------------------------------------------------------
SGA Target Advisory  DB/Inst: ORCL/orcl  End Snap: 2

SGA Target SGA Size   Est DB      Est DB   Est Physical
  Size (M)   Factor Time (s) Time Factor          Reads
---------- -------- -------- ----------- --------------
     1,602       .4  162,913         1.0     17,025,770
     2,136       .5  162,491         1.0     16,919,978
     2,670       .6  162,426         1.0     16,883,035
     3,204       .8  162,312         1.0     16,802,431
     3,738       .9  162,296         1.0     16,797,394
     4,272      1.0  162,296         1.0     16,792,356
     4,806      1.1  162,296         1.0     16,788,998
     5,340      1.3  162,280         1.0     16,785,639
     5,874      1.4  162,280         1.0     16,778,922
     6,408      1.5  162,280         1.0     16,778,922
     6,942      1.6  162,280         1.0     16,778,922
     7,476      1.8  162,280         1.0     16,778,922
     8,010      1.9  162,280         1.0     16,778,922
     8,544      2.0  162,280         1.0     16,778,922
```

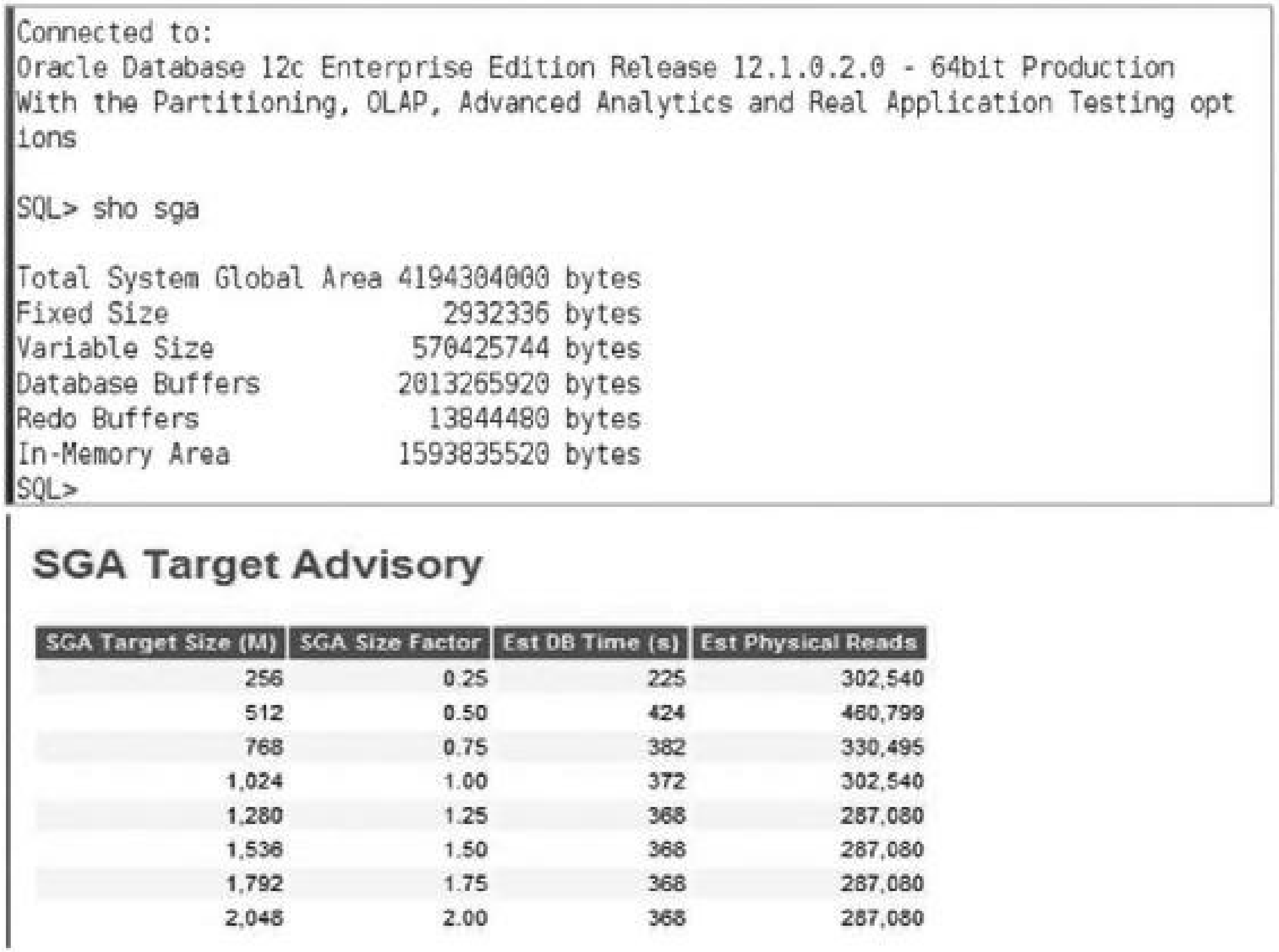
The next section, SGA Memory Summary, is a great breakdown of the SGA areas that you are using during this snapshot interval. You can also see this real time by executing a SHO SGA command in SQL*Plus as a DBA or SYSDBA user.



```
SGA Memory Summary  DB/Inst: ORCL/orcl  Snaps: 1-2

                                                      End Size (Bytes)
SGA regions                     Begin Size (Bytes)      (if different)
------------------------------ -------------------- --------------------
Database Buffers                      2,315,255,808
Fixed Size                                2,188,768
Redo Buffers                             17,420,288
Variable Size                         4,513,073,696
                               -------------------- --------------------
sum                                   6,847,938,560
          -------------------------------------------------------------
```

The AWR Report shows statistics on the following advisories. Figure 14-15 shows the AWR Report for a 12.2 SGA with In-Memory Area set from SQL*Plus and then the SGA Target Advisory.



```
Connected to:
Oracle Database 12c Enterprise Edition Release 12.1.0.2.0 - 64bit Production
With the Partitioning, OLAP, Advanced Analytics and Real Application Testing opt
ions

SQL> sho sga

Total System Global Area 4194304000 bytes
Fixed Size                  2932336 bytes
Variable Size             570425744 bytes
Database Buffers         2013265920 bytes
Redo Buffers               13844480 bytes
In-Memory Area           1593835520 bytes
SQL>
```

SGA Target Advisory

SGA Target Size (M)	SGA Size Factor	Est DB Time (s)	Est Physical Reads
256	0.25	225	302,540
512	0.50	424	460,799
768	0.75	382	330,495
1,024	1.00	372	302,540
1,280	1.25	368	287,080
1,536	1.50	368	287,080
1,792	1.75	368	287,080
2,048	2.00	368	287,080

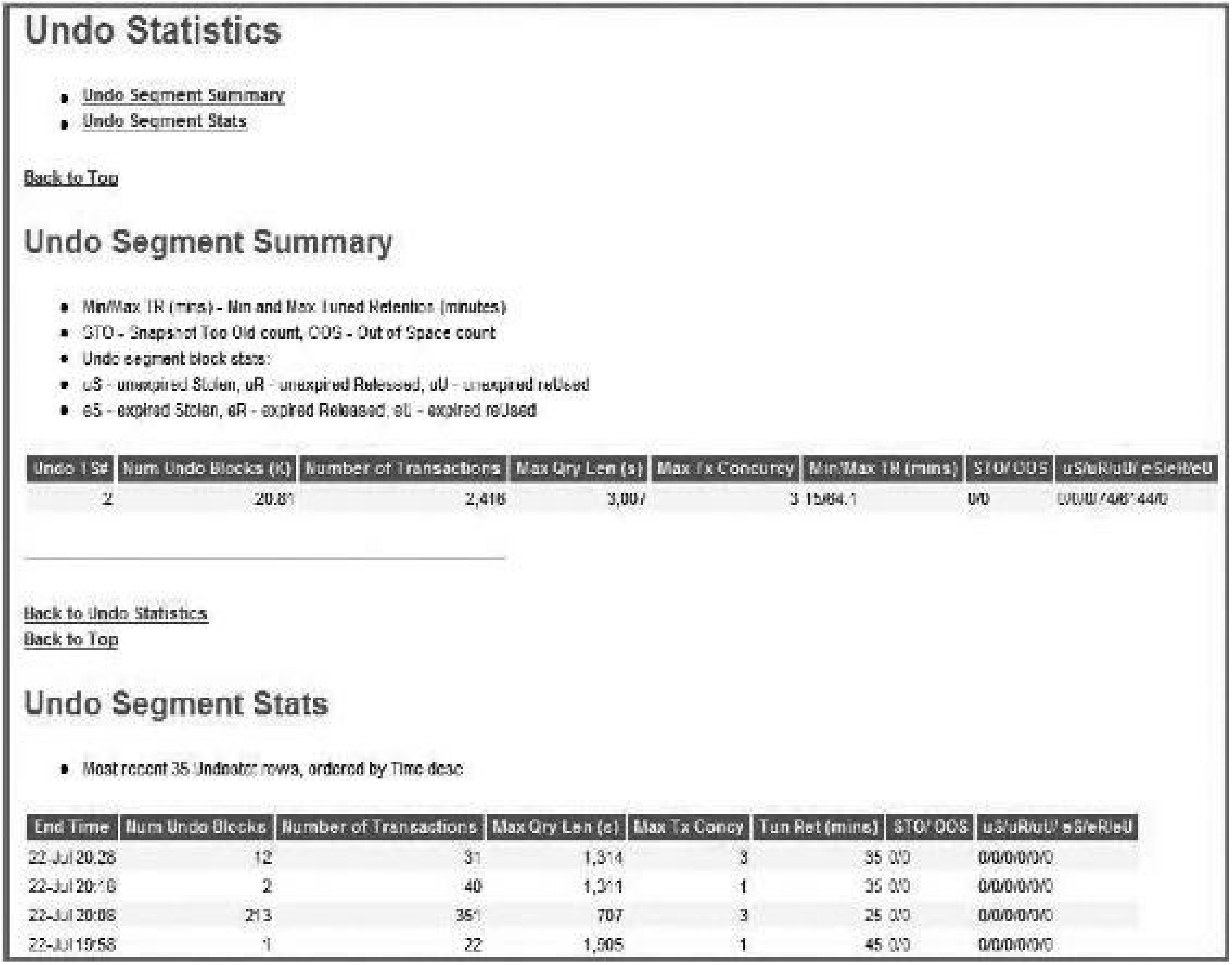
FIGURE 14-15. *The AWR Report SGA Target Advisory (preceded by SGA with In-Memory Area)*

- Instance Recovery Stats
- MTTR Advisory
- Buffer Pool Advisory
- PGA Aggr Summary
- PGA Aggr Target Stats
- PGA Aggr Target Histogram
- PGA Memory Advisory
- Shared Pool Advisory
- SGA Target Advisory
- Streams Pool Advisory
- Java Pool Advisory

TIP
In Oracle 12c, multiple data block sizes are allowed. The AWR Report and/or Statspack shows statistics for each of these block sizes individually. Many advisories are available to help you size the SGA that both the AWR Report (see Figure 14-15) and Enterprise Manager (graphically, see Chapter 5) suggest. These suggestions should be tested first, however, and are not always the best choice. As Robert Freeman would say, "Your mileage may vary."

UNDO Statistics

The next section provides UNDO segment statistics. The first part of this section shows the UNDO tablespace and the number of transactions and UNDO blocks for the entire tablespace. Next, it gives information about how many UNDO blocks are utilized and the number of transactions that have occurred for a given segment (UNDOSTAT ROW). The AWR Report in Oracle provides a summary and UNDO segment stats, some that were not available in previous versions. This new output is shown in Figure 14-16.



Undo Statistics

- Undo Segment Summary
- Undo Segment Stats

Back to Top

Undo Segment Summary

- Min/Max TR (mins) - Min and Max Tuned Retention (minutes)
- STO - Snapshot Too Old count, OOS - Out of Space count
- Undo segment block stats:
- uS - unexpired Stolen, uR - unexpired Released, uU - unexpired reUsed
- eS - expired Stolen, eR - expired Released, eU - expired reUsed

Undo TS#	Num Undo Blocks (K)	Number of Transactions	Max Qry Len (s)	Max Tx Concurcy	Min/Max TR (mins)	STO/ OOS	uS/uR/uU/ eS/eR/eU
2	20.81	2,416	3,007	3	15/64.1	0/0	0/0/0/74/0/144/0

Back to Undo Statistics
Back to Top

Undo Segment Stats

- Most recent 35 Undostat rows, ordered by Time desc

End Time	Num Undo Blocks	Number of Transactions	Max Qry Len (s)	Max Tx Concy	Tun Ret (mins)	STO/ OOS	uS/uR/uU/ eS/eR/eU
22-Jul 20:28	12	31	1,314	3	35	0/0	0/0/0/0/0/0
22-Jul 20:18	2	40	1,311	1	35	0/0	0/0/0/0/0/0
22-Jul 20:08	213	351	707	3	25	0/0	0/0/0/0/0/0
22-Jul 19:58	1	22	1,905	1	45	0/0	0/0/0/0/0/0

FIGURE 14-16. *The AWR Report Undo Statistics*

While I have eliminated the ROLLSTAT information from this version of the book (since most people now use AUTO UNDO), this information can still be reported in Statspack. By using the configuration file, `sprepcon.sql`, you can modify the DISPLAY_ROLLSTAT parameter.

Latch and Mutex Statistics

Latches are low-level queuing mechanisms (the accurate term is *mutual exclusion mechanisms*) used to protect shared memory structures in the SGA (memory). Latches are like locks on memory that are very quickly obtained and released, consuming roughly 32 bytes. Latches are used to prevent concurrent access to a shared memory structure. If the latch is not available, a latch free miss is recorded. The *library cache pin* (protects cursors/SQL) and *library cache latch* (protects the Library Cache) are both replaced by *mutexes* (program objects that negotiate mutual exclusion among threads). Most latch and mutex problems (waits, misses, and sleeps) are related to the failure to use bind variables (library cache mutex waits and shared pool latch waits), REDO generation issues (redo allocation latch waits), buffer cache contention issues (cache buffers lru chain waits), and hot blocks in the buffer cache (cache buffers chain waits). There are also latch and mutex waits related to bugs; check My Oracle Support (Metalink) for bug reports if you suspect this is the case. When latch miss ratios are greater than 0.5 percent, you should investigate the issue. If the latch miss ratio is greater than 2 percent and there are a large number of them, you may have a serious problem. The cache buffers chains (CBC) latch can be shared and is still heavily used in 12*c*R2.

Two types of latches are available: *willing to wait* latches (one example is a shared pool latch) and *not willing to wait* latches (an example is a redo copy latch). A process that is willing to wait will try to acquire a latch. If none are available, it spins and then requests the latch again. It continues to do this up to the _SPIN_COUNT initialization parameter (note that spinning costs CPU). The _SPIN_COUNT default is 2000 for shared latches (20,000 for exclusive latches found by querying X$KSLLCLASS—all eight classes are set to 20,000); also note that for mutexes, the default for the _MUTEX_SPIN_COUNT is 255. If the process can't get a latch after spinning up to the _SPIN_COUNT, it goes to sleep, to not do anything for a while, and then wakes up after one centisecond (one hundredth of a second). It does this twice. The process then starts this whole cycle again, spinning up to the _SPIN_COUNT and then sleeping for twice as long (two centiseconds). After doing this again, it doubles again. So the pattern is 1, 1, 2, 2, 4, 4, and so on. It repeats this until it gets the latch. Every time the latch sleeps, the process creates a latch sleep wait.

Some latches are "not willing to wait." A latch of this type does not wait for the latch to become available. It immediately times out and tries to obtain the latch again. A redo copy latch wait is an example of a "not willing to wait" latch. A "not willing to wait" latch generates information for the IMMEDIATE_GETS and the IMMEDIATE_MISSES columns of the V$LATCH view and also in the Statspack Report. The hit ratio for these latches should approach 99 percent, and the misses should never fall below 1 percent.

By viewing the Latch Activity section of Statspack or querying the V$LATCH view, you can see how many processes had to wait (a latch miss) or sleep (a latch sleep) and the number of times they had to sleep. If you see ##### in any field, it usually means bad news, as the value exceeds the length of the field. V$LATCHHOLDER, V$LATCHNAME, and V$LATCH_CHILDREN are also helpful in investigating latch issues. Here is a partial listing of the latch activity section; there are six sections related to latches (Latch Activity, Latch Sleep, Latch Miss, Mutex Sleep Summary, Parent Latch Statistics, and Child Latch Statistics) for the AWR Report and Statspack Report (this Statspack Report has no major problems as I am not missing more than 1 percent—partial display latches only):

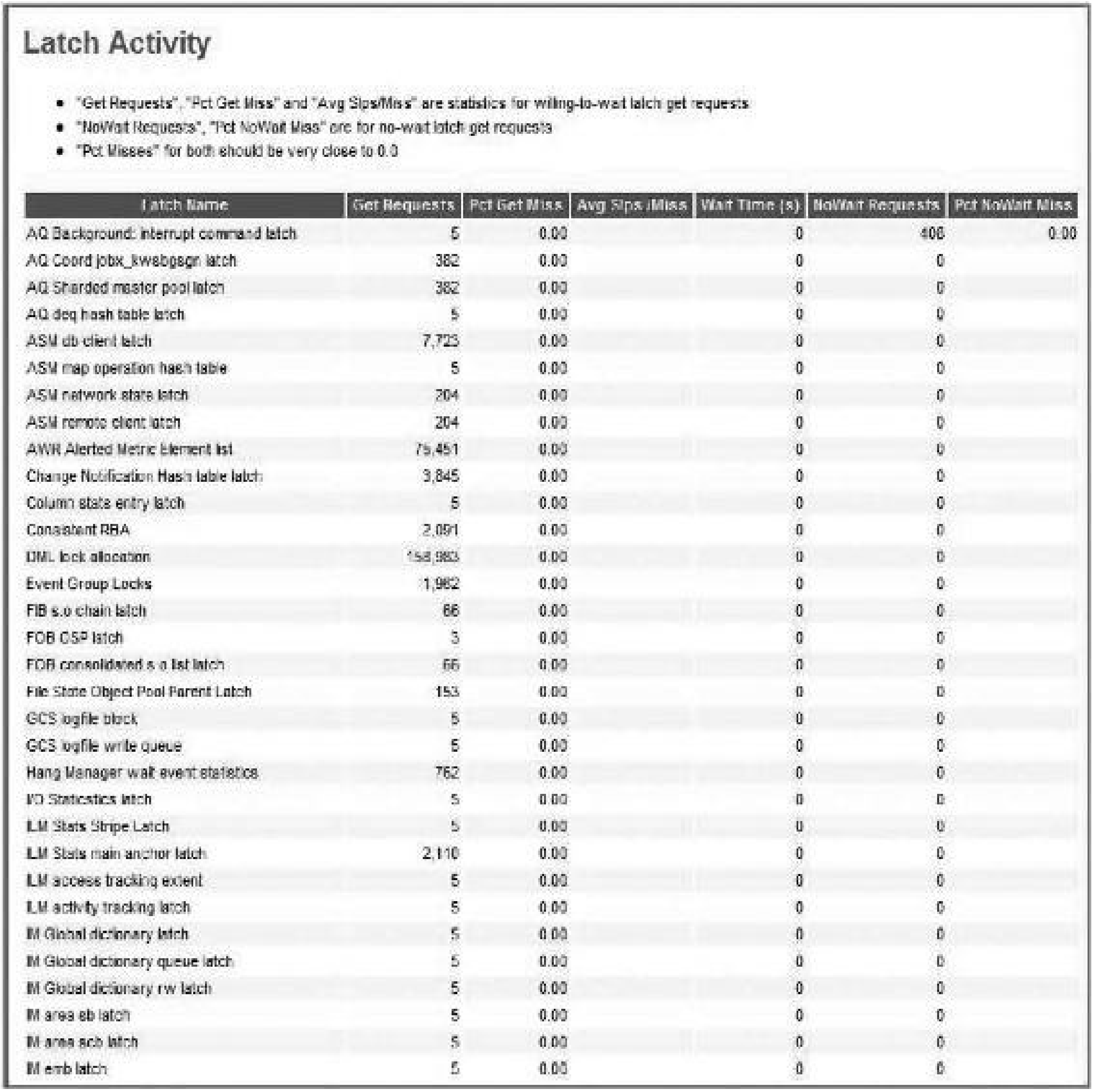
```
Latch Activity  DB/Inst: ORCL/orcl  Snaps: 1 2
->"Get Requests", "Pct Get Miss" and "Avg Slps/Miss" are statistics for
  willing-to-wait latch get requests
->"NoWait Requests", "Pct NoWait Miss" are for no-wait latch get requests
->"Pct Misses" for both should be very close to 0.0

                                           Pct    Avg   Wait                 Pct
                                Get        Get   Slps   Time       NoWait NoWait
Latch                         Requests     Miss  /Miss   (s)     Requests   Miss
------------------------ --------------- ------ ------ ------ ------------ ------
AQ deq hash table latch                1    0.0             0            0
AQ dequeue txn counter l             706    0.0             0            0
ASM db client latch                  543    0.0             0            0
ASM map operation hash t               1    0.0             0            0
cache buffer handles             968,992    0.0    0.0                   0
cache buffers chains         761,788,539    0.0    0.4           21,519,841    0.0
cache buffers lru chain        8,111,269    0.1    0.8           19,834,466    0.1

enqueue hash chains               25,152    0.0             0            1    0.0
enqueues                          16,151    0.0             0            0
lob segment dispenser la               1    0.0             0            0
lob segment hash table l               5    0.0             0            0
lob segment query latch                1    0.0             0            0
redo allocation               12,446,986    0.2    0.0                   0
redo copy                            320    0.0                  10,335,430    0.1
shared pool                       22,339    0.1    0.0      0            0
shared pool sim alloc                  8    0.0             0            0
shared pool simulator                988    0.0             0            0
           ------------------------------------------------------------

Latch Miss Sources for DB:
-> only latches with sleeps are shown
-> ordered by name, sleeps desc
                                                     NoWait              Waiter
Latch Name               Where                       Misses     Sleeps   Sleeps
------------------------ -------------------------- ------- ---------- -------
cache buffers chains     kcbgtcr: kslbegin                0     63,446  47,535
cache buffers chains     kcbgcur: kslbegin                0      9,820   7,603
cache buffers lru chain  kcbzgb: multiple sets nowa       0      4,859       0
enqueues                 ksqdel                           0    106,769  12,576
redo allocation          kcrfwr: redo allocation          0        942   1,032
redo allocation          kcrfwi: before write             0        191      53
redo allocation          kcrfwi: more space               0          2      39
```

Figures 14-17 and 14-18 show similar statistics from the AWR Report, including the new Mutex Sleep Summary in Figure 14-18. Note in Figure 14-17 the new 12*c*R2 In-Memory column store latches that mirror some of those in the buffer cache (i.e., IM Global dictionary latch, etc.). Some of the In-Memory latches include

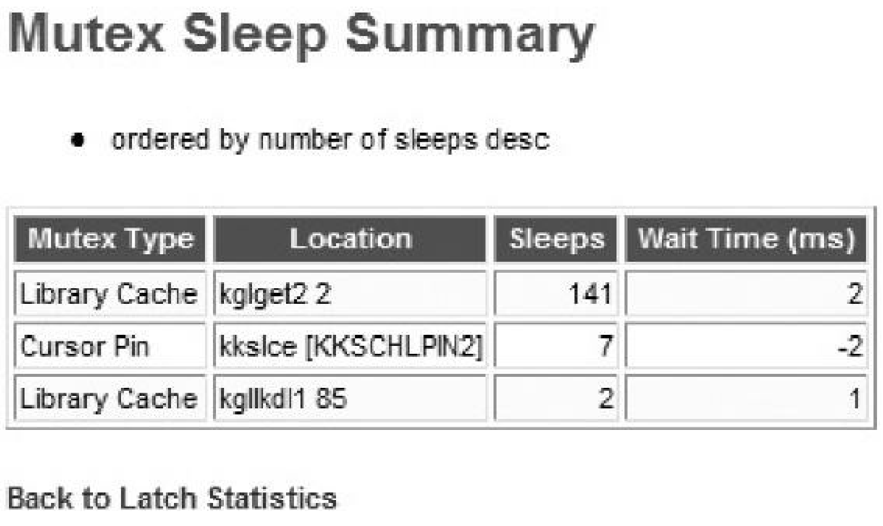


Latch Activity

- "Get Requests", "Pct Get Miss" and "Avg Slps/Miss" are statistics for willing-to-wait latch get requests
- "NoWait Requests", "Pct NoWait Miss" are for no-wait latch get requests
- "Pct Misses" for both should be very close to 0.0

Latch Name	Get Requests	Pct Get Miss	Avg Slps /Miss	Wait Time (s)	NoWait Requests	Pct NoWait Miss
AQ Background: interrupt command latch	5	0.00		0	400	0.00
AQ Coord jobx_kwsbgsgn latch	382	0.00		0	0	
AQ Sharded master pool latch	382	0.00		0	0	
AQ deq hash table latch	5	0.00		0	0	
ASM db client latch	7,723	0.00		0	0	
ASM map operation hash table	5	0.00		0	0	
ASM network state latch	204	0.00		0	0	
ASM remote client latch	204	0.00		0	0	
AWR Alerted Metric Element list	75,451	0.00		0	0	
Change Notification Hash table latch	3,845	0.00		0	0	
Column stats entry latch	5	0.00		0	0	
Consistent RBA	2,091	0.00		0	0	
DML lock allocation	158,983	0.00		0	0	
Event Group Locks	1,982	0.00		0	0	
FIB s.o chain latch	66	0.00		0	0	
FOB CSP latch	3	0.00		0	0	
FOB consolidated s.o list latch	66	0.00		0	0	
File State Object Pool Parent Latch	153	0.00		0	0	
GCS logfile block	5	0.00		0	0	
GCS logfile write queue	5	0.00		0	0	
Hang Manager wait event statistics	762	0.00		0	0	
I/O Statistics latch	5	0.00		0	0	
ILM Stats Stripe Latch	5	0.00		0	0	
ILM Stats main anchor latch	2,110	0.00		0	0	
ILM access tracking extent	5	0.00		0	0	
ILM activity tracking latch	5	0.00		0	0	
IM Global dictionary latch	5	0.00		0	0	
IM Global dictionary queue latch	5	0.00		0	0	
IM Global dictionary rw latch	5	0.00		0	0	
IM area sb latch	5	0.00		0	0	
IM area scb latch	5	0.00		0	0	
IM emb latch	5	0.00		0	0	

FIGURE 14-17. *The AWR Report Latch Activity section (12cR2 includes many new In-Memory latches)*


Mutex Sleep Summary

- ordered by number of sleeps desc

Mutex Type	Location	Sleeps	Wait Time (ms)
Library Cache	kglget2 2	141	2
Cursor Pin	kkslce [KKSCHLPIN2]	7	-2
Library Cache	kgllkdl1 85	2	1

Back to Latch Statistics

FIGURE 14-18. *The AWR Report Mutex Sleep Summary*

- In-Memory area latch
- In-Memory columnar segment hash table latch
- In-Memory columnar ts extent map chunk latch
- In-Memory global pool latch

A mutex (which replaces many types of library cache latches) is used to eliminate the possibility of two processes simultaneously using a common resource (while one or both are trying to change it); when one session is changing the resource, the second can't view it or change it, and when one session is viewing the resource, the second can't change it.

Oracle moved from latches to mutexes because a mutex is lighter weight and provides more granular concurrency than latches. A mutex requires less memory space and fewer instructions. Mutexes take advantage of CPU architecture that has "compare and swap" instructions (and similar types of benefits). Without going into a lot of detail, Oracle uses mutexes (*mutual exclusion*) instead of library cache latches and library cache pin latches to protect objects. With a mutex, if I have the resource and you can't get it after trying a specified number of times (spins), you sleep and try again a very short time later. In 10*g*, Oracle also used mutexes for pins, but you could use the undocumented parameter _KKS_USE_MUTEX_PIN=FALSE to override it. This parameter is no longer available in 12*c*. *A mutex, while similar to a latch, protects a single object, whereas a latch usually protects a group of objects*.

When you receive wait events on *cursor: pin S wait on X*, you are probably waiting on a hard parse; the session needs a mutex in share mode on a resource and someone has it in exclusive mode. A *pin* is when a session wants to re-execute a statement that's in the Library Cache. Waits for pins generally happen with high rates of SQL execution, whereas waiting for a resource held in exclusive mode (X) usually is related to hard parsing. When a session wants a mutex in S (share mode) on a cursor (SQL statement), but another session is holding that mutex in X (exclusive) mode, the session waiting for the mutex in S mode will sleep. After asking enough times and not getting the latch, the session sleeps for a short time and then it begins trying again to get the mutex. A mutex is also not FIFO (first in, first out); order is not guaranteed. All of this is for efficiency.

Library cache latches have been replaced with mutexes. In fact, all library cache latches are replaced with mutexes other than the library cache load lock. The following queries help you find information related to mutex wait events when you get them. (This is an example of a cursor: pin S wait on X wait event; check My Oracle Support for your exact wait and related values. Specific wait events are covered later in this section.)

P1 is the idn, which is the HASH_VALUE of the SQL statement I am waiting on. I can query V$SQL or V$SQLAREA to get the actual SQL_TEXT:

```
select sql_text
from   v$sqlarea
where  hash_value=&&P1;
```

P2 is the mutex value, which is the session id (higher bits) and reference count (which is 0 if I am sleeping/waiting for an X mode holder):

```
select decode(trunc(&&P2/4294967296), 0, trunc(&&P2/65536),
       trunc(&&P2/4294967296)) SID_HOLDING_THE_MUTEX
from   dual;
```

I can also go to V$SESSION to see the blocker:

```
select action, blocking_session, blocking_session_status, sql_id
from   v$session
where  sid = &SID_HOLDING_THE_MUTEX;     (get this from query above)
```

P3 is the location in the code where the wait is occurring. Knowing this location can be very helpful when Oracle Support is helping you with an issue. The library cache: mutex X wait event has the same values for P1, P2, and P3 according to Oracle's documentation. You can also investigate the V$MUTEX_SLEEP and V$MUTEX_SLEEP_HISTORY views for more information. You will generally find that the mutex type is almost always a library cache mutex or cursor pin mutex when querying these views. Cursor parent and cursor stat mutexes also show up in these views. See the following sample queries showing mutex sleeps:

```
select mutex_type, count(*), sum(sleeps)
from   v$mutex_sleep
group  by mutex_type;
```

```
MUTEX_TYPE                         COUNT(*) SUM(SLEEPS)
-------------------------------- ---------- -----------
Library Cache                             8        3891
Cursor Pin                                4        1605
Cursor Parent                             2         129
hash table                                2          27

select mutex_type, count(*), sum(sleeps)
from   v$mutex_sleep_history
group  by mutex_type;

MUTEX_TYPE                         COUNT(*) SUM(SLEEPS)
-------------------------------- ---------- -----------
Library Cache                           201        3891
Cursor Pin                               63         889
Cursor Parent                            20         244
hash table                               14          75
```

One thing to remember about sleeping processes: These processes may also be holding other latches/mutexes that will not be released until the process is finished with them. This can cause even more processes to sleep while waiting for those latches. So you can see how important it is to reduce contention as much as possible. The following table explains the columns in this part of the report:

Column	Description
LATCH NAME	The name of the latch.
GETS	The number of times a "willing to wait" request for a latch was requested and it was available.
MISSES	The number of times a "willing to wait" request for a latch was initially requested but was not available.
SLEEPS	The number of times a "willing to wait request" for a latch failed until the spin count was exceeded and the process went to sleep. The number of sleeps may be greater than the misses. Processes may sleep multiple times before obtaining the latch.
NOWAIT MISSES	The number of times an immediate (not willing to wait) request for a latch was unsuccessful.

The following are some latches and mutexes to look for and remember.

Latch Free When *latch free* is high in the wait events section of the report, then problems need to be investigated in the latch section of the report. This section helps you look for which latches are problematic. The problem could be a sleeping latch (couldn't get the latch and now it's sleeping until the next try) or a spinning latch (waiting and retrying based on spin count).

Library Cache Mutex, Cursor Pin Mutex, and Shared Pool Latch The Library Cache is a hash table you access through an array of hash buckets (similar to the buffer cache). The memory for the

Library Cache comes from the shared pool (the Dictionary Cache used for Oracle internal objects is also part of the shared pool). The *library cache mutex* serializes access to objects in the library cache. Every time a SQL or PL/SQL procedure, package, function, or trigger is executed, this library cache mutex is used to search the shared pool for the exact statement so it can be reused. A single shared pool latch protected the allocation of memory in the Library Cache; seven child latches are available for this.

Contention for the shared pool latch, cursor pin mutex, or library cache mutex primarily occurs when the shared pool is too small or when statements are not reused. When an executable form of a SQL cursor is found in the shared pool, it is a soft parse and it is reused; when it's not found, it's a hard parse or library cache miss (which requires more resources, CPU, and library cache latches/mutexes because it has to rebuild the executable form of the SQL). Per the Oracle 12*c* documentation: *"Reuse of shared SQL for multiple users running the same application avoids hard parsing (reparsing a statement). Soft parses provide a significant reduction in the use of resources, such as the shared pool and library cache latches."* Statements are not generally reused when bind variables are not used. Common but not exact SQL can flood the shared pool with statements. Increasing the size of the shared pool, at times, only makes the problem worse. You can also set the value of the initialization parameter CURSOR_SHARING=FORCE to help fix this issue and to reduce problems when bind variables are not used. CURSOR_SHARING=FORCE substitutes bind variables for literals (not just reduced latch/mutex contention, but also less shared pool use in the library cache area and a faster parse). Note that in 12*c*, Oracle uses adaptive cursor sharing, which enables a SQL statement to use multiple execution plans (which is also true of those that contain bind variables).

If you are not reusing SQL, you may see quite a few cursor: pin S wait on X wait events, in which waiting on a hard parse, a session wants a mutex in S (share) mode on a cursor (SQL statement), but another session is holding that mutex in X (exclusive) mode. You'll also see the reverse of this, cursor: pin X wait on S. The shared pool latch and library cache mutex issues also occur when space is needed in the Library Cache when the shared pool is too small for the number of SQL statements that need to be processed. A *hard* parse occurs when a new SQL statement is issued that does not exist in the shared pool currently because it has to be parsed. Oracle has to allocate memory for the statement from the shared pool, as well as check the statement syntactically and semantically. A hard parse is very expensive in terms of both CPU used and the number of mutexes that need to be used. A *soft* parse occurs when a session issues a SQL statement that is already in the shared pool, *and* it can use an existing version of that statement. As far as the application is concerned, it has asked to parse the statement. While space is being freed up to load a SQL or PL/SQL statement, the shared pool latch (held for allocate and free) is being held exclusively and other users must wait. You can help to reduce contention by increasing the shared pool or by pinning large SQL and PL/SQL statements in memory using the DBMS_SHARED_POOL.KEEP procedures to avoid reloads. Pinning helps reduce many of the mutex and latch waits and ORA-4031 issues as well.

You can increase the number of the library cache hash table bucket count by setting _KGL_BUCKET_COUNT (see Appendix A for more information on the undocumented initialization parameters); note that 9 (the default) puts this at ((2 to the 9th power)*256)–1 = 131,071), which should be more than enough for most systems. The _KGL_LATCH_COUNT parameter (which is set to 0) is still in 12*c*. Remember that you should never set the underscore parameters without direction from Oracle Support. In 12*c*, *each* library cache bucket (131,071) is protected by a mutex!

Note that a count of X$KSMSP shows how many shared pool pieces there are; each row in the table represents a piece of memory in the shared pool. Columns to note are KSMCHCOM (describes the piece of memory), KSMCHPTR (the physical address of the piece of memory), KSMCHSIZ (piece size), and KSMCHCLS (the state/class of the piece of memory). Useful values of KSMCHCLS include the following:

- **recr** A re-creatable piece currently in use that can be a candidate for flushing when the shared pool is low in available memory.
- **freeabl** A freeable piece of memory that is currently in use and not a candidate for flushing but can be freed.
- **free** A free unallocated piece of memory.
- **perm** A permanently allocated piece of memory that can't be freed without deallocating the entire heap.

The shared pool architecture is similar to the buffer cache in that there are a fixed number of hash buckets (that grow to the next level as needed) protected by a fixed number of library cache mutexes (unless changed, as noted earlier). The number of buckets and latches is often (but not always) prime to avoid hashing anomalies. At startup, the database allocates 509 hash buckets and a library cache mutex for each bucket rounded up to the nearest prime number. As the number of objects in the library cache increases, Oracle increases the number of hash buckets in the following order: 509, 1021, 2039, 4093, 8191, 16381, 32749, 65521, 131071, and 4292967293. You can set the number of hash buckets by setting _KGL_BUCKET_COUNT as described earlier. When installed, the default value was 9, which gave me a Library Cache hash table bucket count of 131,071, and a library cache mutex count of 131,071 (many more than in the past; this should reduce a lot of contention). A single hash bucket can contain multiple SQL statements and potentially long hash chains, which explains why you can see long library cache mutex hold times even when no space allocation is needed and no LRU list search is involved.

Also note that a SQL hash value is not the only value used in determining which hash bucket is used; the initial tree starts with object handles, which include name, namespace (CURSOR is the main namespace; others include trigger and cluster), lock owner, lock waiter, pin owner, pin waiter, and other pre-SQL items. The object handle then points to the next level of the tree, the data heap itself (where the statement itself is for a cursor), which includes the type of heap, name (for example, SCOTT.EMP), flags (things like wrapped, valid), tables (for example, privilege, dependencies), and data blocks (everything else—the SQL text). This means that you can have hundreds of identical SQL statements all referenced by different users, and they will be distributed fairly evenly across the hash buckets with no super-long hash chains full of identical SQL, but you will need a larger shared pool. If the statement is *not* in the Library Cache, the library load lock latch (this is still a latch, and the only library cache latch that I saw in 12*c*) is used to load it (the library cache mutex and shared pool latch are also needed in this process).

If the preceding paragraphs are complex or confusing, just focus on this paragraph. The main key to limiting latch and mutex issues on the library cache mutex or shared pool latch is to use bind variables, to use cursor sharing, to parse things once and execute them many times, to use SESSION_CACHED_CURSORS to move the cursors from the shared pool to the PGA, and, if you are sharing cursors and using bind variables, to increase the shared pool (although if you are not sharing statements, reducing it may help). Lastly, try not to do any DDL (ALTER, GRANT, REVOKE…) that would cause things to be invalidated and/or reloaded.

NOTE
I've seen more 10–100G+ shared pools in Oracle 12c than ever before.

Redo Copy Latch The *redo copy* latch is used to copy REDO records from the PGA into the redo log buffer. The number of redo copy latches has a default of 2*CPU_COUNT, but you can set this using the _LOG_SIMULTANEOUS_COPIES initialization parameter (the default was 2 copy latches on my system, but I've seen it set to 16 as well). Increasing this parameter may help to reduce contention for the redo copy latch.

Redo Allocation Latch The *redo allocation* latch allocates the space in the redo log buffer. You can reduce contention by increasing the size of the log buffer (LOG_BUFFER) or by using the NOLOGGING feature, which reduces the load on the redo log buffer. You should also try to avoid unnecessary commits.

Row Cache Objects The *row cache objects* latch contention usually means that contention is present in the data dictionary. This contention may also be a symptom of excessive parsing of SQL statements that depend on public synonyms. Increasing the shared pool usually solves this latch problem. You usually increase the shared pool for a library cache mutex problem well before this one is a problem. Also, according to My Oracle Support (Metalink Note 166474.1), "Use Locally Managed tablespaces for your application objects, especially indexes. This will decrease Row Cache locks in a surprising fashion and consequently avoid common hanging problems."

Cache Buffers Chains (CBC) The *cache buffers chains (CBC)* latch is needed to scan the SGA buffer cache for database cache buffers. In Oracle 12*c*, the CBC can be shared, eliminating much of the contention. Tuning the code to use fewer buffers (and hence fewer CBCs) is the best solution to eliminating problems with this latch. Also, reducing the popularity of the block reduces the length of the hash chain (as discussed in the next item).

CBC latches are used when searching for, adding, or removing a buffer from the buffer cache. The buffer hash table, X$BH, holds headers (on a hash chain protected by a CBC latch) that point to DB_BLOCK_BUFFERS (data block buffers) in memory. Buffers are "hashed to a chain," and the _DB_BLOCK_HASH_BUCKETS parameter defines the number of chains (buckets) to which a buffer will hash. The more buckets (chains) present, the smaller the "chain" length will be with buffers hashed to the same chain (as long as the number is prime). The CBC latches are used to protect a buffer list in the buffer cache. If _DB_BLOCK_HASH_BUCKETS was not set to a prime number in the past, you probably had many buffers hashed to one chain and none hashed to others (causing hot blocks to tie up other blocks on the chain) because of hashing anomalies.

In 12*c*, my _DB_BLOCK_HASH_BUCKETS was set to a default of exactly 1M (1,048,576 = 1024*1024), which was about 4× the number of _DB_BLOCK_BUFFERS (set by Oracle behind the scenes based on the DB_CACHE_SIZE). Contention on this latch could indicate a "hot block" or bad setting for _DB_BLOCK_HASH_BUCKETS prior to 9*i*. Prior to version 8*i*, Oracle made this the prime number higher than DB_BLOCK_BUFFERS/4, which worked pretty well, although multiple blocks still got hashed to the same chain. In 8*i*, Oracle made this DB_BLOCK_BUFFERS*2, but they forgot to make it prime (which, because it is a hashed value, caused many blocks to be hashed to the same chain); *many* users experienced severe problems with this latch (you can set _DB_BLOCK_HASH_BUCKETS = next prime(DB_BLOCK_BUFFERS*2) to solve this issue in prior versions). Since 9*i*, Oracle sets it to a value reducing this contention, and there are enough "hash latches," as people often call them. Your mileage may vary, so I continue to leave this section in the book. I also leave very important notes about other versions since most DBAs that I know still run multiple versions of the Oracle database. You will access *many* hash latches (latches used to scan the hash chain) because you need one every time you access a block, but you *should not* have a miss ratio of over 1–2 percent on this latch. In 12*c*, these hash latches (CBC latches) are shared, and the hash chain can be scanned in both directions.

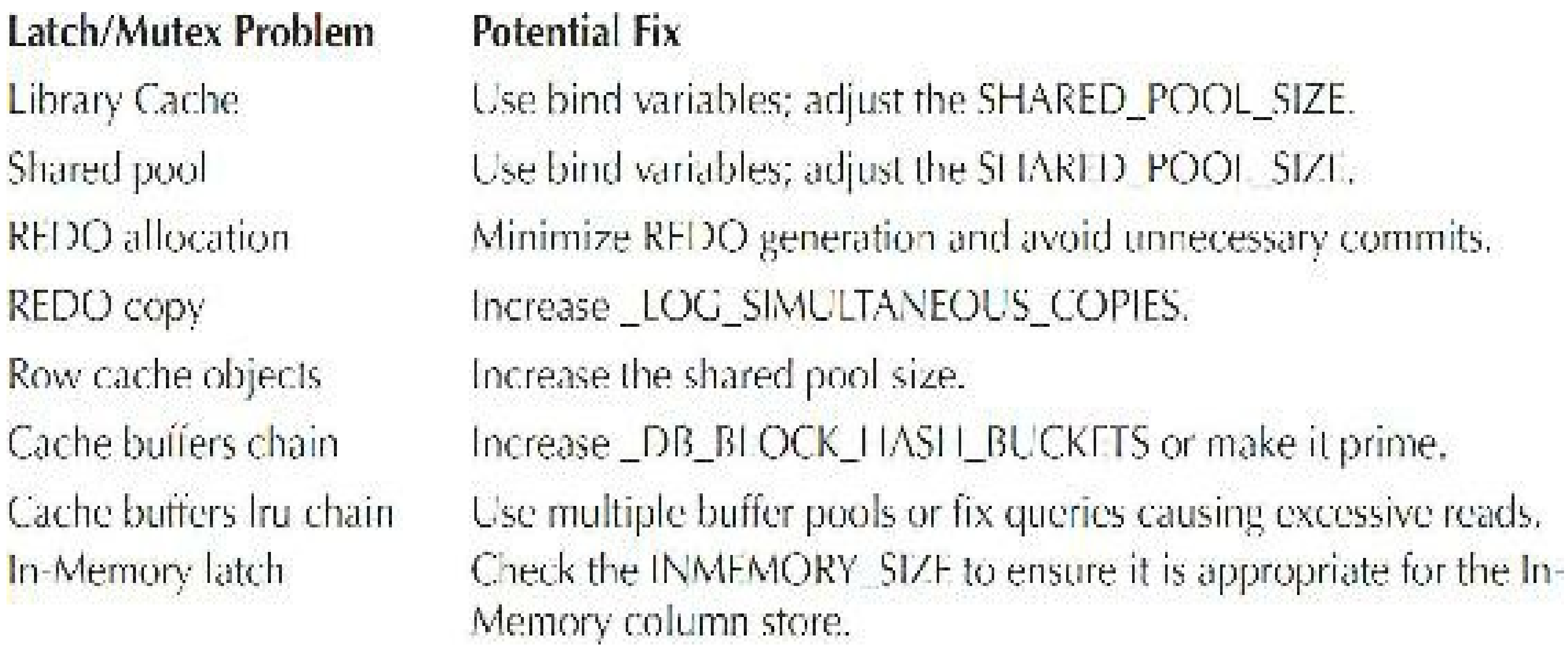
CR Versions for a Given Block Only one block is CURRENT, and no more than six other CR versions of the block are allowed. All of them are located on the same doubly linked (can move both ways) hash chain. In 12*c*, you *can* see more than six versions of a block in memory for high volumes of SELECTs to a given block. They are in multiple states, but only six are in a state=3 (CR), and only one is a state=1 (CURRENT). The number of CR blocks is limited to six as any DML activity clears or as more DML tries to be performed in a given block. For DML, you need the CURRENT version (of which there is only *one* CURRENT version of any given block), and for a read query, you can use the CURRENT version if it is not being used, and/or you can build a CONSISTENT READ (CR) version by applying any UNDO needed to the CURRENT version of a changed block after cloning it. This process of cloning a block to build a CR version may include: reading the ITL, mapping to the UNDO header (the ITL also maps directly to the UNDO block), and applying the UNDO to get the correct CR version that you need, which happens when IMU is not used (more on IMUs later in "Tuning and Viewing at the Block Level"). When IMU is used, everything happens at the block level in memory until a commit or rollback. When you have multiple versions of a block (one CURRENT and a few CR versions), the hash chain gets longer, and the CBC latch gets held longer as it scans the hash chain. This is why Oracle now limits the number of clones (CR versions) of a block (limits the chain length). Although you can change this by setting _DB_BLOCK_MAX_CR_DBA, which is the maximum allowed number of CR buffers for a given DBA (data block address), it's a setting that performs well out of the box.

Hot Blocks Blocks often accessed in the buffer cache cause "cache buffers chains" latch issues, or *hot blocks*. Hot blocks may also be a symptom of poorly tuned SQL statements. A hot record creates a hot block that can cause issues for other records inside that block as well as any block "hashed" to the same chain. To find the hot block, query V$LATCH_CHILDREN for the address and join it to V$BH to identify the blocks protected by this latch (doing this shows all blocks affected by the hot block). You can identify the object by querying the DBA_EXTENTS view according to the file# and DBABLK found in V$BH. Using a reverse-key index, if the hot block is on an index, moves sequential records to other blocks so they are not locked up by the hot block in the chain. If the hot block is the index root block, a reverse-key index won't help.

Cache Buffers LRU Chain The *cache buffers lru chain* latch is used to scan the least recently used

(LRU) chain containing all of the blocks in the buffer cache. A small buffer cache, excessive buffer cache throughput, many cache-based sorts, and the DBWR not keeping up with the workload are all culprits that can cause this issue. Try to fix the queries that are causing the excessive logical reads and/or use multiple buffer pools.

Some of the most common latch problems and potential solutions are described in the following table (note that there is also a *shard latch* if using 12*c*R2 sharding):



Latch/Mutex Problem	Potential Fix
Library Cache	Use bind variables; adjust the SHARED_POOL_SIZE.
Shared pool	Use bind variables; adjust the SHARED_POOL_SIZE.
REDO allocation	Minimize REDO generation and avoid unnecessary commits.
REDO copy	Increase _LOG_SIMULTANEOUS_COPIES.
Row cache objects	Increase the shared pool size.
Cache buffers chain	Increase _DB_BLOCK_HASH_BUCKETS or make it prime.
Cache buffers lru chain	Use multiple buffer pools or fix queries causing excessive reads.
In-Memory latch	Check the INMEMORY_SIZE to ensure it is appropriate for the In-Memory column store.

Since Oracle9*i* (for people with multiple versions of Oracle to manage), you could configure LRU latches so each buffer pool has *n* CPUs' worth of latches. For example, if the system has eight CPUs, you should set

buffer_pool_keep = buffers:*XXXX*, lru_latches=8
buffer_pool_recycle = buffers:*YYYY*, lru_latches=8

Here, *XXXX* and *YYYY* are the desired number of buffers in the keep and recycle pools, respectively. There is really no reason to have more LRU latches than the number of processes that may be concurrently executing.

In 12*c*, the parameters are now DB_KEEP_CACHE_SIZE and DB_RECYCLE_CACHE_SIZE, and both accept only the size in bytes (you cannot specify LRU_LATCHES):

db_keep_cache_size= 4G (you can also use K or M, and the default is 0)
db_recycle_cache_size=1G (you can also use K or M, and the default is 0)

Some latch problems have often been bug related in the past, so make sure you check My Oracle Support (Metalink) for issues related to latches. Any of the latches that have a hit ratio less than 99 percent should be investigated. Some of the more common latches on the problem list were detailed in this chapter and include the cache buffers chains, redo copy, library cache mutex, and the cache buffers lru chain.

TIP
Latches are like locks on pieces of memory (or memory buffers). If the latch hit ratio is less than 99 percent, you have a serious problem because not even the lock to get memory can be gotten. Oracle 12cR2 has a shard latch (for sharding), and many In-Memory latches, including in-memory area latch, in-memory columnar segment hash table latch, in-memory columnar ts extent map chunk latch, and in-memory global pool latch.

Tuning and Viewing at the Block Level (Advanced)

Infrequently, when you have a hot block or some other block-level issue, you may need to find the exact location of the block for a given object and the number of versions (as was discussed in the preceding section). Here, I briefly discuss some of the block-level Oracle details.

CAUTION
This section should not be used by beginners.

An internal table called the buffer hash table (X$BH) holds block headers. Blocks are linked to a hash chain that is protected by a CBC latch (cache buffers chains latch). This links to the actual address located in memory (the memory set up with DB_CACHE_SIZE, SGA_TARGET, or MEMORY_TARGET, if used, which is the cache used for data). For a given block in Oracle, only one version of a block is CURRENT, and there are no more than five other CR versions of the block. So only six versions of a given block (maximum) are in memory at a time. Later in this section, I tell you how to control this with an undocumented parameter. Oracle recommends that you not use the undocumented parameters unless you are directed by Oracle Support or your database may not be supported.

When you perform a DML transaction (INSERT, UPDATE, or DELETE), you always need the CURRENT version of a block. Oracle has something called an *in-memory undo (IMU)*, which can give you some hard-to-understand results when you are viewing information at the block level (whether it's dirty or not). IMU was new as of 10*g*; what it means is that the UNDO records and REDO records for some transactions are stored in memory until the transaction commits. When a CR block is needed, the database first checks to see if the UNDO records are stored in the memory pool; if so, it applies the UNDO and REDO records from memory instead of retrieving them from the UNDO segments and redo logs/buffers (doing this in memory is much faster). When you are querying a block for the first time, you always use the CURRENT version of a block. If the block is being used, you build a clone of the block called a CONSISTENT READ (CR) version by applying any UNDO needed to the CURRENT version of the block to get it to a point in time that makes it useful to you (perhaps you need a version of the block before DML was performed and not committed by another user). This complex, Oracle-patented process may include reading the ITL and mapping the record to the UNDO header, or else mapping it directly to the UNDO block and then applying the UNDO to get the correct CR version that you need. Let's take a look at how this happens:

1. User 1 updates a record in block 777 (user 1 has not committed).
2. User 2 queries the same block and sees that the lock byte is set for a row being queried.
3. User 2 goes to the ITL portion of the block and gets the XID (transaction ID).
4. The XID maps to the UNDO block, which holds the information before the update was performed. If using IMU, then a check is done to see if the UNDO for this transaction is available in memory before going to the UNDO block.
5. A clone of the block is made (call it block 778).
6. The UNDO information is applied to the block, rolling it back to where it used to be (its contents go to a past state, including the SCN).
7. Block 777 is a CURRENT block.
8. Block 778 is a CONSISTENT READ block before the user 1 update occurred.
9. If another user performs a query against the same block before the commit, that user can also read the CR version.

Note *especially* the fact that the block is not *rolled back* to what it was, but it is *rolled forward* (to what it used to be). While the result is the same, how Oracle performs this operation is *critical* to understanding how Oracle works. Oracle blocks are always moving forward in time (this is why the REDO works if the machine gets turned off—it's always applying things forward sequentially). There are also links to all blocks for the LRU and LRU-W (least recently used–write) chains to help make buffer replacement and writing much faster. These links are also maintained in the buffer headers.

Here are some nice (rarely found) queries to get block-level information.

Finding the block number (56650) for a given object (EMP1)

```
select rowid,empno,
       dbms_rowid.rowid_relative_fno(rowid) fileno,
       dbms_rowid.rowid_block_number(rowid) blockno,
       dbms_rowid.rowid_row_number(rowid)    rowno, rownum,
       rpad(to_char(dbms_rowid.rowid_block_number(rowid), 'FM0xxxxxxx') || '.' ||
       to_char(dbms_rowid.rowid_row_number  (rowid), 'FM0xxx     ) || '.' ||
       to_char(dbms_rowid.rowid_relative_fno(rowid), 'FM0xxx     ), 18) myrid
from   emp1;

ROWID                     EMPNO      FILENO     BLOCKNO        ROWNO      ROWNUM              MYRID
------------------ ---------- ---------- ---------- ---------- ---------- ------------------

AAAM4cAABAAANIKAAA        7369          1       56650            0          1 0000dd4a.0000.0001
AAAM4cAABAAANIKAAB        7499          1       56650            1          2 0000dd4a.0001.0001
… (output truncated)
AAAM4cAABAAANIKAAN        7934          1       56650           13         14 0000dd4a.000d.0001

14 rows selected.
```

Finding the versions (1 CURRENT and 5 CR versions) of a block for a given block number (56650)

```
select lrba_seq, state, dbarfil, dbablk, tch, flag, hscn_bas,cr_scn_bas,
      decode(bitand(flag,1), 0, 'N', 'Y') dirty,   /* Dirty bit */
      decode(bitand(flag,16), 0, 'N', 'Y') temp,   /* temporary bit */
      decode(bitand(flag,1536),0,'N','Y') ping,   /* ping (shared or null) bit */
      decode(bitand(flag,16384), 0, 'N', 'Y') stale, /* stale bit */
      decode(bitand(flag,65536), 0, 'N', 'Y') direct, /* direct access bit */
      decode(bitand(flag,1048576), 0, 'N', 'Y') new    /* new bit */
from  x$bh
where dbablk = 56650
order by dbablk;

LRBA_SEQ      STATE    DBARFIL     DBABLK        TCH        FLAG   HSCN_BAS
---------- ---------- ---------- ---------- ---------- ---------- ----------
CR_SCN_BAS D T P S D N
---------- - - - - - -
         0          3          1      56650          1     524416          0
   4350120 N N N N N N
         0          3          1      56650          1     524416          0
   4350105 N N N N N N
       365          1          1      56650          7   33562633    4350121
         0 Y N N N N N
         0          3          1      56650          1     524416          0
   4350103 N N N N N N
         0          3          1      56650          1     524416          0
   4350089 N N N N N N
         0          3          1      56650          1     524288          0
   4350087 N N N N N N
```

NOTE

In the preceding listing, `state=1` is CURRENT and `state=3` is CR; only the CURRENT block is (can be) dirty.

Finding the setting for the maximum CR versions of a block

```
select a.ksppinm, b.ksppstvl, b.ksppstdf, a.ksppdesc
from   x$ksppi a, x$ksppcv b
where  a.indx = b.indx
and    substr(ksppinm,1,1) = '_'
and    ksppinm like '%&1%'
order  by ksppinm;

Enter a value for 1: db_block_max_cr_dba

KSPPINM       KSPPSTVL KSPPSTDF KSPPDESC
-------------------- -------- - ------ ---------------------------------------------
 _db_block_max_cr_dba        6 TRUE    Maximum Allowed Number of CR buffers per dba
```

Dumping what’s inside the block for EMP1

```
SQL> select header_file, header_block, blocks from dba_segments
  2  where segment_name = 'EMP'
  3  and owner = 'SCOTT';

HEADER_FILE HEADER_BLOCK     BLOCKS
----------- ------------ ----------
          4           27          8

ALTER SYSTEM DUMP DATAFILE 4 BLOCK 28;
System Altered.
```

TIP

Never go to the block level unless you absolutely have to go there. The block level is a great place to find hot block and ITL issues, but it takes a lot of time and energy on the part of an advanced DBA to pinpoint problems at this level.

Dictionary and Library Cache Statistics

The next two sections contain the Dictionary and Library Cache information. Listed first is all of the data dictionary information. This data pertains to all of the objects in the database. This information is accessed for every SQL statement that gets parsed and again when the statement is executed. The activity in this area can be very heavy. Maintaining a good hit ratio is very important to prevent recursive calls back to the database to verify privileges. You can also evaluate the efficiency of the Dictionary Cache by querying the V$ROWCACHE view. The query that follows shows the information that the Statspack Report lists for this section of the report:

```
Dictionary Cache Stats  DB/Inst: ORCL/orcl  Snaps: 1-2
->"Pct Misses"  should be very low (< 2% in most cases)
->"Final Usage" is the number of cache entries being used in End Snapshot
                                   Get    Pct    Scan   Pct      Mod      Final
Cache                         Requests   Miss    Reqs  Miss     Reqs      Usage
------------------------- ------------ ------ ------- ----- -------- ----------
dc_awr_control                       2    0.0       0              0          1
dc_global_oids                      28    0.0       0              0         51
dc_histogram_data                1,095   13.7       0              0        657
dc_histogram_defs                  972   25.8       0              0        739
dc_objects                       6,775    1.9       0             21      1,965
dc_props                            60    0.0       0              0          1
dc_rollback_segments                22    0.0       0              0         22
dc_segments                      1,689    8.1       0            201        419
dc_tablespace_quotas               494    0.0       0              0          2
dc_tablespaces                   1,068    0.0       0              0          9
dc_users                         3,041    0.0       0              0        183
outstanding_alerts                   2  100.0       0              0          2
sch_lj_oids                          2    0.0       0              0          2
```

The second part of this section of the report deals with the performance of the Library Cache. These statistics are generated from the V$LIBRARYCACHE view. The Library Cache contains the shared SQL and PL/SQL areas. These areas are represented by the BODY, SQL AREA, TABLE/PROCEDURE, and TRIGGER values (these are values in the NAMESPACE column). They contain all of the SQL and PL/SQL statements that are cached in memory. The other names are areas that Oracle uses. If your PCT MISS value is high in this section of the report, you may need to improve cursor sharing in your application or increase the size of the shared pool (as discussed in the "Top Wait Events" section of this chapter). The following listing shows sample data for this section:

```
Library Cache Activity  DB/Inst: ORCL/orcl  Snaps: 1-2
->"Pct Misses"  should be very low
```

```
                       Get  Pct         Pin    Pct               Invali-
Namespace         Requests  Miss   Requests   Miss    Reloads  dations
--------------- ---------- ----- ------------ ----- ---------- --------
BODY                    23  17.4          98   6.1          2        0
CLUSTER                 19   0.0          19   0.0          0        0
EDITION                 13   0.0          26   0.0          0        0
INDEX                   47  93.6          47  93.6          0        0
OBJECT ID                5 100.0           0                0        0
SCHEMA                 315   0.3           0                0        0
SQL AREA             1,278  40.1       7,249  11.5        132       54
SQL AREA BUILD         308  83.8           0                0        0
SQL AREA STATS         296  70.3         296  70.3          0        0
TABLE/PROCEDURE      2,182  10.2       4,141  21.0        375        0
```

Here is what the columns mean in this part of the report:

Column	Description
NAMESPACE	The name of the library namespace.
GET REQUESTS	The number of times the system requested a handle to an object in this namespace.
PCT MISS (Get Miss Ratio)	The number of *gethits* divided by the number of *gets* is the *gethit ratio*. The gethits are the number of times a request was made for an object and the object was already in the cache. The hit ratio should be as close to 0.99 as possible. The PCT MISS should be less than 1 percent.
PIN REQUESTS	The number of times an item in the cache was executed. A high number is what you are after.
PCT MISS (Pin Miss Ratio)	The number of *pinhits* divided by the number of *pins* shows the *pinhit ratio*. Pinhits are the number of times that objects the system is pinning are already in the cache. This ratio should be as close to 1 as possible. The miss ratio should be less than 1 percent.
RELOADS	The number of Library Cache misses on an execution step. The number of reloads divided by the number of pins should be around 0 percent. If the ratio between this is greater than 1 percent, you should probably increase the size of the shared pool. These are hard parses!
INVALIDATIONS	The total number of times objects in this namespace were marked invalid because a dependent object was modified. These are hard parses!

TIP

If the pinhit ratio is less than 0.95 when the report is run for an extended period of time, the SHARED_POOL_SIZE is probably too small for your best system performance. If the reloads are greater than 1 percent, this also points to a SHARED_POOL_SIZE that is too small.

SGA Memory Statistics

Following an SGA memory summary (from V$SGA) and a listing of the memory changes during the snapshot interval, the reports both list the database initialization parameters in use at the beginning and end of the report.

Taken as a whole, the report generates a significant amount of data, allowing you to develop a profile of the database and its usage. By drawing on the initialization, file I/O, and SGA data, you can develop an understanding of the major components in the database configuration. Here is a sample listing of this section of the report:

```
SGA Memory Summary  DB/Inst: ORCL/orcl  Snaps: 1-2

                                                     End Size (Bytes)
SGA regions                     Begin Size (Bytes)     (if different)
------------------------------ -------------------- --------------------
Database Buffers                      2,315,255,808
Fixed Size                                2,188,768
Redo Buffers                             17,420,288
Variable Size                         4,513,073,696
                               -------------------- --------------------
sum                                   6,847,938,560
          -------------------------------------------------------------

SGA breakdown difference  DB/Inst: ORCL/orcl  Snaps: 1-2
-> Top 35 rows by size, ordered by Pool, Name (note rows with null values for
   Pool column, or Names showing free memory are always shown)
-> Null value for Begin MB or End MB indicates the size of that Pool/Name was
   insignificant, or zero in that snapshot

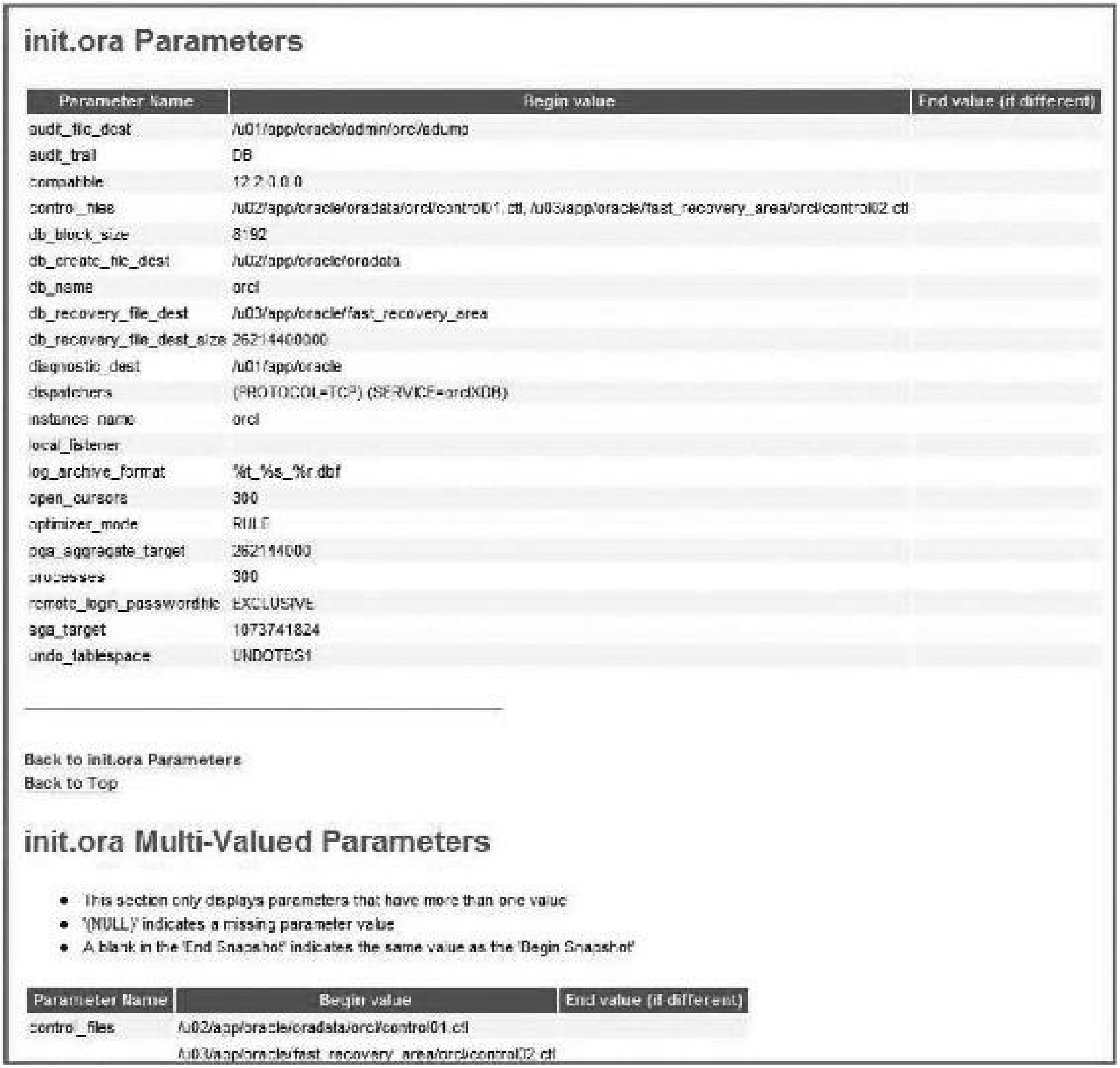
Pool   Name                                 Begin MB         End MB  % Diff
------ ------------------------------ -------------- -------------- --------
java p free memory                              16.0           16.0     0.00
large  PX msg pool                               7.8            7.8     0.00
large  free memory                              24.2           24.2     0.00
shared ASH buffers                              15.5           15.5     0.00
shared CCUR                                     77.1           77.6     0.64
shared FileOpenBlock                            10.5           10.5     0.00
shared KGLH0                                    17.4           17.4     0.07
shared KGLHD                                    21.5           21.6     0.31
shared KGLS                                     28.8           29.0     0.64
shared PCUR                                     40.7           41.1     0.82
shared PLDIA                                    12.8           12.8     0.00
shared PLMCD                                    15.1           15.1     0.00
shared SQLA                                    393.6          396.4     0.70
shared db_block_hash_buckets                    22.3           22.3     0.00
shared free memory                             242.4          238.1    -1.75
stream free memory                              16.0           16.0     0.00
       buffer_cache                          2,208.0        2,208.0     0.00
       fixed_sga                                 2.1            2.1     0.00
       log_buffer                               16.6           16.6     0.00
       shared_io_pool                          928.0          928.0     0.00

SQL Memory Statistics  DB/Inst: ORCL/orcl  Snaps: 1-2

                                  Begin            End         % Diff
                          -------------- -------------- --------------
   Avg Cursor Size (KB):           36.81          36.79           -.05
 Cursor to Parent ratio:            1.78           1.78            .16
          Total Cursors:          12,334         12,395            .49
          Total Parents:           6,928          6,951            .33
```

Nondefault Initialization Parameters

This last section shows the parameters in the initialization file that are set to a value other than the default (see Figure 14-19). The list is generated by querying the V$PARAMETER view where the default column is equal to FALSE. This list can be used as a reference. While you are tuning the database, these parameters can provide a record of how the database performed with certain values. The output that follows shows this section of the Statspack Report:



init.ora Parameters

Parameter Name	Begin value	End value (if different)
audit_file_dest	/u01/app/oracle/admin/orcl/adump	
audit_trail	DB	
compatible	12.2.0.0.0	
control_files	/u02/app/oracle/oradata/orcl/control01.ctl, /u03/app/oracle/fast_recovery_area/orcl/control02.ctl	
db_block_size	8192	
db_create_file_dest	/u02/app/oracle/oradata	
db_name	orcl	
db_recovery_file_dest	/u03/app/oracle/fast_recovery_area	
db_recovery_file_dest_size	26214400000	
diagnostic_dest	/u01/app/oracle	
dispatchers	(PROTOCOL=TCP) (SERVICE=orclXDB)	
instance_name	orcl	
local_listener		
log_archive_format	%t_%s_%r.dbf	
open_cursors	300	
optimizer_mode	RULE	
pga_aggregate_target	262144000	
processes	300	
remote_login_passwordfile	EXCLUSIVE	
sga_target	1073741824	
undo_tablespace	UNDOTBS1	

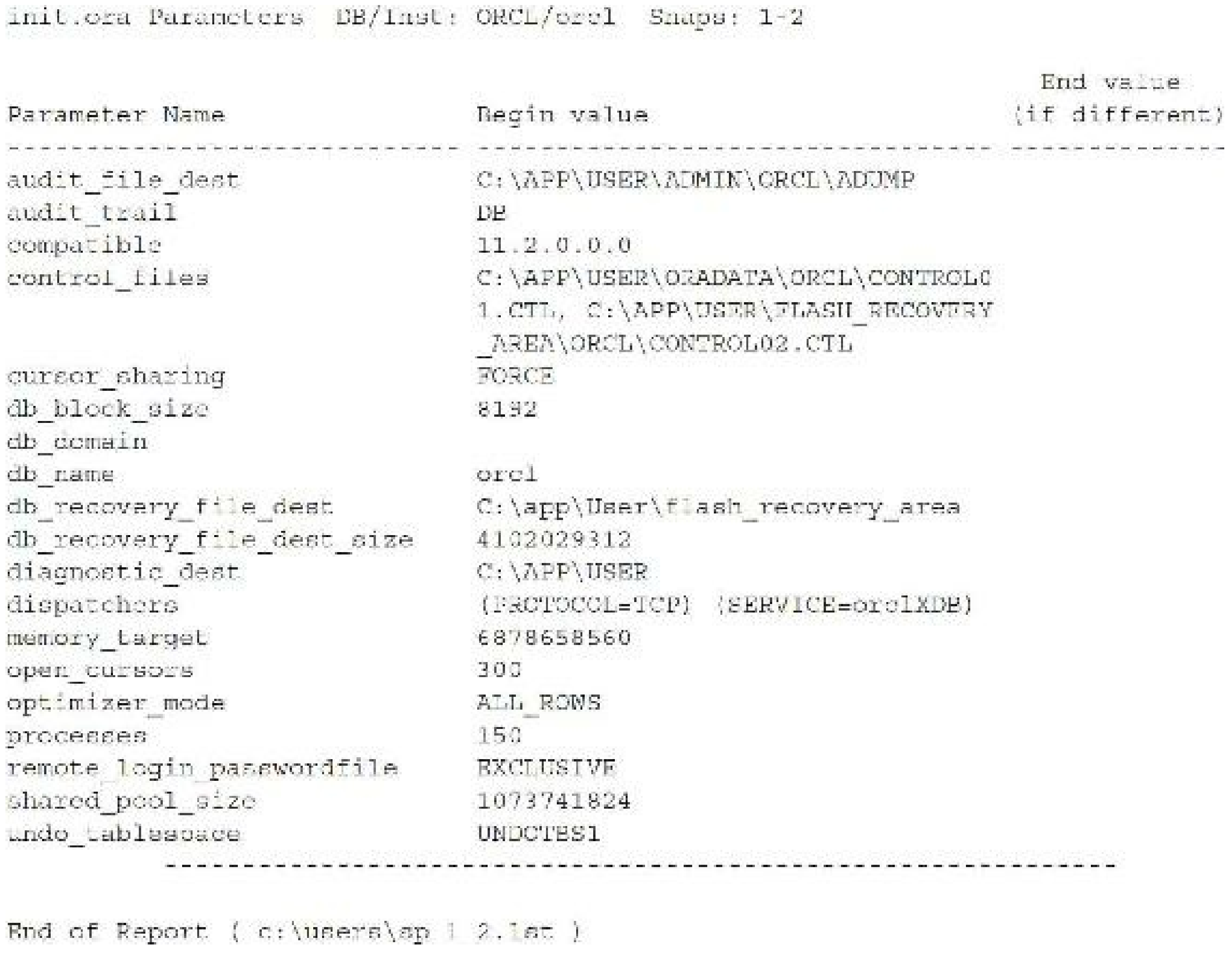
Back to init.ora Parameters
Back to Top

init.ora Multi-Valued Parameters

- This section only displays parameters that have more than one value
- '(NULL)' indicates a missing parameter value
- A blank in the 'End Snapshot' indicates the same value as the 'Begin Snapshot'

Parameter Name	Begin value	End value (if different)
control_files	/u02/app/oracle/oradata/orcl/control01.ctl	
	/u03/app/oracle/fast_recovery_area/orcl/control02.ctl	

FIGURE 14-19. *The AWR Report initialization parameters*



```
init.ora Parameters  DB/Inst: ORCL/orcl  Snaps: 1-2

                                                                    End value
Parameter Name                Begin value                          (if different)
----------------------------- ----------------------------------- --------------
audit_file_dest               C:\APP\USER\ADMIN\ORCL\ADUMP
audit_trail                   DB
compatible                    11.2.0.0.0
control_files                 C:\APP\USER\ORADATA\ORCL\CONTROL0
                              1.CTL, C:\APP\USER\FLASH_RECOVERY
                              _AREA\ORCL\CONTROL02.CTL
cursor_sharing                FORCE
db_block_size                 8192
db_domain
db_name                       orcl
db_recovery_file_dest         C:\app\User\flash_recovery_area
db_recovery_file_dest_size    4102029312
diagnostic_dest               C:\APP\USER
dispatchers                   (PROTOCOL=TCP) (SERVICE=orclXDB)
memory_target                 6878658560
open_cursors                  300
optimizer_mode                ALL_ROWS
processes                     150
remote_login_passwordfile     EXCLUSIVE
shared_pool_size              1073741824
undo_tablespace               UNDOTBS1
          -------------------------------------------------------------

End of Report ( c:\users\sp_1_2.lst )
```

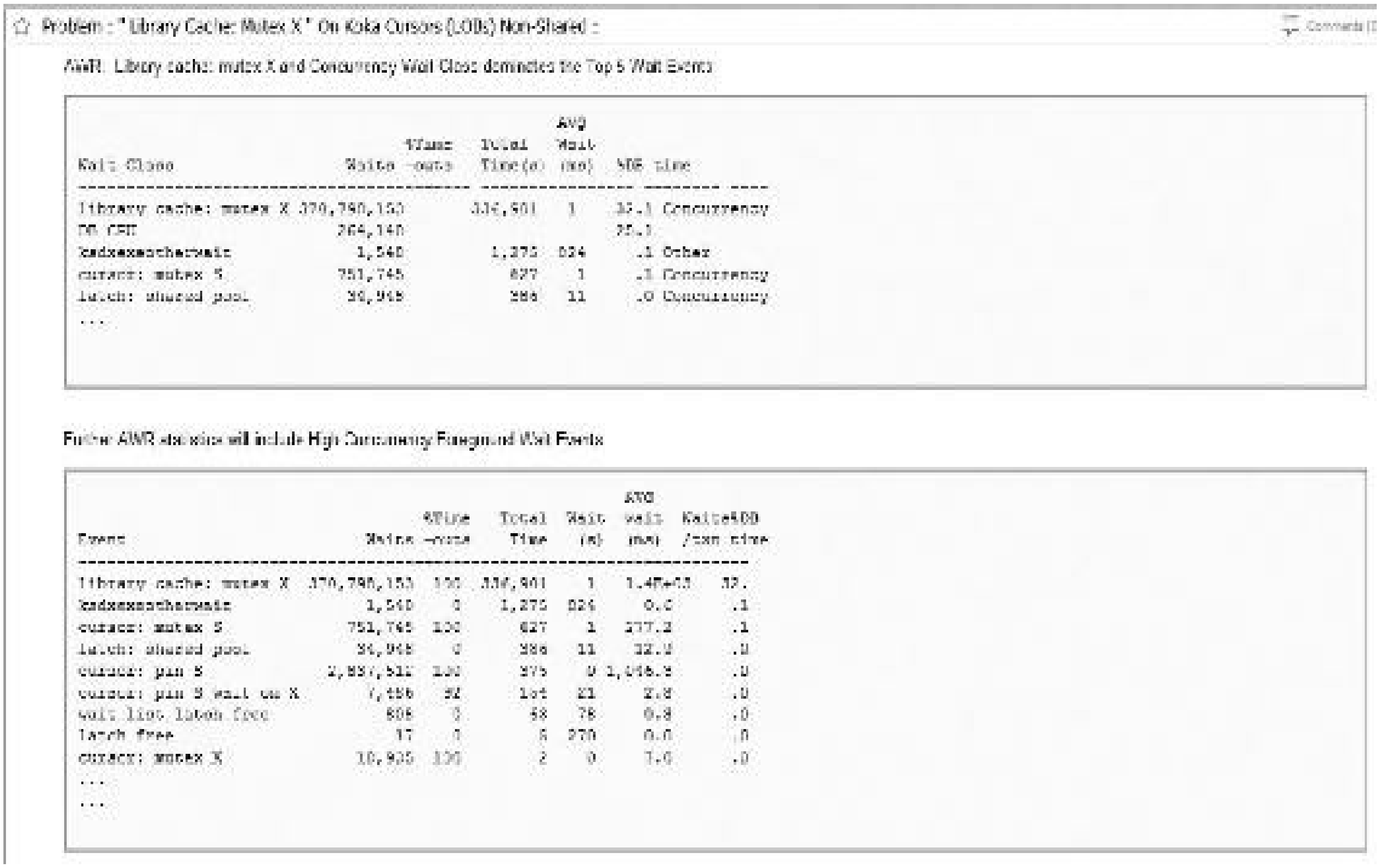
Top 15 Things to Look for in AWR Report and Statspack Output

As you’ve seen throughout this chapter, AWR Report is much better than Statspack. Some DBAs still use Statspack (and it’s free), so I’ve included it in this chapter. Many DBAs already know how to use Statspack but are not always sure what to check regularly. Remember to separate OLTP and batch activity when you run Statspack because they usually generate different types of waits. The SQL script `spauto.sql` can be used to run Statspack every hour on the hour. See the script in $ORACLE_HOME/rdbms/admin/spauto.sql for more information (note that JOB_QUEUE_PROCESSES, which is the maximum number of job queue slave processes, must be greater than 0). Since every system is different, this is only a general list of things you should *regularly* check in your Statspack or AWR output:

- Top 10 foreground wait events in AWR (timed events) or Top 5 Timed Events in Statspack
- Top Background Wait Events
- Load profile (includes In-Memory)

- Other wait events (working their way to the Top 5)
- Latch waits/Mutex sleeps (in 12*c*R2, there are many In-Memory latches)
- Top SQL
- Instance efficiency hit ratios out of the ordinary
- Instance activity
- File I/O and segment statistics
- Memory allocation
- Buffer waits
- Initialization Parameters (near the end of each report)
- In the AWR Report, the Active Session History (ASH) Report (described a bit later), which includes sections for Top SQL with Top Events and Top Event P1/P2/P3 Values
- In the AWR Report in 12*c*R2, GoldenGate and Streams Replication sections (if relevant to your system)
- Use of In-Memory effectively

A final note on the top 10 foreground wait events is to look for bugs when you have a *high* number of wait events that are normally not so high. You can only do this if you are regularly monitoring your reports or if you have captured baselines for comparisons. Take a look at the bug in Figure 14-20 from My Oracle Support that shows the behavior of a high number of "Library Cache: Mutex X" on Koka Cursors (LOBs) Non-Shared that *dominates* the Top 5 Wait Events. This is a clue you may have a *bug* to search for or a *real bad* SQL statement. See the appropriate section of this chapter for how to fix major problems depending on the wait event.


Problem : " Library Cache: Mutex X " On Koka Cursors (LOBs) Non-Shared :

AWR. Library cache: mutex X and Concurrency Wait Class dominates the Top 5 Wait Events

```
                                                      AVG
                                    %Time   Total    Wait
Wait Class                   Waits  -outs   Time(s)  (ms)   %DB time
------------------------------------------ ---------------- -------- ----
library cache: mutex X 370,790,153        336,901    1     32.1 Concurrency
DB CPU                     264,140                         25.1
kxdxexecotherwait            1,540          1,275  824       .1 Other
cursor: mutex S            751,745            827    1       .1 Concurrency
latch: shared pool          36,945            386   11       .0 Concurrency
...
```

Further AWR statistics will include High Concurrency Foreground Wait Events

```
                                                        AVG
                                %Time   Total   Wait   wait   Waits%DB
Event                     Waits -outs    Time    (s)   (ms)   /txn time
---------------------------------------------------------------------
library cache: mutex X  370,798,153  100 336,901    1   1.4E+03   32.
kxdxexecotherwait             1,540    0   1,275  824       0.0     .1
cursor: mutex S             751,745  100     627    1     277.2     .1
latch: shared pool           36,945    0     386   11      32.9     .0
cursor: pin S             2,837,512  100     375    0 1,046.5     .0
cursor: pin S wait on X       7,456   92     164   21       2.8     .0
wait list latch free            606    0      58   78       0.8     .0
latch free                       17    0       5  270       0.0     .0
cursor: mutex X              10,905  100       2    0       7.0     .0
...
...
```

FIGURE 14-20. *Listing for a "Library Cache: Mutex X" heavy wait events*

Managing the Statspack Data

If you are one of the holdouts still using Statspack, you should manage the data generated by Statspack to guarantee that the space usage and performance of the Statspack application meets your requirements as the application data grows. Managing Statspack data includes the following steps:

1. Regularly analyze the Statspack data. At a minimum, you should analyze the Statspack schema prior to running the `spreport.sql` script:
   ```
   execute DBMS_UTILITY.ANALYZE_SCHEMA('PERFSTAT','COMPUTE');
   ```
2. Purge old data. Because you cannot generate valid interval reports across database shutdown/startup actions, data prior to the last database startup may not be as useful as the most current data. When the data is no longer needed, purge it from the tables. Oracle provides a script, `sppurge.sql`, to facilitate purges. The `sppurge.sql` script, located in the /rdbms/admin directory under the Oracle software home directory, lists the currently stored snapshots and prompts you for two input parameters: the beginning and ending snapshot numbers for the purge. The related records in the STATS$ tables are then deleted. Due to the size of the transactions involved, databases using rollback segments should force the session to use a large rollback segment during the deletes:

```
SQL> commit;
SQL> set transaction use rollback segment roll_large;
SQL> @sppurge
```

The `sppurge` script prompts you to back up your old statistics before purging them. You can back up the data by exporting the PERFSTAT schema.

3. Truncate the Statspack tables when the data is not needed. Old statistical data may no longer be relevant, or you may have imported the old statistics during database migrations or creations. To truncate the old tables, execute the `sptrunc.sql` SQL*Plus script from within the PERFSTAT account. The script is located in the /rdbms/admin directory under the Oracle software home directory.
4. Include the Statspack tables in your backup scheme. If you are using Export, Oracle provides a parameter file named `spuexp.par` to assist you.
5. Include the Statspack tables in your space monitoring procedures.

Upgrading Statspack

To upgrade old Statspack data to a new version of the database, execute the scripts provided by Oracle. Oracle does not support upgrading Statspack directly from 8.1.6 to 9.0.1 or 9.2 to 10.2 or 11; you must go through multiple steps. The scripts only upgrade your current schema to the next release level, for example 9.0.1 to 9.2, so you might have to run multiple scripts to complete the upgrade (note that even upgrades from Oracle8 are included with the 12*c*R2 release):

1. Upgrade from the 9.0 Statspack objects to 9.2 by executing the `spup90.sql` script.
2. Upgrade from the 9.2 Statspack objects to 10.1 by executing the `spup92.sql` script.
3. Upgrade from the 10.1 Statspack objects to 10.2 by executing the `spup10.sql` script.
4. Upgrade from the 10.2 Statspack objects to 11 by executing the `spup102.sql` script.
5. Upgrade from the 11.01 Statspack objects to 11.2 by executing the `spup1101.sql` script.
6. Upgrade from the 11.2 Statspack objects to 11.2.0.2 by executing the `spup11201.sql` script.
7. Upgrade from the 11.2.0.2 Statspack objects to 12.1 by executing the `spup112.sql` script.
8. Upgrade from the 12.1 Statspack objects to 12.1.0.2 by executing the `spup12102.sql` script.
9. Upgrade from the 12.1.0.2 Statspack objects to 12.2 by executing the `spup12200.sql` script.

Deinstalling Statspack

Since Statspack includes public synonyms as well as private objects, you should remove the application via a SYSDBA-privileged account. Oracle provides a script, `spdrop.sql`, to automate the deinstallation process. From within the /rdbms/admin directory under the Oracle software home directory, log in to SQL*Plus and execute the script as shown in the following listing:

```
SQL> connect system/manager as SYSDBA
SQL> @spdrop
```

The `spdrop.sql` script calls scripts (`spdtab.sql`, `spdusr.sql`) that will drop the tables, the package, the public synonyms, and the PERFSTAT user. To reinstall Statspack, execute the `spcreate.sql` script, as shown earlier in this chapter.

Quick Notes on the New ADDM Report

You can also use the Automatic Database Diagnostics Monitor (ADDM) Report, called `addmrpt.sql`, to analyze a snapshot range. Run the `addmrpt.sql` script from SQL*Plus (the script is located in the $ORACLE_HOME/rdbms/admin directory). The script provides you with a list of snapshots from which you can generate the report (like Statspack or the AWR Report from SQL*Plus). You select a begin snapshot and an end snapshot, and finally, you define the name of the report that you want `addmrpt.sql` to create. The `addmrpt.sql` script then runs the ADDM analysis on the snapshot pair you entered and provides the output analysis report. Using ADDM through Enterprise Manager Cloud Control (covered in Chapter 5) is much more detailed and is recommended. The resulting report contains a header and then detailed findings. The command to run it is listed here, and following that command is the header; yours should look much like this example (note that if you *shut down* between snapshots of the AWR or ADDM that you are running the report for, it will result in an ORA-20200 error—instance shutdown between snaps):

```
SQL> @C:\app\User\product\12.2.0\dbhome_2\RDBMS\ADMIN\addmrpt

Current Instance
~~~~~~~~~~~~~~~~

   DB Id    DB Name      Inst Num Instance
----------- ------------ -------- ------------
 1272868336 ORCL                1 orcl

Instances in this Workload Repository schema
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

   DB Id     Inst Num DB Name      Instance     Host
------------ -------- ------------ ------------ ------------
* 1272868336        1 ORCL         orcl         USER-PC

Using 1272868336 for database Id
Using          1 for instance number

Specify the number of days of snapshots to choose from
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Entering the number of days (n) will result in the most recent
(n) days of snapshots being listed.  Pressing <return> without
specifying a number lists all completed snapshots.

Listing the last 3 days of Completed Snapshots

                                                        Snap
Instance     DB Name        Snap Id    Snap Started    Level
------------ ------------ --------- ------------------ -----
orcl         ORCL               342 09 May 2011 15:38      1
… (partial listing only)
                                358 11 May 2011 04:00      1
                                359 11 May 2011 05:00      1
                                360 11 May 2011 06:00      1
                                361 11 May 2011 07:00      1
                                362 11 May 2011 08:00      1
                                363 11 May 2011 11:44      1

Specify the Begin and End Snapshot Ids
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Enter value for begin_snap: 358
Begin Snapshot Id specified: 358

Enter value for end_snap: 363
End   Snapshot Id specified: 363
```

```
Specify the Report Name
~~~~~~~~~~~~~~~~~~~~~~~
The default report file name is addmrpt_1_358_363.txt.  To use this name,
press <return> to continue, otherwise enter an alternative.

Enter value for report name: awr rep1
Using the report name awr rep1

Running the ADDM analysis on the specified pair of snapshots ...
Generating the ADDM report for this analysis ...
```

Now look at the report output:

```
          ADDM Report for Task 'TASK_488'
          -------------------------------

Analysis Period
---------------
AWR snapshot range from 358 to 363.
Time period starts at 11 MAY 11 04.00.49 AM
Time period ends at 11 MAY 11 11.44.42 AM

Analysis Target
---------------
Database 'ORCL' with DB ID 1272868336.
Database version 11.2.0.1.0.
ADDM performed an analysis of instance orcl, numbered 1 and hosted at USER-PC.

Activity During the Analysis Period
-----------------------------------
Total database time was 12314 seconds.
The average number of active sessions was .44.
```

A summary information section is related to the ADDM analysis. Following the header and individual findings, the summary is listed. An example of one such finding is seen here:

```
Summary of Findings
-------------------
   Description                Active Sessions      Recommendations
                              Percent of Activity
   ----------------------     -------------------  ---------------
1  Virtual Memory Paging      .44 | 100            3
… (partial listing only)

          Findings and Recommendations
          ----------------------------

Finding 1: Virtual Memory Paging
Impact is .44 active sessions, 100% of total activity.
-------------------------------------------------------
Significant virtual memory paging was detected on the host operating system.

Recommendation 1: Host Configuration
Estimated benefit is .44 active sessions, 100% of total activity.
------------------------------------------------------------------
Action
   Host operating system was experiencing significant paging but no
   particular root cause could be detected. Investigate processes that do
   not belong to this instance running on the host that are consuming
   significant amount of virtual memory. Also consider adding more physical
   memory to the host.

Recommendation 2: Database Configuration
Estimated benefit is .44 active sessions, 100% of total activity.
------------------------------------------------------------------
Action
   Consider enabling Automatic Shared Memory Management by setting the
   parameter "sga_target" to control the amount of SGA consumed by this
   instance.

Recommendation 3: Database Configuration
Estimated benefit is .44 active sessions, 100% of total activity.
------------------------------------------------------------------
Action
   Consider enabling Automatic PGA Memory Management by setting the
   parameter "pga_aggregate_target" to control the amount of PGA consumed
   by this instance.
```

If SQL issues are discovered, the finding looks like the one shown here, suggesting that I run the Tuning Advisor to tune the statement:

```
FINDING 1: 51% impact (309 seconds)
-----------------------------------
SQL statements consuming significant database time were found.
      ACTION: Run SQL Tuning Advisor on the SQL statement with SQL_ID
         "db78fxqxwxt7r".
         RELEVANT OBJECT: SQL statement with SQL_ID db78fxqxwxt7r and
         PLAN_HASH 3879501264
         SELECT a.emp, b.dname
         FROM EMP a, DEPT b
         WHERE a.deptno=b.deptno;
```

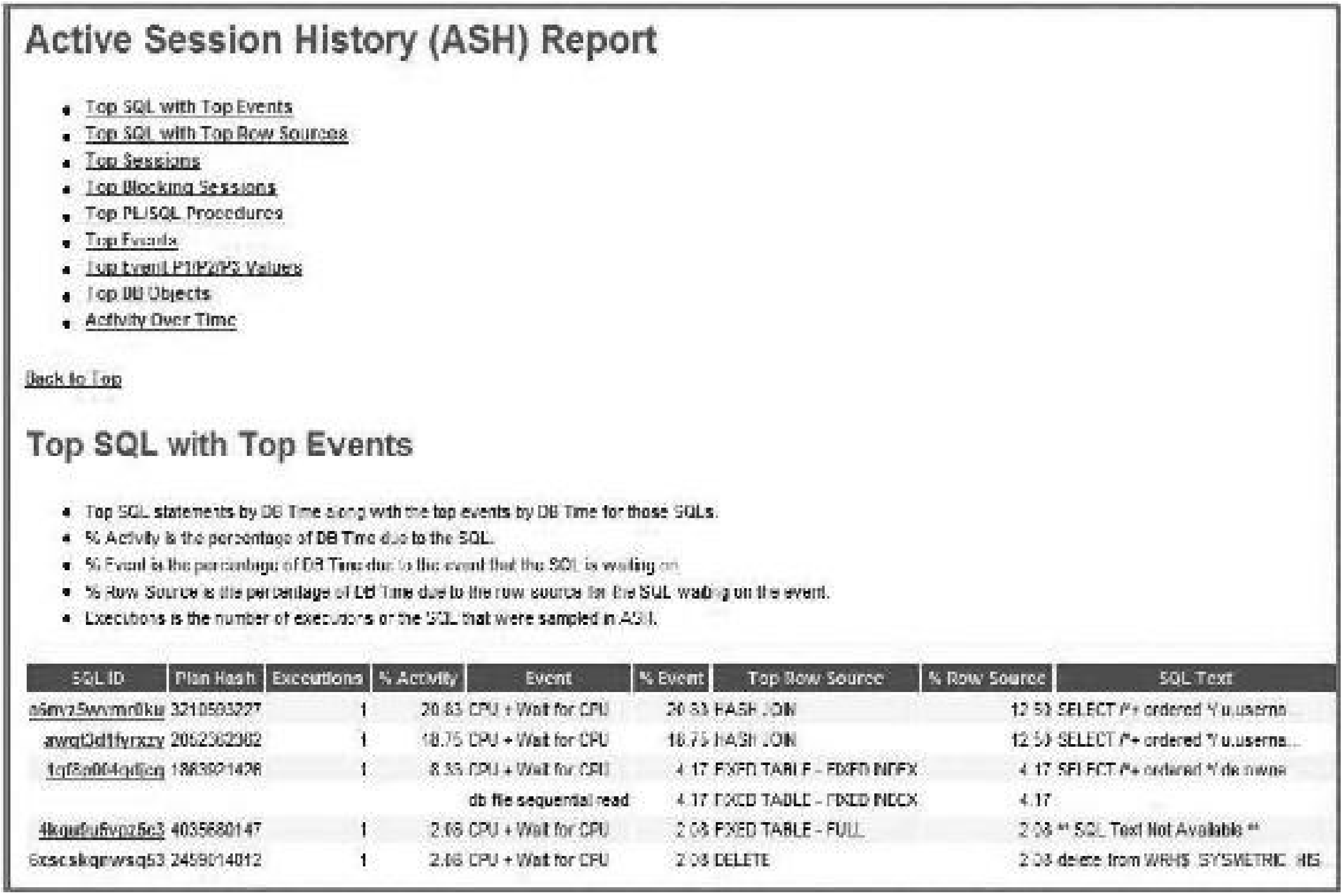
A few interesting things appear in this report. First, the finding indicates that the problem identified had a 51 percent overall impact in the DB time. In other words, the ADDM report is sorting its findings according to those processes that are consuming the most database time. I see, looking at this finding further, that it is a SQL statement that is causing problems (usually the source of most issues), and ADDM suggests that I tune the statement. Oracle gives me the SQL address and hash value so I can find the SQL statement in the SQL area. Note that the ACTION suggests that I run the SQL Tuning Advisor to generate some suggested tuning actions on the SQL statement in question. In Chapter 5 and Chapter 8, I discuss the SQL Tuning Advisor and show you just how it can help you tune SQL statements in Oracle Database 12*c*.

If not enough work has been done on the instance or if not enough work is being done currently, instead of giving you suggestions, it displays the following:

```
-------------------------------------------------------------------------------
THERE WAS NOT ENOUGH INSTANCE SERVICE TIME FOR ADDM ANALYSIS.
-------------------------------------------------------------------------------
```

The ADDM report is a good start for getting tips for tuning. As with any new utility, there is room for improvement and growth in future releases of Oracle, and it is best used from the Enterprise Manager interface if possible. I have not addressed other aspects related to ADDM in this section, such as user-defined alerts and the SQL Tuning Advisor, which I discussed in Chapter 5 and Chapter 8.

While ADDM is helpful, there is also an Active Session History (ASH) Report at the end of the AWR Report with a few *very* worthwhile sections to explore. My favorites are Top SQL with Top Events (Figure 14-21) and Top Event P1/P2/P3 Values (Figure 14-22).



Active Session History (ASH) Report

- Top SQL with Top Events
- Top SQL with Top Row Sources
- Top Sessions
- Top Blocking Sessions
- Top PL/SQL Procedures
- Top Events
- Top Event P1/P2/P3 Values
- Top DB Objects
- Activity Over Time

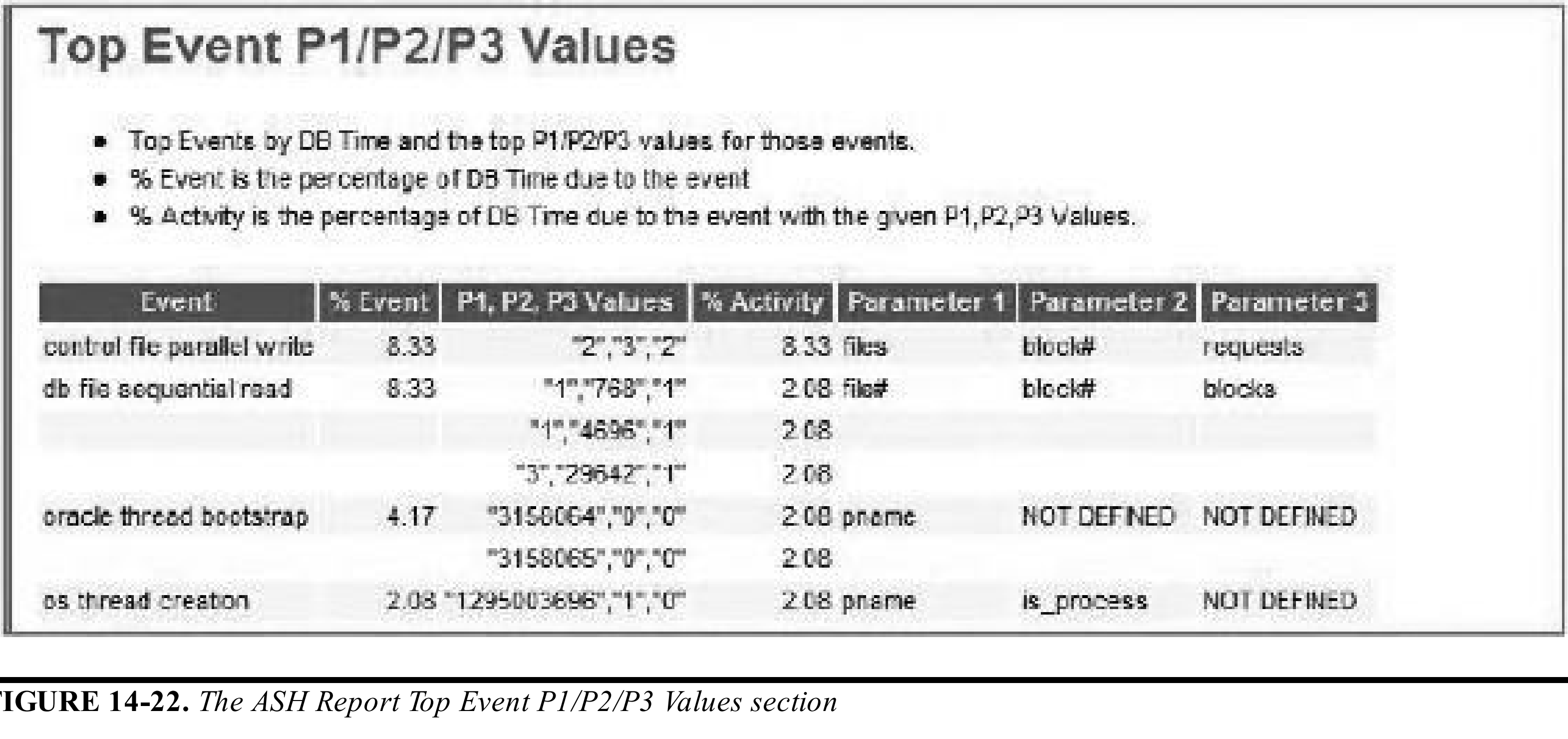
Back to Top

Top SQL with Top Events

- Top SQL statements by DB Time along with the top events by DB Time for those SQLs.
- % Activity is the percentage of DB Time due to the SQL.
- % Event is the percentage of DB Time due to the event that the SQL is waiting on.
- % Row Source is the percentage of DB Time due to the row source for the SQL waiting on the event.
- Executions is the number of executions of the SQL that were sampled in ASH.

SQL ID	Plan Hash	Executions	% Activity	Event	% Event	Top Row Source	% Row Source	SQL Text
a6mvz5wvmn8ku	3210593227	1	20.83	CPU + Wait for CPU	20.83	HASH JOIN	12.50	SELECT /*+ ordered */ u.userna...
awqt3d1fyrxzy	2052362362	1	18.75	CPU + Wait for CPU	18.75	HASH JOIN	12.50	SELECT /*+ ordered */ u.userna...
1qf8n064qdjcg	1863921426	1	8.33	CPU + Wait for CPU	4.17	FIXED TABLE - FIXED INDEX	4.17	SELECT /*+ ordered */ de.owne...
				db file sequential read	4.17	FIXED TABLE - FIXED INDEX	4.17	
4kqu6u6vpz6c3	4035680147	1	2.08	CPU + Wait for CPU	2.08	FIXED TABLE - FULL	2.08	** SQL Text Not Available **
6xscskqnwsq53	2459014012	1	2.08	CPU + Wait for CPU	2.08	DELETE	2.08	delete from WRH$_SYSMETRIC_HIS...

FIGURE 14-21. *The ASH Report Top SQL with Top Events section*



Top Event P1/P2/P3 Values

- Top Events by DB Time and the top P1/P2/P3 values for those events.
- % Event is the percentage of DB Time due to the event
- % Activity is the percentage of DB Time due to the event with the given P1,P2,P3 Values.

Event	% Event	P1, P2, P3 Values	% Activity	Parameter 1	Parameter 2	Parameter 3
control file parallel write	8.33	"2","3","2"	8.33	files	block#	requests
db file sequential read	8.33	"1","768","1"	2.08	file#	block#	blocks
		"1","4896","1"	2.08			
		"3","29642","1"	2.08			
oracle thread bootstrap	4.17	"3158064","0","0"	2.08	pname	NOT DEFINED	NOT DEFINED
		"3158065","0","0"	2.08			
os thread creation	2.08	"1295003696","1","0"	2.08	pname	is_process	NOT DEFINED

FIGURE 14-22. *The ASH Report Top Event P1/P2/P3 Values section*

TIP
The ADDM Report can be a helpful tuning utility, but ADDM is better used through Oracle Enterprise Manager for maximum benefits. The ASH Report also has some nice areas worth investigating, including my favorites: Top SQL with Top Events and Top Event P1/P2/P3 Values.

Scripts in 12*c*R2

Here is a listing of scripts that you will find in 12*c*R2. Please refer to the documentation for a complete description of each of these.

Script	Description	Calls	Run As	Environment
`spcreate.sql`	Creates the Statspack environment.	spcpkg.sql	SYSDBA	Any instance
`spdrop.sql`	Drops the entire Statspack environment.	`spdtab.sql` and `spdusr.sql`	SYSDBA	Any instance
`spreport.sql`	The main script to generate the Statspack Report.	sprepins.sql	PERFSTAT user	Any instance
`sprepins.sql`	Generates a Statspack Instance Report for the database and instance specified.		PERFSTAT	Oracle RAC and Data Guard systems
`sprepsql.sql`	Generates a Statspack SQL Report for a given SQL hash value.	sprsqinsl.sql	PERFSTAT	Any instance

`sprsqins.sql`	Generates a Statspack SQL Report for the SQL hash value specified for the database and instance specified.	sprepcon.sql	PERFSTAT	Oracle RAC and Data Guard systems
`spauto.sql`	Automates Statspack statistics collection (snap) using DBMS_JOB.		PERFSTAT	Any instance with JOB_QUEUE_PROCESSES > 0
`sprepcon.sql`	Configures SQL*Plus variable to set things like thresholds. Called automatically as part of the Statspack instance report.		PERFSTAT	Instances where you want to show or hide sections of the report
`sppurge.sql`	Purges a range of snapshot IDs for a given database instance (does not purge baseline snapshots).		PERFSTAT	Use Statspack package procedure instead
`sptrunc.sql`	Truncates all performance data in Statspack tables (CAREFUL!).		PERFSTAT	Any instance
`spuexp.par`	Exports parameter file for exporting the entire PERFSTAT user.		PERFSTAT	Taking export backups of the PERFSTAT schema
`spup816.sql`	To upgrade from 8.1.6 to 8.1.7.		SYSDBA	DB with 8.1.6 version of Statspack schema and a valid backup
`spup817.sql`	To upgrade from 8.1.7 to 9.0.		SYSDBA	DB with 8.1.7 version of Statspack schema and a valid backup
`spup90.sql`	To upgrade from 9.0 to 9.2.		SYSDBA	DB with 9*i* version of Statspack schema and a valid backup

`spup92.sql`	To upgrade from 9.2 to 10.1.	PERFSTAT	DB with 9*i*R2 version of Statspack schema and a valid backup
`spup10.sql`	To upgrade from 10.1 to 10.2.	SYSDBA	DB with 10gR1 version of Statspack schema and a valid backup
`spup102.sql`	To upgrade from 10.2 to 11.1.	SYSDBA	DB with 10gR2 version of Statspack schema and a valid backup
`spup1101.sql`	To upgrade from 11.0.1 to 11.2.	SYSDBA	DB with 11gR1 version of Statspack schema and a valid backup
`spup11201.sql`	To upgrade from 11.2 to 11.2.0.2.	SYSDBA	DB with 11gR2 version of Statspack schema and a valid backup
`spup112.sql`	To upgrade from 11.2.0.2 to 12.1.	SYSDBA	DB with 11gR2 version of Statspack schema and a valid backup
`spup12102.sql`	To upgrade from 12.1 to 12.1.0.2.	SYSDBA	DB with 12cR1 version of Statspack schema and a valid backup
`spup12200.sql`	To upgrade from 12.1.0.2 to 12.2.	SYSDBA	DB with 12cR1 version of Statspack schema and a valid backup

NOTE
You must use the specific version of Statspack with that version of the database (for instance, you must use the 12.2 Statspack schema with the 12.2 database). Also note that `spdoc.txt` *is the complete instruction and documentation file for Statspack.*

Tips Review

- Allocate at least 120M for the initial creation of the PERFSTAT schema's objects. Oracle 12*c* requires approximately the same space as Oracle 11*g*. You must license the Oracle Diagnostics Pack to access the AWR dictionary views necessary for the AWR Report. Statspack does not include In-Memory information, but the 12*c*R2 AWR Report does.
- Be sure the TIMED_STATISTICS database initialization parameter is set to TRUE prior to gathering statistics.
- Pin the Statspack package following database startup if you plan to run the SNAP procedure on a scheduled basis.
- A second report, `sprepsql.sql`, can be used for additional research into the problem SQL statements identified via the `spreport.sql` report.
- If you choose to run *both* Statspack and the AWR, ensure that you stagger the AWR data collection from the Statspack collection by at least 30 minutes to avoid a performance hit as well as conflicts. If you are running the AWR Report, you should not also need to run Statspack.
- With the new 12*c*R2 AWR Report, you can choose to get text (similar to Statspack output), HTML, or the new Active HTML format (which summons OEM at the end of the report if desired) when you run `awrrpt.sql`. The HTML format is much better than text, as you can click various links within the report to navigate among sections easily. You can also run the AWR Report within OEM.
- If you use Oracle Enterprise Manager (OEM), you can run the AWR Report directly from Cloud Control or Database Control from multiple versions of OEM.
- Get to know your system by reviewing and understanding your system's regular Load Profile. Significant changes to the Load Profile during what should be similar workloads or common times during the day may warrant further investigation. The In-Memory (IM) statistics are *not* a part of the Statspack Report in 12*c*R2, but are contained in the AWR Report.
- The library cache pin (protects cursors/SQL) and library cache latch (protects the Library Cache) are both replaced by mutexes (program objects that negotiate mutual exclusion among threads).
- Tuning by wait events is one of the best possible reactive tuning methods.
- In 12*c*R2, the top 10 foreground wait events in the AWR Report reveal to you the largest issues on your system at the macro level (Top 5 timed events in Statspack). Rarely do these waits point you to a specific problem. Other parts of the AWR Report or Statspack Report will tell you why you are receiving the waits.
- Tuning the top 25 buffer get and top 25 physical get queries can yield system performance gains of anywhere from 5 percent to 5000+ percent. The SQL section of the Statspack Report tells you which queries to consider tuning first. The top 10 SQL statements should not be substantially more than 10 percent of all of your buffer gets or disk reads. Near the end of the new 12*c* AWR Report, the Top SQL is connected with the Top Events to help you even more!

- If many sorts are being performed to disk (greater than 1–5 percent of the total number of rows being sorted), you may need to increase the initialization parameters associated with sorting. See Chapter 4 for more information on these.
- The buffer cache hit ratio should be greater than 95 percent. If it is less than 95 percent, you should consider increasing the size of the data cache by increasing the MEMORY_TARGET (if used) or increasing the minimum setting for the DB_CACHE_SIZE initialization parameter (given that physical memory is available to do this).
- If full table scans are being performed, serious performance issues may result and data hit ratios will be distorted. These tables need to be identified so the appropriate indexes are created or used. See Chapters 8 and 9 on query tuning for more information.
- If the number of physical reads is heavier on one physical disk, balancing the data properly or using ASM correctly will probably improve performance. See Chapter 3 for tips on fixing I/O problems with either data files or tablespaces. See Chapter 3 for tips on fixing I/O problems (and using ASM) with either datafiles or tablespaces.
- In Oracle 12*c*, multiple data block sizes are allowed. The AWR Report and/or Statspack shows statistics for each of these block sizes individually. Many advisories are available to help you size the SGA that both the AWR Report and Enterprise Manager (see Chapter 5) suggest. These suggestions should be tested first, however, and are not always the best choice. As Robert Freeman would say, "Your mileage may vary."
- Latches are like locks on pieces of memory (or memory buffers). If the latch hit ratio is less than 99 percent, you have a serious problem because not even the lock to get memory can be gotten. Oracle 12*c*R2 has a shard latch (for sharding), and many In-Memory latches, including in-memory area latch, in-memory columnar segment hash table latch, in-memory columnar ts extent map chunk latch, and in-memory global pool latch.
- Never go to the block level unless you *absolutely* have to go there. The block level is a great place to find hot block and ITL issues, but it takes a lot of time and energy on the part of an advanced DBA to pinpoint problems at this level.
- The ADDM Report can be a helpful tuning utility, but ADDM is better used through Oracle Enterprise Manager for maximum benefits. The ASH Report also has some nice areas worth investigating, including my favorites: Top SQL with Top Events and Top Event P1/P2/P3 Values.

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Special thanks to Robert Freeman, who contributed much of the AWR information. Thanks to Kevin Loney for the entire installation portion of this chapter written for the last version and some added notes. Tuning is an iterative process; as Hollyann always says: "If at first you don't succeed, skydiving is not for you; try tuning instead!" Thanks to Greg Pucka for the original chapter on estat/bstat. Rich Niemiec upgraded this chapter (painful as usual!).

CHAPTER
15

Performing a Quick System Review (DBA)

Oracle 12*c* introduced many new features that can be leveraged for automatic tuning. While some DBAs are great at planning and implementing a new version, fewer are good at evaluating and effectively implementing the new features that will help their system. In 12*c*, you now have to consider pluggable databases (PDBs, introduced in Chapter 3) and how to leverage an additional In-Memory (IM; see Chapter 4) column store (if licensed). With the introduction of Enterprise Manager Cloud Control (Chapter 5) combined with the Automatic Workload Repository (AWR) and the AWR Report (see Chapter 14 for a comparison to Statspack), you can monitor and tune your system in different and more productive ways. And with the advent of SQL Performance Analyzer (SPA), the SQL Tuning Advisor, the Adaptive Optimizer (12*c*), Real Application Testing, Exadata Simulation, and the Result Cache comes different ways to fix your system more productively. One of the keys to a good system review is checking to see if you've implemented the features that fit your needs and have a good return on the license cost of the feature as well as the time it takes to implement it. Although nobody seems to like tests or evaluations, *simple* evaluations can help to point out future performance problems and/or current issues.

One of the key approaches to achieving a focus on improving and maintaining excellent system performance is to perform a system review on at least an annual basis. This review could be an *internal review* or an *external review* of your system performance. Many companies have developed methods for measuring system performance and overall system speed that are tailored directly for their system. This chapter does not describe the six-month process that many of the more detailed evaluations propose; instead, it serves as a very simple barometer of how your system rates compared to others in the industry. Variations in your business processes may cause your score to be higher or lower using this simple review. You will need to adjust these scales and/or some of the criteria to fit your unique system. Tips covered in this chapter include the following:

- The Total Performance Index (TPI) and reasons you might want to use it
- How to evaluate your Education Performance Index (EPI)
- How to evaluate your System Performance Index (SPI)
- How to evaluate your Memory Performance Index (MPI)
- How to evaluate your Disk Performance Index (DPI)
- How to evaluate your Total Performance Index (TPI)
- An overall system review example

- The immediate action items list
- The system information list
- Rating the DBA with the help of an impartial expert

Total Performance Index (TPI)

I created the Total Performance Index (TPI) as a basic tool for Oracle DBAs to measure their system and compare it to other systems, using a quick and simple scoring method as shown in the following table. This index is only meant to be a barometer to see if improvements might be beneficial. Many system categories differ based on your business case and system use, but this system tells you how close or far your system is to or from others in the industry. Four categories are included: Education, System, Memory, and Disk. This chapter shows how you can measure your TPI using several simple queries (including example ratings). For detailed information on a particular category, please refer to the chapter in this book related to that issue. To help identify how your system is progressing, use your TPI to compare future growth in the number of users or changes in hardware and software. You can also customize the index to conform to tools you use most often, such as Oracle Enterprise Manager (OEM) or Automatic Database Diagnostic Monitor (ADDM). The following table gives you the overall breakdown by index:

Category Index	Maximum Score
Education Performance Index (EPI)	250
System Performance Index (SPI)	250
Memory Performance Index (MPI)	250
Disk Performance Index (DPI)	250
Total Performance Index (TPI)	**1000**

Education Performance Index (EPI)

This section measures the knowledge and education of your technical staff members. The following table illustrates how to receive a perfect EPI score. This rating system is not meant to be an all-encompassing benchmark of knowledge and education, but rather a barometer to see how your staff might benefit from educational improvements.

Category	Level Required	Maximum Score
DBAs required to tune database	Yes	30
Developers required to tune code written	Yes	30
DBAs last trained in tuning	Less than 1 year	30
Developers last trained in tuning	Less than 1 year	30
DBAs proficient in Enterprise Manager	Yes	30
DBAs proficient in using the V$ views	Yes	20
DBAs trained on 12*c* new features	Yes	20
Developers trained on 12*c* new features	Yes	20
DBAs trained to use EXPLAIN PLAN	Yes	10
Developers trained to use EXPLAIN PLAN	Yes	10
DBAs trained to use SQL Performance Analyzer and SQL Tuning Advisor	Yes	10
Developers trained to use SQL Performance Analyzer and SQL Tuning Advisor	Yes	10
Education Performance Index (EPI)	**Section Total**	**250**

Rate Your System

Are DBAs *required* to tune the database?	Yes	30 points
	No	0 points
	Score	30
Are developers *required* to tune the code that they write?	Yes	30 points
	No	0 points
	Score	0
When is the last time that your DBAs attended a training course that included tuning?	<1 year	30 points
	1–2 years	20 points
	>2 years	0 points
	Score	20
When is the last time that your developers attended a training course that included tuning?	<1 year	30 points
	1–2 years	20 points
	>2 years	0 points
	Score	20
Are DBAs proficient in using Oracle Enterprise Manager as a performance tuning tool?	Yes	30 points
	No	0 points
	Score	30
Are DBAs proficient in using the V$ views to find or fix deeper performance issues?	Yes	20 points
	No	0 points
	Score	20
Have DBAs been trained on 12*c* new features, including the In-Memory column store and CDB/PDBs?	Yes	20 points
	No	0 points
	Score	20
Have developers been trained on 12*c* new features that are applicable?	Yes	20 points
	No	0 points
	Score	0
Have DBAs been trained on how to use EXPLAIN PLAN/DBMS_XPLAN? (See Chapter 6.)	Yes	10 points
	No	0 points
	Score	10

Have developers been trained on how to use EXPLAIN PLAN, Autotrace, or DBMS_XPLAN?	Yes	10 points
	No	0 points
	Score	0
Have DBAs been trained on how to use SQL Performance Analyzer and SQL Tuning Advisor?	Yes	10 points
	No	0 points
	Score	10
Have developers been trained on how to use SQL Performance Analyzer and SQL Tuning Advisor?	Yes	10 points
	No	0 points
	Score	0
Example Education Performance Index (EPI)	**Total Score**	**160 (Grade: B)**

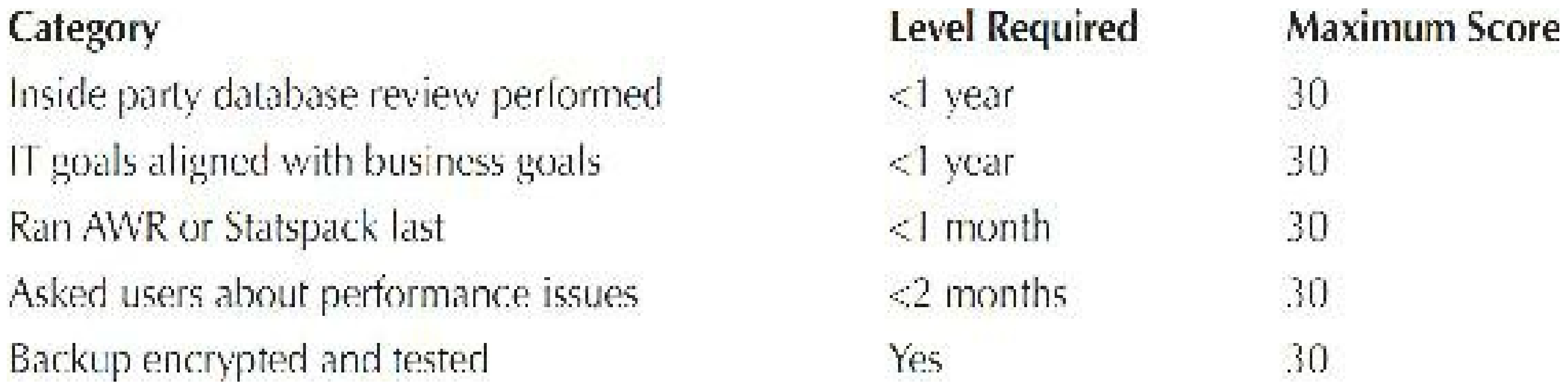
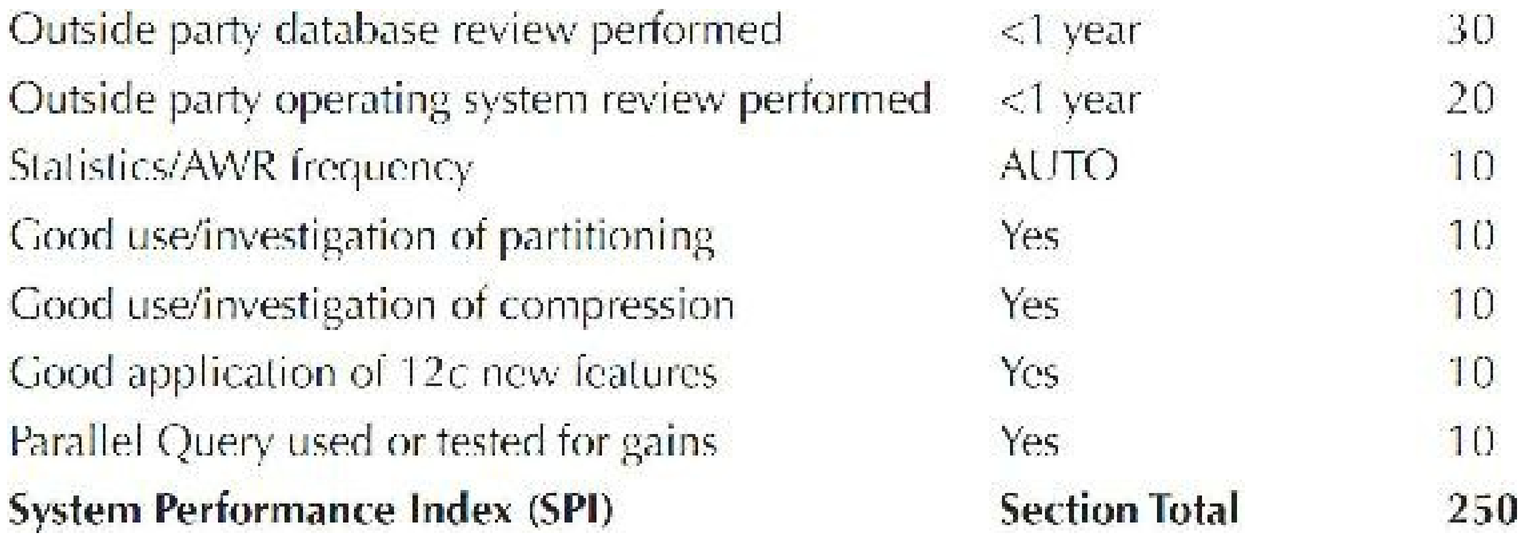
Grade Your System

EPI Grade	Comments	Score
A+	Top 10 percent of most systems	250
A	Top 20 percent of most systems	210–249
B	Top 40 percent of most systems	150–209
C	Top 70 percent of most systems	90–149
Needs help now	Bottom 30 percent of most systems	<90

TIP
Measuring your EPI (Education Performance Index) can be helpful in identifying educational improvements that might be beneficial.

System Performance Index (SPI)

This section measures overall system issues. The following table illustrates how to receive a perfect SPI score. This rating system is not meant to be an all-encompassing benchmark of overall system issues; rather, it is a barometer to see if your system might benefit from improvements.

Category	Level Required	Maximum Score
Inside party database review performed	<1 year	30
IT goals aligned with business goals	<1 year	30
Ran AWR or Statspack last	<1 month	30
Asked users about performance issues	<2 months	30
Backup encrypted and tested	Yes	30
Outside party database review performed	<1 year	30
Outside party operating system review performed	<1 year	20
Statistics/AWR frequency	AUTO	10
Good use/investigation of partitioning	Yes	10
Good use/investigation of compression	Yes	10
Good application of 12c new features	Yes	10
Parallel Query used or tested for gains	Yes	10
System Performance Index (SPI)	**Section Total**	**250**

Rate Your System

When is the last time your database was reviewed by a business user?	<1 year	30 points
	1–2 years	20 points
	>2 years	0 points
	Score	30
Are IT goals regularly aligned with objectives of the business to ensure IT is delivering business ROI on IT investments?	<1 year	30 points
	1–2 years	20 points
	>2 years	0 points
	Score	30
When is the last time you ran *and* reviewed the results of the AWR Report or Statspack? Are you regularly reviewing Oracle Performance Advisors? (See Chapter 14.)	<1 month	30 points
	1–3 months	20 points
	4–6 months	10 points
	>6 months	0 points
	Score	20
When is the last time users of your system were asked about system performance or where things could be improved? Are thresholds set appropriately?	<2 months	30 points
	3–6 months	20 points
	7–12 months	10 points
	>1 year	0 points
	Score	20
Has your backup plan been tested to determine if it would work and the time that it would take to recover? Is it an encrypted backup?	Yes	30 points
	No	0 points
	Score	30

When is the last time your database was reviewed by an outside party?	<1 year	30 points
	1–2 years	20 points
	>2 years	0 points
	Score	20
When is the last time that your operating system and storage layout was reviewed by an outside party?	<1 year	20 points
	1–2 years	10 points
	>2 years	0 points
	Score	20
How frequently do you collect statistics?	AUTO	10 points
	Monthly	5 points
	Unsure	0 points
	Score	10
Has partitioning been evaluated or implemented, and is it in use where advantageous?	Yes	10 points
	Not needed	10 points
	Not tested	0 points
	Score	10
Has compression been evaluated or implemented, and is it in use where advantageous?	Yes	10 points
	Not needed	10 points
	Not tested	0 points
	Score	10
Have 12*c* new features been evaluated or implemented, and are they in use where advantageous?	Yes	10 points
	Not needed	10 points
	Not tested	0 points
	Score	10
Has Parallel Query been evaluated, and is it in use where advantageous?	Yes	10 points
	Not needed	10 points
	Not tested	0 points
	Score	10
Example System Performance Index (SPI)	**Total Score**	**220** (A+)

Grade Your System

SPI Grade	Comments	Score
A+	Top 10 percent of most systems	>210
A	Top 20 percent of most systems	180–210
B	Top 40 percent of most systems	140–179
C	Top 70 percent of most systems	80–139
Needs help now	Bottom 30 percent of most systems	<80

TIP
Measuring your SPI (System Performance Index) can be helpful in identifying overall system improvements that might benefit your system.

Memory Performance Index (MPI)

This section measures memory use and allocation. The following table illustrates how to receive a perfect MPI score. This rating system is not meant to be an all-encompassing benchmark of memory use and allocation; rather, it is a barometer to see if your system might benefit from memory use and allocation improvements.

Category	Level Required	Maximum Score
Top 25 (worst memory) statements tuned	Yes	60
Top 10 statements' memory use*	<5 percent	30
Buffer cache hit ratio (can also measure variance)*	>98 percent	30
Dictionary cache hit ratio (can also measure variance)*	>98 percent	30
Library cache hit ratio (can also measure variance)*	>98 percent	30
PGA sorts in memory (can also measure variance)*	>98 percent	30
Buffers in X$BH at state=0*	10–25 percent	20
Using Result cache effectively	Yes	10
Pin/cache frequently used objects	Yes	10
Memory Performance Index (MPI)	**Section Total**	**250**

**Adjust value only where needed based on knowledge of system and if IM cache is also used.*

Top 25 “Memory Abuser” Statements Tuned

I have found that the top 25 statements accessed on most systems, when left untuned, make up over 75 percent of all memory and disk reads of the entire system. The code that follows lists and illustrates how to find the top 25 worst memory abusers.

Query to get the top 25 worst memory abusers

```
set serverout on size 1000000
declare
 top25 number;
 text1 varchar2(4000);
 x number;
 len1 number;
cursor c1 is
  select buffer_gets, substr(sql_text,1,4000)
  from v$sqlarea
  order by buffer_gets desc;
begin
 dbms output.put line('Gets'||'     '||'Text');
 dbms_output.put_line('----------'||' '||'----------------------');
 open c1;
 for i in 1..25 loop
  fetch c1 into top25, text1;
  dbms_output.put_line(rpad(to_char(top25),9)||' '||substr(text1,1,66));
  len1:=length(text1);
  x:=66;
  while len1 > x 1 loop
   dbms_output.put_line('"          '||substr(text1,x,66));
  x:=x+66;
  end loop;
 end loop;
end;
/
```

Sample partial output

```
Gets     Text
16409      select f.file#, f.block#, f.ts#, f.length from fet$ f, ts$ t where
"          e t.ts#=f.ts# and t.dflextpct!=0
6868       select job from sys.job$  where next date < sysdate  order by next
"          t_date, job
6487       SELECT BUFFER GETS,SUBSTR(SQL TEXT,1,3500)   FROM V$SQLAREA ORDER
"           BY BUFFER_GETS DESC
3450       SELECT BUFFER_GETS,SUBSTR(SQL_TEXT,1,4000)   FROM V$SQLAREA ORDER
"           BY BUFFER_GETS DESC
(...Simplistic Partial Listing Displayed)
```

Rate Your System

How many of your top 25 memory statements in the V$SQLAREA view have you attempted to tune?	0	0 points
	1–5	20 points
	6 15	40 points
	16–25	60 points
	Score	60

Top 10 “Memory Abusers” as a Percent of All Statements

I have found that the top 10 statements accessed on most systems, when left untuned, can make up over 50 percent of all memory reads of the entire system. This section measures how severe the most harmful memory-using statements are, as a percentage of the entire system.

Script to retrieve this percentage

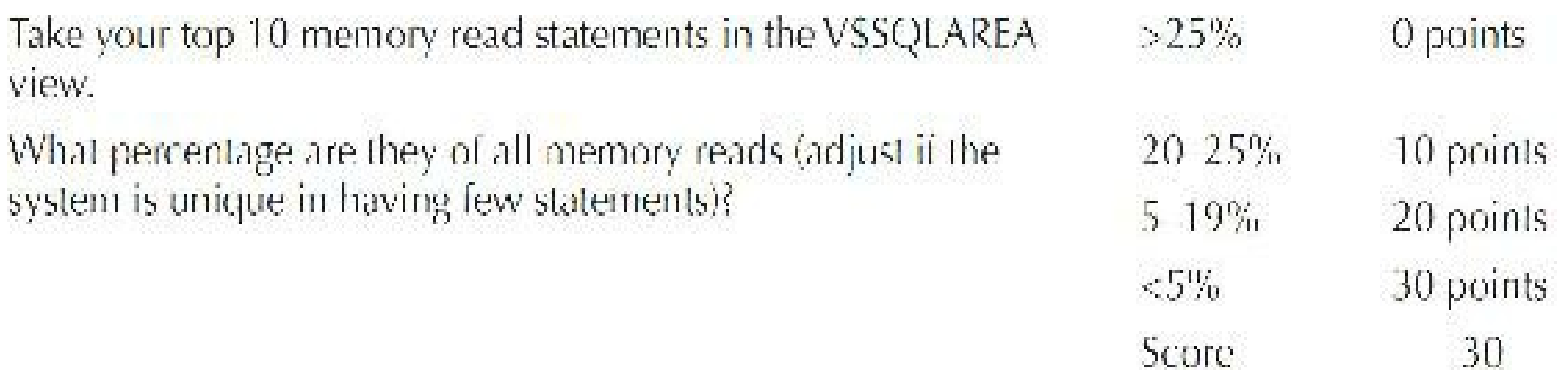
```
select sum(pct_bufgets) "Percent"
from   (select rank() over ( order by buffer_gets desc ) as rank_bufgets,
         to_char(100 * ratio_to_report(buffer_gets) over (), '999.99') pct_bufgets
        from   v$sqlarea )
where  rank_bufgets < 11;
```

Sample output

```
Percent
-------
  4.03

PL/SQL procedure successfully completed.
```

Rate Your System



Take your top 10 memory read statements in the V$SQLAREA view.	>25%	0 points
What percentage are they of all memory reads (adjust if the system is unique in having few statements)?	20 25%	10 points
	5 19%	20 points
	<5%	30 points
	Score	30

Buffer Cache Hit Ratio

You don't have to use the actual hit ratio as a scoring mechanism; you can use the variance from the norm instead. The buffer cache hit ratio represents how often frequently requested blocks of data have been found in the memory structure without requiring disk access. Hit ratios are used more in third-party tuning products than ever before, and they are also being used more by Oracle than ever before, primarily because they are a great barometer. But hit ratios can be misleading and should always be used as a barometer and indicator that you may want to look deeper. Nobody ever uses hit ratios as the sole way to tune a system (as some people claim), just as an indicator to know where to dig deeper (I've asked this in very large sessions and nobody ever uses only hit ratios). People who say you shouldn't use hit ratios at all don't generally understand their value or how to use them. The DBAs who don't look at hit ratios can miss a *major* issue that could have been potentially fixed at a very low cost. Hit ratios are very rarely the indicator of good performance, but often can be an indicator of bad performance. Their best use is as a barometer or an indicator of changing performance. Hit ratios can be easily calculated by using the dynamic performance view V$SYSSTAT and V$SYSMETRIC (see Chapter 12 for additional examples). See Chapter 4 for initialization parameters used for memory allocation within Oracle.

Query for buffer cache hit ratio

```
select    (1 - (sum(decode(name, 'physical reads',value,0)) /
          (sum(decode(name, 'db block gets',value,0)) +
          sum(decode(name, 'consistent gets',value,0))))) * 100 "Hit Ratio"
from      v$sysstat;
```

Sample output

```
 Hit Ratio
----------
98.8249067
```

Rate Your OLTP System

What is your buffer cache hit ratio? (You can also use variance from the norm as the scoring mechanism.)	<90%	0 points
	90–94%	10 points
	95–98%	20 points
	>98%	30 points
	Score	30

You can also expand the preceding query to include the actual ratings in your result. The query that follows shows how this is accomplished using the DECODE function. You can also apply this to the remainder of the queries in this chapter if you would like to include the score in your results. At TUSC, we always used a PL/SQL procedure to accomplish the results (we also displayed them graphically).

Query for hit ratio with rating

```
select (1 - (sum(decode(name, 'physical reads',value,0)) /
(sum(decode(name, 'db block gets',value,0)) +
sum(decode(name, 'consistent gets',value,0))))) * 100 "Hit Ratio",
decode(sign((1-(sum(decode(name, 'physical reads',value,0)) /
(sum(decode(name, 'db block gets',value,0)) +
sum(decode(name, 'consistent gets',value,0))))) * 100 - 98),1,30,
decode(sign((1-(sum(decode(name, 'physical reads',value,0)) /
(sum(decode(name, 'db block gets',value,0)) +
sum(decode(name, 'consistent gets',value,0))))) * 100 - 95),1,20,
decode(sign((1-(sum(decode(name, 'physical reads',value,0)) /
(sum(decode(name, 'db block gets',value,0)) +
sum(decode(name, 'consistent gets',value,0))))) * 100 - 90),1,10,0)))
"Score"
from v$sysstat
/
```

Sample output

```
 Hit Ratio      Score
---------- ----------
99.8805856         30
```

The data in V$SYSSTAT reflects the statistics for logical and physical reads for all buffer pools. To derive the hit ratio for the buffer pools individually, query the V$BUFFER_POOL_STATISTICS dynamic performance view.

The buffer cache hit ratio can be used to validate physical I/O simulated in the dynamic performance view V$DB_CACHE_ADVICE. This dynamic performance view provides information that assists in sizing the cache by providing information that predicts the number of physical reads for each possible cache size. Included in the data is a physical read factor, which predicts the number of physical reads that are estimated to change if the buffer cache is resized to a given value. To use V$DB_CACHE_ADVICE, set the parameter DB_CACHE_ADVICE to ON and allow a representative workload to stabilize prior to querying the view. Following is the query to validate physical I/O simulated by the buffer cache advisory.

Query to validate physical I/O

```
COLUMN size_for_estimate FORMAT 999,999,999,999 heading 'Cache Size in MB'
COLUMN buffers_for_estimate      FORMAT 999,999,999 heading 'Buffers'
COLUMN estd_physical_read_factor FORMAT 999.99 heading 'Estd Phys Read Fctr'
COLUMN estd_physical_reads       FORMAT 999,999,999 heading 'Estd Phys Reads'
SELECT size_for_estimate,
       buffers_for_estimate,
       estd_physical_read_factor,
       estd_physical_reads
FROM V$DB_CACHE_ADVICE
WHERE name = 'DEFAULT'
  AND block_size = (SELECT value FROM V$PARAMETER
                    WHERE  name = 'db_block_size')
  AND advice_status = 'ON'
/
```

Sample output

```
Cache Size in MB      Buffers Estd Phys Read Fctr Estd Phys Reads
---------------- ------------ ------------------- ---------------
               4          501                1.36          11,130
               8        1,002                1.27          10,427
              12        1,503                1.19           9,743
              16        2,004                1.00           8,205
              20        2,505                 .96           7,901
              24        3,006                 .84           6,856
              28        3,507                 .81           6,629
              32        4,008                 .76           6,249
(...Simplistic Listing Displayed)
```

Dictionary Cache Hit Ratio

The Dictionary Cache hit ratio displays the percentage of memory reads for the data dictionary and other objects.

Query for Dictionary Cache hit ratio

```
select      (1-(sum(getmisses)/sum(gets))) * 100 "Hit Ratio"
from        v$rowcache;
```

Sample output

```
 Hit Ratio
----------
95.4630137
```

Rate Your System

What is your Dictionary Cache hit ratio?	<85%	0 points
(You can also use variance from the norm	86 92%	10 points
as the scoring mechanism.)	92–98%	20 points
	>98%	30 points
	Score	20

Library Cache Hit Ratio

The Library Cache hit ratio reveals the percentage of memory reads for actual statements and PL/SQL objects. Note that a high hit ratio is not *always* good; see Chapter 4 for a detailed explanation.

Query for Library Cache hit ratio

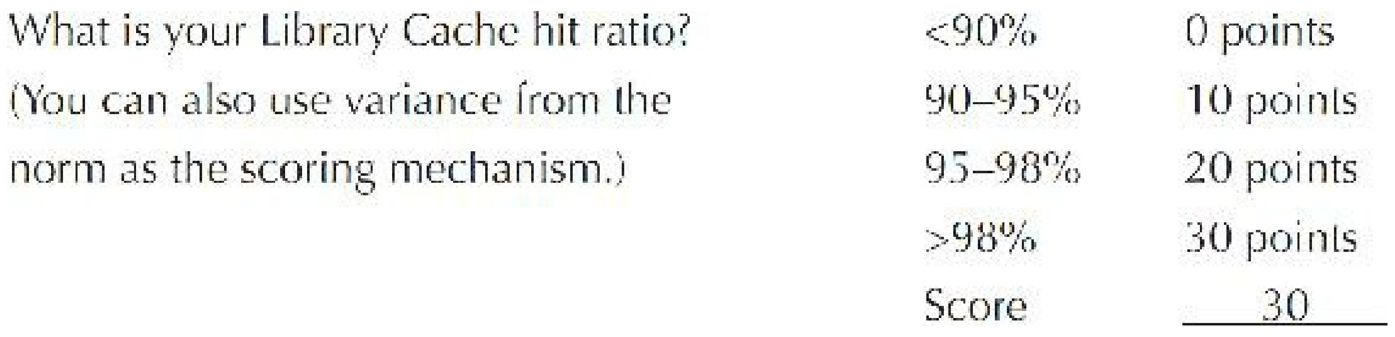
```
select      Sum(Pins) / (Sum(Pins) + Sum(Reloads)) * 100  "Hit Ratio"
from        v$LibraryCache;
```

Sample output

```
Hit Ratio
----------
99.9670304
```

The hit percentage is 99.97 percent, which means that only 0.03 percent of executions resulted in reparsing.

Rate Your System



What is your Library Cache hit ratio?	<90%	0 points
(You can also use variance from the	90–95%	10 points
norm as the scoring mechanism.)	95–98%	20 points
	>98%	30 points
	Score	30

PGA Memory Sort Ratio

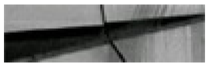
Automatic PGA Memory Management simplifies the way PGA memory is allocated. By default, PGA Memory Management is enabled. When running in this mode, Oracle adjusts, dynamically, the size of the portion of the PGA memory dedicated to work areas, which is based on 20 percent of the SGA memory size. When running in Automatic PGA Memory Management mode, sizing of work areas for all sessions is automatic. In 10*g*, the total amount of PGA memory available to active work areas in the instance is automatically derived from the SORT_AREA_SIZE or the PGA_AGGREGATE_TARGET (preferred) initialization parameter. In 11*g*, if you use the MEMORY_TARGET parameter, Oracle manages both the SGA and PGA. In 12*c*, Oracle limits the upper bound for the PGA with PGA_AGGREGATE_LIMIT. See Chapter 4 for initialization parameters used for memory allocation within Oracle and a discussion of the new parameters in 12*c* and Automatic Memory Management (AMM).

The objective is to have sort operations in the PGA performed in memory versus in the I/O subsystem (on disk) when possible. Statistics related to PGA memory sorts can be derived by the query in the next section or from the AWR Report, which reflects overall values for sorts in memory and disk, as well as the percentage of those in memory. The values reflect activity since the start of the instance. Values for a PGA Memory Sort Ratio greater than 98 percent are desired. Depending on the value of the memory currently allocated to the PGA by AMM (or set with PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT), user sorts may fit into memory or be performed on disk in a specified temporary tablespace if this initialization parameter is not high enough to hold the sort.

Query for PGA Memory Sort Ratio

You can receive specific sorting statistics (memory, disk, and rows) by running the following queries or go to the AWR Report or Statspack output file (`report.txt`) to get these statistics (see Chapter 14 for more information on Statspack and the AWR Report).

Query to get PGA Memory Sort Ratio



```
select    a.value "Disk Sorts", b.value "Memory Sorts",
          round((100*b.value)/decode((a.value+b.value),0,1,(a.value+b.value)),2)
          "Pct Memory Sorts"
from      v$sysstat a, v$sysstat b
where     a.name = 'sorts (disk)'
and       b.name = 'sorts (memory)';
```

Sample output

```
Disk Sorts Memory Sorts    Pct Memory Sorts
---------- ------------ -------------------
        16        66977               99.98
```

Rate Your System

What percentage of sorts are performed in memory?	<90%	0 points
(You can also use variance from the norm	90–94%	10 points
as the scoring mechanism.)	95–98%	20 points
	>98%	30 points
	Score	30

Percentage of Data Buffers Still Free

When you start the Oracle database, users start using memory for their queries. Although this memory is reusable when the user's query is complete, when the following query runs on a system after two hours of processing, it is a good indication of how quickly the buffers are being used up (high-volume systems may need to vary the time frame to be much shorter). The number of free buffers divided by the total number of records in X$BH (which is the total data block buffers allocated—one record in the table for each buffer) is the percentage. Also note that you have to run this query as SYS. Remember that having many free buffers is not necessarily the best situation. See Chapter 13 on queries to this table for more information. This could also be done from the In-Memory (IM) column store as well if you are licensed for this and use it (see Chapter 4 for detailed information and queries on IM). For a data warehouse, you might split half the scoring for the buffer cache and the other half for the IM column store.

Query for free data buffers

```
SET VERIFY off
COLUMN PctTotBCMem for all
SELECT /*+ ordered */
       tot_bc_mem.TotBCMem,
       decode(state,
                  0,'Free',
                  1,'Exclusive',
                  2,'SharedCurrent' ,
                  3,'ConsistentRead',
                  4,'BeingRead',
                  5,'InMediaRecoveryMode',
                  6,'InInstanceRecoveryMode',
                  7,'BeingWritten',
                  8,'Pinned',
                  9,'Memory',
                 10,'mrite',
                 11,'Donated') "BlockState",
       SUM(blsiz) "SumStateTypeMem",
       COUNT(1)   "NumOfBlksThisTyp",
       ROUND(SUM(blsiz)/tot_bc_mem.TotBCMem,2)*100||'%' "PctTotBCMem"
  FROM (SELECT sum(blsiz) TotBCMem
        FROM X$bh) tot_bc_mem,
             X$bh
GROUP BY tot_bc_mem.TotBCMem,
            decode(state,
                   0,'Free',
                   1,'Exclusive',
                   2,'SharedCurrent' ,
                   3,'ConsistentRead',
                   4,'BeingRead',
                   5,'InMediaRecoveryMode',
                   6,'InInstanceRecoveryMode',
                   7,'BeingWritten',
                   8,'Pinned',
                   9,'Memory',
                  10,'mrite',
                  11,'Donated')
ORDER BY SUM(blsiz);
CLEAR COLUMNS
```

```
  TOTBCMEM BlockState                SumStateTypeMem NumOfBlksThisTyp PctTotBCMem
---------- ---------------------- --------------- ---------------- -----------
 209739776 Free                         12828672             1566 6%
 209739776 ConsistentRead               43368448             5294 21%
 209739776 Exclusive                   153542656            18743 73%
```

Rate Your System

What percentage of buffers in X$BH are at a state=0 (free) after two hours of running in production? (You may vary this to an appropriate level for your unique system.)	<5%	0 points
(You can also change the scoring to focus half on the	5–10%	20 points
buffer cache and the other half on the IM column store.)	10–25%	10 points
	>25%	0 points
	Score	20

Note that the reason you get 0 points for greater than 25 percent free is because the data buffers are probably oversized and potentially wasting memory (ensure the system has been running awhile). The scoring should be tailored to your individual system use. Remember this rating is only a general guideline and one that definitely needs to be tailored to your system.

Using the Result Cache Effectively

The Result Cache is a separate shared memory pool to store query results. This Result Cache is allocated directly from the shared pool upon database startup but is maintained separately. The Result Cache allows a query's result (for instance, a sum of all salaries after being calculated) to be cached in memory, allowing for large performance improvements for future queries executed multiple times that require the same results. By default, the Result Cache is set to 0.25 percent of the value of MEMORY_TARGET (if set), 0.50 percent of the value of SGA_TARGET (if set), or 1 percent of the SHARED_POOL_SIZE parameter (if set). You can also set it directly by using the RESULT_CACHE_MAX_SIZE=*amount* and the RESULT_CACHE_MODE=force parameters (set to force to use it automatically). Setting RESULT_CACHE_MAX_SIZE to 0 disables the Result Cache feature. You can use DBMS_RESULT_CACHE.FLUSH to clear it. Note results are *not* passed between RAC/Grid nodes. Please see Chapter 4 for more information. Also, check the documentation for other restrictions and rules.

Rate Your System

Are you using the Result Cache effectively?	Yes/no need	10 points
	No	0 points
	Score	10

Pinning/Caching Objects

Objects can be pinned into memory using DBMS_SHARED_POOL.KEEP if they are often-used objects, as shown in Chapter 10. Tables can also be pinned into memory by caching the table when it is created, or by using the ALTER command to cache a table. See Chapter 7 for more information on caching tables.

Some of the recommended packages to *consider* for pinning are the following:

DBMS_ALERT	DBMS_DESCRIBE
DBMS_DDL	DBMS_LOCK
DBMS_OUTPUT	DBMS_PIPE
DBMS_SESSION	DBMS_SHARED_POOL
DBMS_STANDARD	DBMS_UTILITY

Rate Your System

Do you pin PL/SQL objects or	Yes/no need	10 points	
cache tables when needed?	No	0 points	
	Score	10	
Example Memory Performance Index (MPI)	**Total Score**	**240**	**(A+)**

Grade Your System

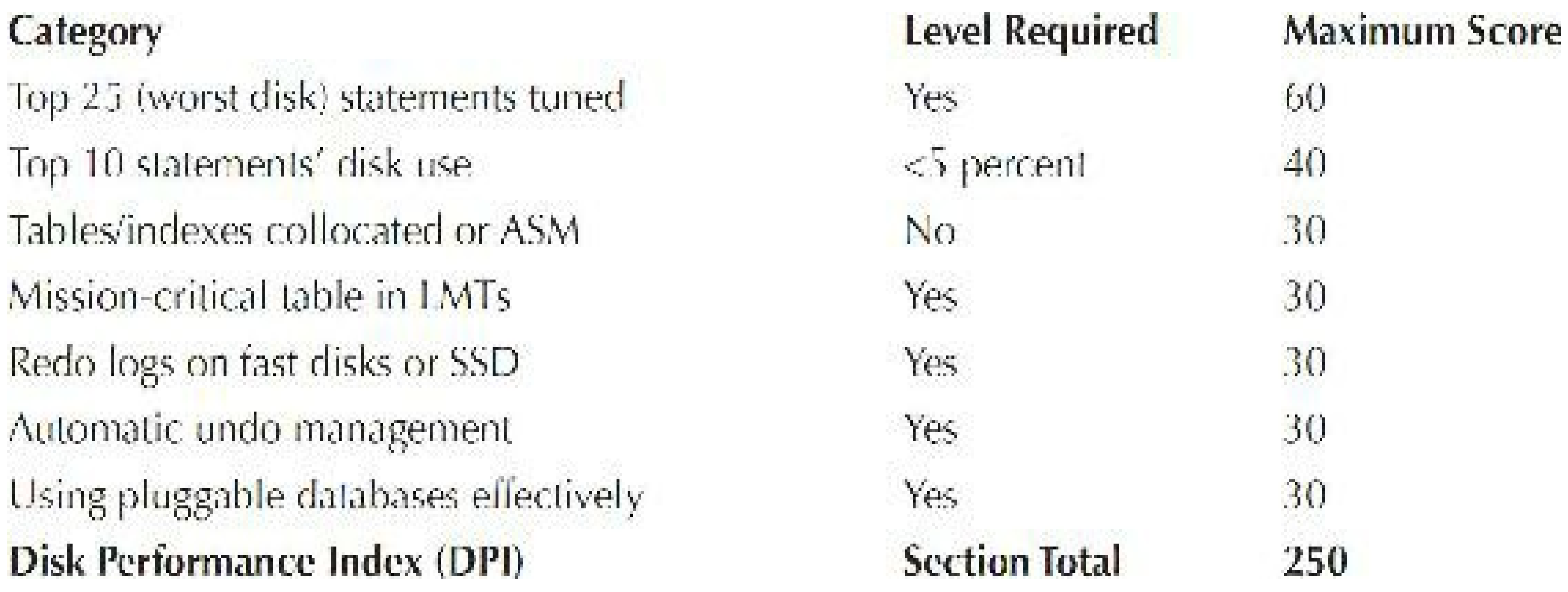
MPI Grade	**Comments**	**Score**
A+	Top 10 percent of most systems	>230
A	Top 20 percent of most systems	200–230
B	Top 40 percent of most systems	160–199
C	Top 70 percent of most systems	100–159
Needs help now	Bottom 30 percent of most systems	<100

TIP

Measuring your MPI (Memory Performance Index) can be helpful in identifying potential memory allocation and usage improvements that could benefit your system.

Disk Performance Index (DPI)

This section measures disk use. The following table illustrates how to receive a perfect DPI score. This rating system is not meant to be an all-encompassing benchmark of disk use; rather, it is a barometer to see if disk use improvements might be beneficial. With the advent of storage area networks (SANs) and other disk and disk-caching technology, you may need to alter the rating system to be more appropriate for your system. Strongly consider using Oracle features such as Automatic Storage Management (ASM), Locally Managed Tablespaces (LMTs), and Automatic Segment Space Management (ASSM). (See Chapter 3 for more information on these features.)



Category	Level Required	Maximum Score
Top 25 (worst disk) statements tuned	Yes	60
Top 10 statements' disk use	<5 percent	40
Tables/indexes collocated or ASM	No	30
Mission-critical table in LMTs	Yes	30
Redo logs on fast disks or SSD	Yes	30
Automatic undo management	Yes	30
Using pluggable databases effectively	Yes	30
Disk Performance Index (DPI)	**Section Total**	**250**

Top 25 "Disk-Read Abuser" Statements Tuned

I have found that the top 25 statements with the most disk reads accessed on most systems, when left untuned, can make up over 75 percent of all disk and/or memory reads of the entire system. This section lists the most intense 25 disk-reading statements for the entire system. The example that follows shows a pretty well-tuned system where only data dictionary queries show up (you would usually not tune these).

Query to get the 25 worst disk-read abusers

```
set serverout on size 1000000
declare
 top25 number;
 text1 varchar2(4000);
 x number;
 len1 number;
cursor c1 is
  select disk_reads, substr(sql_text,1,4000)
  from v$sqlarea
  order by disk_reads desc;
```

```
begin
 dbms_output.put_line('Reads'||'    '||'Text');
 dbms_output.put_line('----------'||' '||'----------------------');
 open c1;
 for i in 1..25 loop
  fetch c1 into top25, text1;
  dbms_output.put_line(rpad(to_char(top25),9)||' '||substr(text1,1,66));
  len1:=length(text1);
  x:=66;
  while len1 > x-1 loop
   dbms_output.put_line('"          '||substr(text1,x,66));
  x:=x+66;
  end loop;
 end loop;
end;
/
```

Sample partial output

```
Reads    Text
1156       select file#, block#, ts# from seg$ where type# = 3
122        select distinct d.p_obj#,d.p_timestamp from sys.dependency$ d, obj
"          j$ o where d.p_obj#>=:1 and d.d_obj#=o.obj# and o.status!=5
111        BEGIN sys.dbms_ijob.remove(:job); END;
(...Simplistic Partial Listing Displayed)
```

Rate Your System

How many of your top 25 disk-read statements in the V$SQLAREA view have you attempted to tune?	0	0 points
	1–5	20 points
	6–15	40 points
	16–25	60 points
	Score	60

Top 10 Disk-Read Abusers as Percentage of All Statements

This section measures the effect of the top 10 heaviest disk-reading statements as a percentage of the entire system.

Script to retrieve this percentage

```
Set serverout on;
DECLARE
 CURSOR c1 is
  select   disk_reads
  from      v$sqlarea
  order by  disk_reads DESC;

 CURSOR c2 is
  select    sum(disk_reads)
  from      v$sqlarea;
 Sumof10 NUMBER:=0;
 mydr NUMBER;
 mytotdr NUMBER;
BEGIN
 dbms_output.put_line('Percent');
 dbms_output.put_line('-------');
 OPEN c1;
 FOR i IN 1..10 LOOP
  FETCH c1 INTO mydr;
  sumof10 := sumof10 + mydr;
 END LOOP;
 CLOSE c1;
 OPEN c2;
 FETCH c2 INTO mytotdr;
 CLOSE c2;
 dbms_output.put_line(sumof10/mytotdr*100);
END;
/
```

Sample output

```
Percent
4.59
```

Alternative—simple and fast SQL

```
select sum(pct_bufgets)
from ( select rank() over ( order by disk_reads desc ) as rank_bufgets,
       to_char(100 * ratio_to_report(disk_reads) over (), '999.99') pct_bufgets
       from   v$sqlarea )
where rank_bufgets < 11;

SUM(PCT_BUFGETS)
----------------
           4.59
```

Rate Your System

Take your top 10 disk-read statements in the V$SQLAREA view. What percentage are they of all disk reads?	>25%	0 points
	20–25%	20 points
	5–19%	30 points
	<5%	40 points
	Score	40

Tables/Indexes Separated or Using ASM

Tables and their corresponding indexes should be located on separate physical disks for smaller systems to decrease file I/O for a given disk. This is, of course, becoming harder to do, as DBAs are often unaware of where things are because of how a SAN may be managed. In Enterprise Manager, Oracle gives you a way to see and move *hot* (frequently used) and *cold* (not frequently used) data. Moving data to a hotter or colder region of the disk is now very easy. *Information lifecycle management (ILM)*, or the management of data throughout its lifetime, is becoming more and more important. In Oracle 12*c*, ILM is simplified through the Heat Map, which automatically collects segment- and row-level statistics, used to define compression and storage policies that are automatically maintained throughout the life cycle of the data (see Chapter 3). Older data can now be kept longer on physical, but slower, disks. Newer data can be cached to ensure speed when accessing it. Chapter 3 covers physical data and I/O in great detail and provides queries to assist in this matter. Note that if you use ASM, you should ensure that when you add new disks, you follow the tips on rebalancing that are listed in Chapter 3. ASM has a feature called *intelligent data placement* that enables you to specify hot/cold disk regions in ASM to ensure that frequently accessed data is placed on the fast/outermost (hot) tracks. It also has the new Heat Map that can be used (even in Enterprise Manager).

Rate Your System

Is your data properly striped and/or mirrored to reduce contention? Have you used some of the Oracle tools available for ILM?	No	0 points
	Yes/ASM	20 points
	Yes + ILM	30 points
	Score	30

Mission-Critical Table Management

Locally managed tablespaces (LMTs) with ASSM is the norm. Also, review row chaining; row-chaining is also common when the database block size is too small. Tablespaces implemented using ASSM are sometimes referred to as locally managed tablespaces with bitmap segment-space management, or bitmap tablespaces. To use ASSM, create locally managed tablespaces, with the segment space management clause set to AUTO. ASSM in locally managed tablespaces eliminates the need to specify the PCTUSED, FREELISTS, and FREELIST GROUPS storage attributes for the tablespace. If possible, switch from manual space management to ASSM.

When a table is updated and the updated record block does not have enough room to fit the changes, a record is "chained" to another block. In this situation, a record spans more than one block and, in most instances, creates additional I/O. By analyzing a table for chained rows and querying the CHAINED_ROWS table, identifying tables that have chained records is possible. The CHAINED_ROWS table is created using the script `utlchain.sql` or `utlchn1.sql`, which resides in a file under the $ORACLE_HOME/rdbms/admin directory, where Oracle software is located (note that the exact name and location may vary depending on your platform). You may also consider the ALTER TABLE SHRINK SPACE COMPACT command, but please investigate the use/restrictions of this command in the Oracle documentation beforehand. To populate the CHAINED_ROWS table, use the ANALYZE command. The ANALYZE command has an option to determine chained rows in a table as follows:

```
ANALYZE table TABLE_NAME list chained rows into chained_rows;
Table analyzed.
```

The command places the output into a table called CHAINED_ROWS. The following query selects the most informative columns of the CHAINED_ROWS table:

```
SELECT OWNER_NAME,          /*owner of object*/
       TABLE_NAME,          /*Name of table*/
       CLUSTER_NAME,        /*Name of cluster if applicable*/
       HEAD_ROWID,          /*ID of the first part of the row*/
       ANALYZE_TIMESTAMP /*Timestamp associated with last analyze*/
FROM   CHAINED_ROWS;
```

Rate Your System

Are mission-critical tables stored in LMTs with ASSM, and do you address chaining issues?	No	0 points
	Yes	30 points
	Score	30

Key Oracle Files Separated

Separating often-accessed Oracle datafiles or effectively using ASM and the Heat Map can help eliminate I/O bottlenecks as well as eliminate potential saturation of the disk's memory cache. Separating heavily written files (especially redo logs) generally improves performance.

Rate Your System

Are redo logs on different disks than database datafiles?	Yes	30 points
	Disk array	20 points
	No	0 points
	Score	20

Automatic Undo Management

Automatic undo management (AUM) should be used where possible. When configured in this manner, the database automatically determines how long UNDO data should be kept on the basis of the length of time queries take to run. UNDO data preserved within this window of time is said to be in the unexpired state. After this time, the state of the UNDO data changes to expired. UNDO data is a good candidate for overwriting only when it is in the expired state. The length of time that Oracle keeps UNDO data in the unexpired state depends on tablespace configuration. When creating a database with the Database Configuration Assistant (DBCA), the UNDO tablespace is set, by default, to extend itself automatically to maintain unexpired UNDO for the longest-running query. You can also specify a minimum UNDO retention period (in seconds) by setting the UNDO_RETENTION initialization parameter. This is only used with AUTOEXTEND tablespaces. Oracle extends the UNDO tablespace up to the size of MAXSIZE. Only when it is not possible to expand anymore is unexpired UNDO data overwritten.

When using a fixed-sized UNDO tablespace, Oracle automatically keeps the UNDO data in the unexpired state for the longest possible time for the tablespace of the specified size. If the UNDO tablespace does not have adequate free or expired space to store active UNDO data generated by current transactions, then Oracle might be forced to overwrite the unexpired UNDO data. This situation might cause long-running queries to fail with an error and an alert.

In the event that AUTOEXTEND is disabled (by default it is enabled) for automatic undo management, autoextending the UNDO tablespace will require adjusting the size of the tablespace manually. In this case, ensure that the tablespace is large enough to meet the read-consistency requirements for the longest-running query. Also, if using flashback features, then make certain the tablespace is large enough to accommodate flashback operations. The queries listed next estimate the number of bytes required when sizing the UNDO tablespace under different conditions. With AUM, you do not have to create individual UNDO segments (Oracle does it for you). If you use AUM, you do not have to specify rollback segments.

The following information is appropriate for UNDO query A, B, and C. Sizing an UNDO tablespace requires three pieces of information:

- **(UR)** UNDO_RETENTION in seconds
- **(UPS)** Number of UNDO data blocks generated per second
- **(DBS)** Overhead, which varies based on extent and file size (DB_BLOCK_SIZE)

  UndoSpace = (UR * (UPS * DBS) + DBS)

Or, when the guesstimate equates to 0, then add a multiplier (24) to the overhead (DBS) to derive more appropriate results:

UndoSpace = [UR * (UPS * DBS)] + (DBS * 24)

Two pieces of information can be obtained from the initialization file: UNDO_RETENTION and DB_BLOCK_SIZE. The third piece of the formula requires a query against the database. The number of UNDO blocks generated per second can be acquired from V$UNDOSTAT as follows:

```
SELECT (SUM(undoblks))/ SUM ((end_time - begin_time) * 86400)
FROM   v$undostat;
```

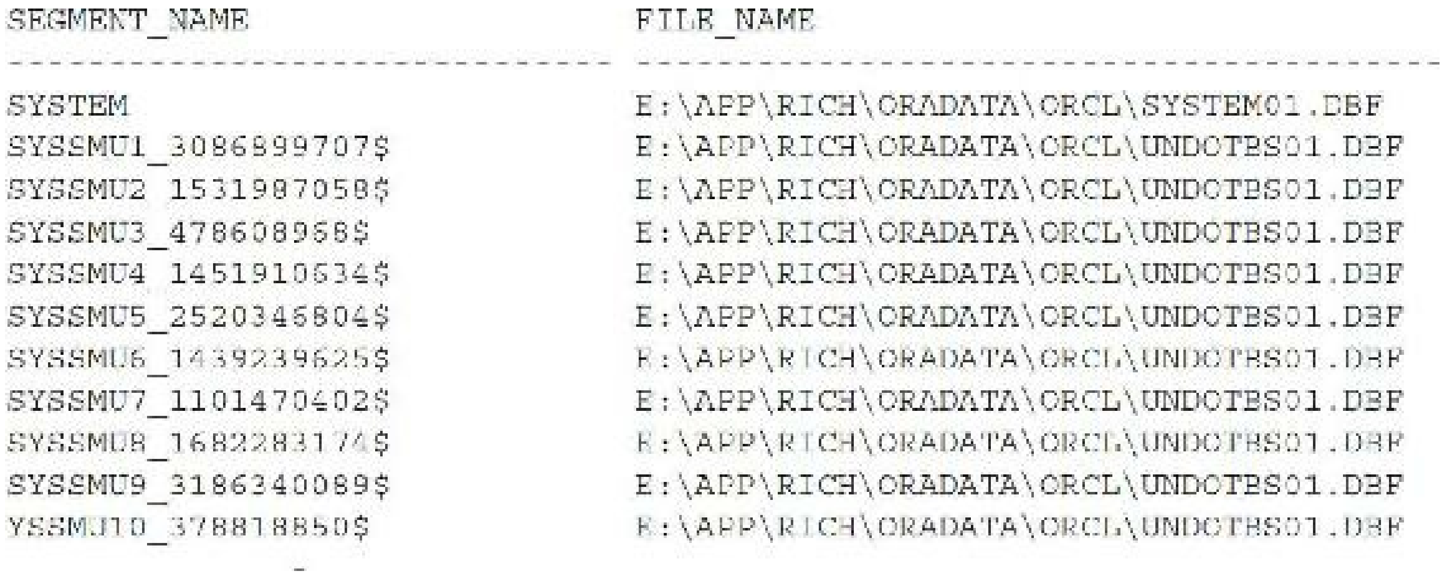
To convert days to seconds, you multiply by 86,400, the number of seconds in a day. The result of the query returns the number of UNDO blocks per second. This value needs to be multiplied by the size of an UNDO block, which is the same size as the database block defined in DB_BLOCK_SIZE. The query that follows represents a point-in-time estimate based on the UNDO blocks per second at the time of execution. The query can be utilized when UNDO space has not been allocated. If this time frame is during high activity or a worst-case scenario for UNDO, then the results derived provide a good estimate.

Segment/file query

```
col file_name for a40

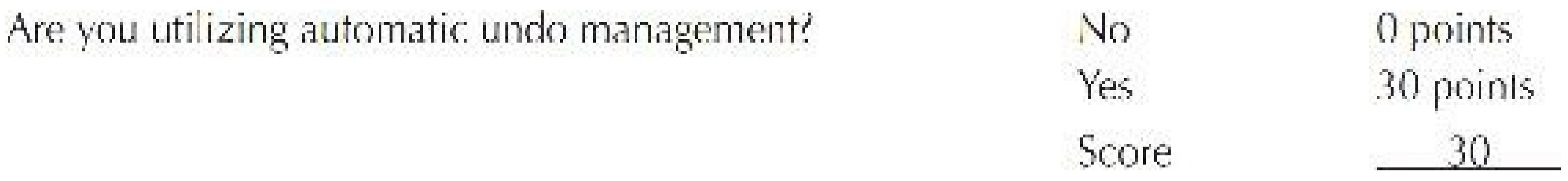
select    segment_name, file_name
from      dba_data_files, dba_rollback_segs
where     dba_data_files.file_id = dba_rollback_segs.file_id;
```

Sample output



```
SEGMENT_NAME                   FILE_NAME
------------------------------ ----------------------------------------
SYSTEM                         E:\APP\RICH\ORADATA\ORCL\SYSTEM01.DBF
SYSSMU1_3086899707$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU2_1531987058$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU3_478608958$             E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU4_1451910634$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU5_2520346804$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU6_1439239625$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU7_1101470402$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU8_1682283174$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
SYSSMU9_3186340089$            E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
YSSMU10_378818850$             E:\APP\RICH\ORADATA\ORCL\UNDOTBS01.DBF
```

Rate Your System



Are you utilizing automatic undo management?	No	0 points
	Yes	30 points
	Score	30

Using Pluggable Databases Effectively

The pluggable databases architecture, new in 12*c* and covered in detail in Chapter 3, enables you to have a container database (CDB) with multiple pluggable databases (PDBs). As a quick review, pluggable databases are also called *multitenant databases* because each "tenant" can have their own PDB. "Pluggable" databases can be unplugged from one CDB and plugged into another CDB easily, therefore making databases portable between environments and allowing upgrade of a database by unplugging it from one environment at one version and plugging it into a new environment at a higher version. You can also unplug from an on-premises CDB and plug into the cloud (or vice versa). This feature also allows a single PDB to be independently recovered (you can flashback an individual PDB in 12*c*R2). Because each PDB looks to an application like any traditional Oracle database (called a non-CDB), no application changes are needed to work with the PDB architecture. Non-CDBs are now deprecated.

The following are some notes to keep in mind regarding CDB/PDBs (subject to change):

- CDB = container database (has a root database and also a seed PDB).
- PDB = pluggable database (plugged into a CDB).
- Non-CDB = traditional Oracle database instance (neither a CDB nor a PDB).
- Why PDBs? To consolidate hundreds of database on one machine. Too many resources are required when you add up the SGAs for each of the instances when not using PDBs. One CDB has one SGA and resources shared for multiple PDBs.

- Share PDBs (big data sources, acquisitions, partners, shared research, governments).
- In 12*c*R2, can refresh a read-only PDB, can flashback an individual PDB, and can recover an individual PDB.
- Move existing PDBs to a new platform or location or clone them (snapshot).
- Patch/upgrade a PDB by plugging it into a CDB at a later version.

The following shows how to determine whether a database is a CDB or a non-CDB (this is a CDB, as indicated by YES in the CDB column):

```
select name, crated, cdb, con_id
from   v$database;

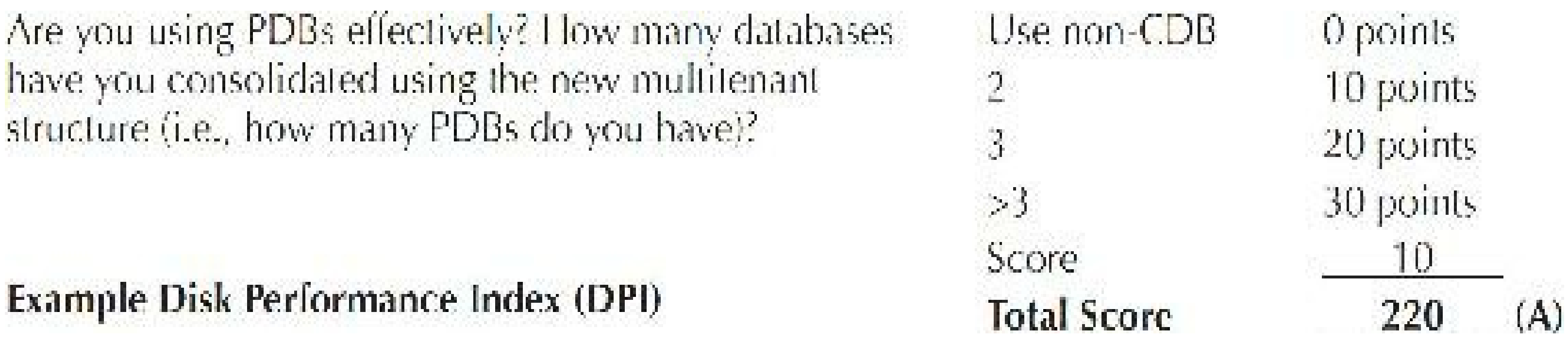
NAME       CREATED   CDB     CON_ID
---------- --------- --- ----------
CDB1       19-FEB-12 YES          0
```

Use the following command to see how many PDBs you have. As the output shows, I have three PDBS, but only PDB_SS and PDB1 were created by me (each PDB might represent a different application). PDB$SEED was created by Oracle when I installed the database. I can clone the *seed* PDB (which in itself is not used) to create new, empty PDBs.

```
select name, open_mode, open_time
from v$pdbs;

NAME             OPEN_MODE  OPEN_TIME
---------------- ---------- --------------------------
PDB$SEED         READ ONLY  23-FEB-13 05.29.19.861 AM
PDB1             READ WRITE 23-FEB-13 05.29.25.846 AM
PDB SS           READ WRITE 23-FEB-13 05.29.37.587 AM
```

Rate Your System



Are you using PDBs effectively? How many databases have you consolidated using the new multitenant structure (i.e., how many PDBs do you have)?	Use non-CDB	0 points	
	2	10 points	
	3	20 points	
	>3	30 points	
	Score	10	
Example Disk Performance Index (DPI)	**Total Score**	**220**	(A)

Grade Your System

DPI Grade	Comments	Score
A+	Top 10 percent of most systems	>235
A	Top 20 percent of most systems	205–235
B	Top 40 percent of most systems	170–204
C	Top 70 percent of most systems	110–169
Needs help now	Bottom 30 percent of most systems	<110

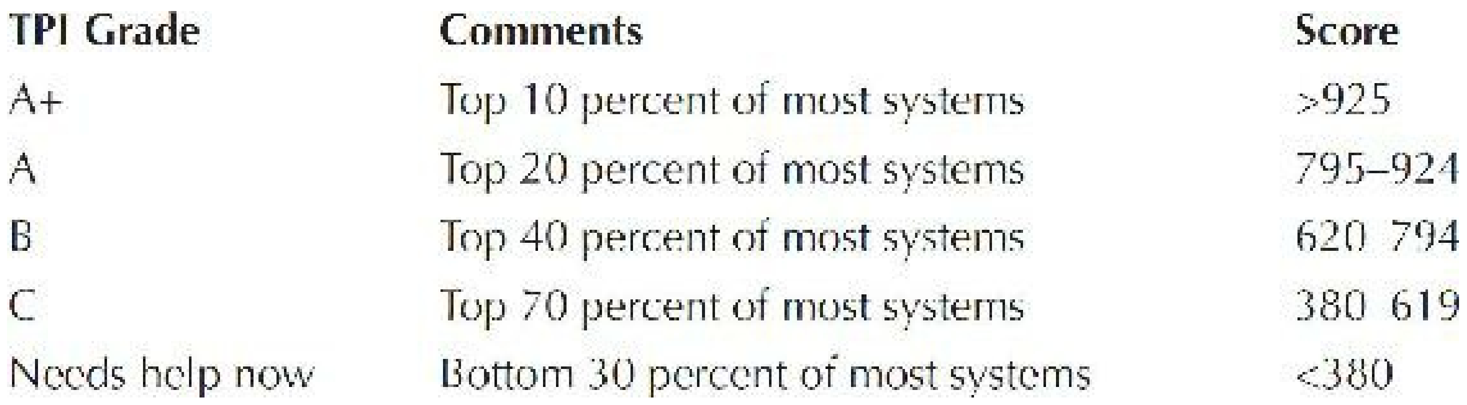
TIP
Measuring your DPI (Disk Performance Index) can be helpful in identifying potential disk improvements that might benefit your system.

Total Performance Index (TPI)

The Total Performance Index is the composite score of the Education, System, Memory, and Disk indexes, as shown here:

Category Index	Maximum Score		
Education Performance Index (EPI)	250		
System Performance Index (SPI)	250		
Memory Performance Index (MPI)	250		
Disk Performance Index (DPI)	250		
Total Performance Index (TPI)	**1000**		
Example Education Performance Index (EPI)	Total Score	160	(B)
Example System Performance Index (SPI)	Total Score	220	(A+)
Example Memory Performance Index (MPI)	Total Score	240	(A+)
Example Disk Performance Index (DPI)	Total Score	220	(A)
Example Total Performance Index (TPI)	**Total Score**	**840**	**(A)**

Grade Your System



TPI Grade	Comments	Score
A+	Top 10 percent of most systems	>925
A	Top 20 percent of most systems	795–924
B	Top 40 percent of most systems	620 794
C	Top 70 percent of most systems	380 619
Needs help now	Bottom 30 percent of most systems	<380

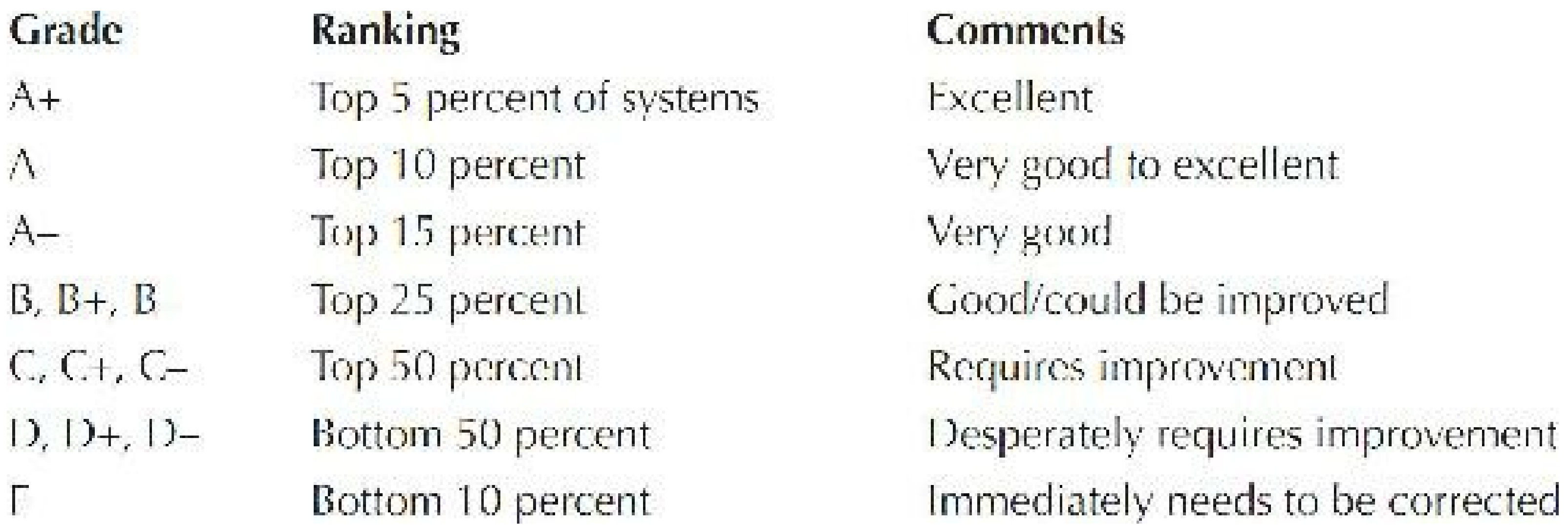
TIP
Measuring your TPI (Total Performance Index) can be helpful in identifying bottlenecks; it is a simple barometer of your overall system performance and may help you find areas needing improvement.

Overall System Review Example

The following is an example rating scale. You can use the rating results to generate a yearly review for your system. Some of the items (such as backup and recovery ratings) are not covered in depth. The objective of this section is to give you ideas of some of the areas you might consider reviewing. This is not an actual client system review but a slightly modified version of several reviews to help generate discussion items for your review template. The goal is to give you a “feel” for a review.

Rating System

Here is an example rating report that you may use as a guideline as you detail an overall review and its ratings. Having a review that includes a rating for items that desperately need improvement or attention (where appropriate) is important in generating manager support. In many cases, DBAs need managerial support to be allowed the time to address major issues with their system. At times, if the system is up and running, upper management may not realize that a change is needed. This review can be a catalyst for needed change as issues are identified.



Grade	Ranking	Comments
A+	Top 5 percent of systems	Excellent
A	Top 10 percent	Very good to excellent
A–	Top 15 percent	Very good
B, B+, B	Top 25 percent	Good/could be improved
C, C+, C–	Top 50 percent	Requires improvement
D, D+, D–	Bottom 50 percent	Desperately requires improvement
F	Bottom 10 percent	Immediately needs to be corrected

TIP
Have your system reviewed on an annual basis by an outside party or, at the minimum, by someone inside your company.

Example System Review Rating Categories

The following table summarizes the results of the system review. Although some TPI categories are discussed, this section is an addition to the TPI that goes into greater depth. An overview of the recommended changes should follow this section, and the TPI rating could precede or follow this section. This section is more subjective, so an experienced person who you respect should make these evaluations. The ratings should include more detailed comments than those given here as an example. The recommended changes should be detailed with supporting documentation.

NOTE
This is an example, not an actual review.

Category	Grade	Comments
Overall review	C+	The system is running poorly at times due to an insufficient amount of memory allocated for the data. Currently the new In-Memory (IM) column stores isn't being used, but it could be leveraged nicely for data warehousing. Several areas need to be corrected for substantially improved system performance, especially as additional users and data are added. Oracle 12*c* new features are not implemented. In addition to not leveraging IM, the system is also not leveraging PDBs. Enterprise Manager features, such as SPA and the AWR Report, could help with tuning, but are not being used on a regular basis. An Exadata simulation might be worth running to evaluate new hardware, and the Oracle Public Cloud should be considered for an encrypted backup and developer testing.
Architecture	B	The overall architecture is good, but the SAN and cache should be investigated to determine whether I/O distribution across available controllers can be improved. Compression should be investigated to save space and improve performance.
Hardware sizing	A–	The hardware is well sized for the business activity, but future growth may dictate a hardware evaluation in the near future. The system is not tuned to take full advantage of the current hardware.
Security	F	Passwords are never changed, even when employees leave the company. Several unprotected files have hard-coded passwords. The default accounts are not locked when unused. This is unacceptable! The security information that Oracle provides at www.oracle.com/security has not been reviewed.
Memory allocation	B+	Of the 2G of memory, MEMORY_TARGET is set effectively, but more of the memory can be allocated to data by setting a (larger) minimum for the DB_CACHE_SIZE. Consider more Flash Cache (of some brand) to improve performance. Start investigating where you can utilize the Result Cache and IM for better performance.
Database tuning	D–	The top 25 queries make up 98 percent of all resource usage. No effort has been made to tune these queries.
Disk configuration	B	Disk I/O is reasonably balanced but could be improved by partitioning a few of the hardest-hit tables and indexes.
Redo logs	B+	Redo logs are sized well, but you may want to add a few more of them for batch processing when they switch much faster.

Archived log files	A+	File systems containing the archive log files are independent of other Oracle filesystems. Archived log files are archived to tape but also kept on disk for fast recoveries. New 12c Data Guard features are being used.
Undo	A+	Automatic undo management has been implemented and tuned.
Control files	A–	Multiple control files are located on different physical disks, but a backup of control files to TRACE does not exist.
Initialization parameters	A+	The system has 2GB of SGA. Obsolete initialization parameters have been removed.
Table design	C–	There is no database-level referential integrity.
Tables	C–	Tables are not partitioned to the degree that they could be, and Parallel should be set on some of the larger tables. Some of the smaller tables need to be altered so they will be cached in memory. New partitioning options are available in 12c that are not being used.
Indexes	C–	Indexes should be partitioned more. Bitmap indexes are not being employed for low-cardinality (few unique rows) columns of query-only tables. New index partitioning options available in 12c are not being used.
Tablespaces	C+	Tablespaces are severely undersized for future growth.

Items Requiring Immediate Action

Once you have reviewed your system, you need to make a comprehensive list of items that you need to address immediately. The following list is a summary (partial list only) of some of the issues that could warrant immediate action after a review:

- Lock the default accounts when unused! Let's do it now.
- SYSTEM and SYS passwords in production should be different in development.
- Any default or commonly used passwords should be changed. Change all user passwords, as security is currently compromised.
- MEMORY_TARGET has been set, but minimums have not been set correctly for key initialization parameters. The minimum setting for DB_CACHE_SIZE needs to be increased immediately (MEMORY_TARGET is set correctly though)! You can do this with the system running if the MEMORY_TARGET is large enough. You can also use SGA_TARGET, so the

DB_CACHE_SIZE is used only as a minimum for the SGA (see Chapters 1 and 4 for more information). PGA_AGGREGATE_LIMIT should be set to limit a runaway PGA.

- The top 25 queries causing disk and memory reads need to be tuned.

TIP
A system review should always include immediate action items. This ensures that the time needed for improvements will be allocated.

Other Items Requiring Action

The second list that you should make includes items needing attention *after* the most pressing issues have been addressed. A summary example list is shown here. Your list should include more detail on how the action will be corrected.

- Monitor the items detailed in this document at least once per quarter with the current growth rate of the system. Ensure that you are estimating future system size. Leverage the Oracle Public Cloud to offload infrequently used data.
- Resize the database objects that are currently oversized and undersized.
- Change all passwords at least once per quarter.
- Fix file protection so users are unable to delete Oracle software.
- Remove hard-coded passwords from scripts and backup jobs.
- Consider adding additional indexes for the top 25 worst disk-read queries to improve query performance.

If you're making initialization parameter changes, compile a list with both the current and suggested values. Refer to Appendix A for a complete list of initialization parameters with descriptions. Lastly, make sure you repeat the review after you have made the changes to ensure everything has been implemented correctly.

System Information List

This section describes some of the system information that you should gather and keep with the review. As you look back on a review, you need to know what the system parameters were at the time of the review. Any ratings of specific items (such as backup and recovery) could be placed in this section. I also have included a sample DBA review that illustrates some of the areas that may be reviewed. Have someone else rate your DBA skills so you can continue to improve. This section has been greatly simplified for the book. It is a quick list designed to give a "picture" of the system as whole.

Memory-Related Values

The following are memory-related questions and answers about the system:

- What is the current memory for the hardware? **400G.**
- What is the current number of users? **5000 total/500 concurrent.**
- What will be the future number of users? **1000–1500 concurrent in the next three months.**
- What other software is used on the system? **None that has a major influence.**
- Is the system client/server or browser/server? **Browser/server.**
- What response times are required? **Subsecond—OLTP transactions make up main mix.**
- How large is the database? **Currently 20T, with 500G currently free in the database.**
- How large are often-accessed tables? **One million rows is the average/100 million for the largest table.**
- What future software will affect memory? **None.**
- Are you implementing any other features/options? **Oracle In-Memory column store as soon as possible, Oracle GoldenGate in three months, Violin Memory Flash Memory in the next three months, and investigating Exadata and Oracle Public Cloud (and Amazon Web Services) over the next year.**

Disk-Related Values

The following are disk-related questions and answers:

- What is the maximum SAN capacity for the hardware? **20× current capacity.**
- What disk sizes are available? **4T and 8T.**
- What size will the database be in one year? **10 to 100 percent larger than current.**
- Is there a RAID (striping) level for database files/OS? **Yes; RAID 1+0.**
- Will you have multiplexed redo logs? **Yes.**
- What software will be installed in the future? **No additions in near future.**
- What system utilities will be installed? **Oracle Enterprise Manager with Diagnostics Pack.**
- What transfers happen nightly? **Bulk order transfers.**

- Any earlier notes on implementation? **Pluggable databases as soon as possible, Violin Memory Flash Memory in the next three months, and investigating Exadata and Oracle Public Cloud (and Amazon Web Services) over the next year.**

CPU-Related Values

The following are CPU-related questions and answers:

- What is the maximum number of processors for the hardware? **6 dual currently/12 quad maximum.**
- Is there a future upgrade path? **Yes; path to 64 quad core processors.**
- What is the transaction processing load? **60 percent CPU average/90 percent sustained maximum.**
- What is the batch load? **Some heavy at night/okay during the day.**
- Are hot backups employed? **RMAN backups are employed with archiving.**
- Are batch processes running during the day? **None affect performance.**
- Will Parallel Query be used in the future? **Currently being used on some processes.**
- Will there be a future distributed setup? **Yes, with Oracle GoldenGate.**

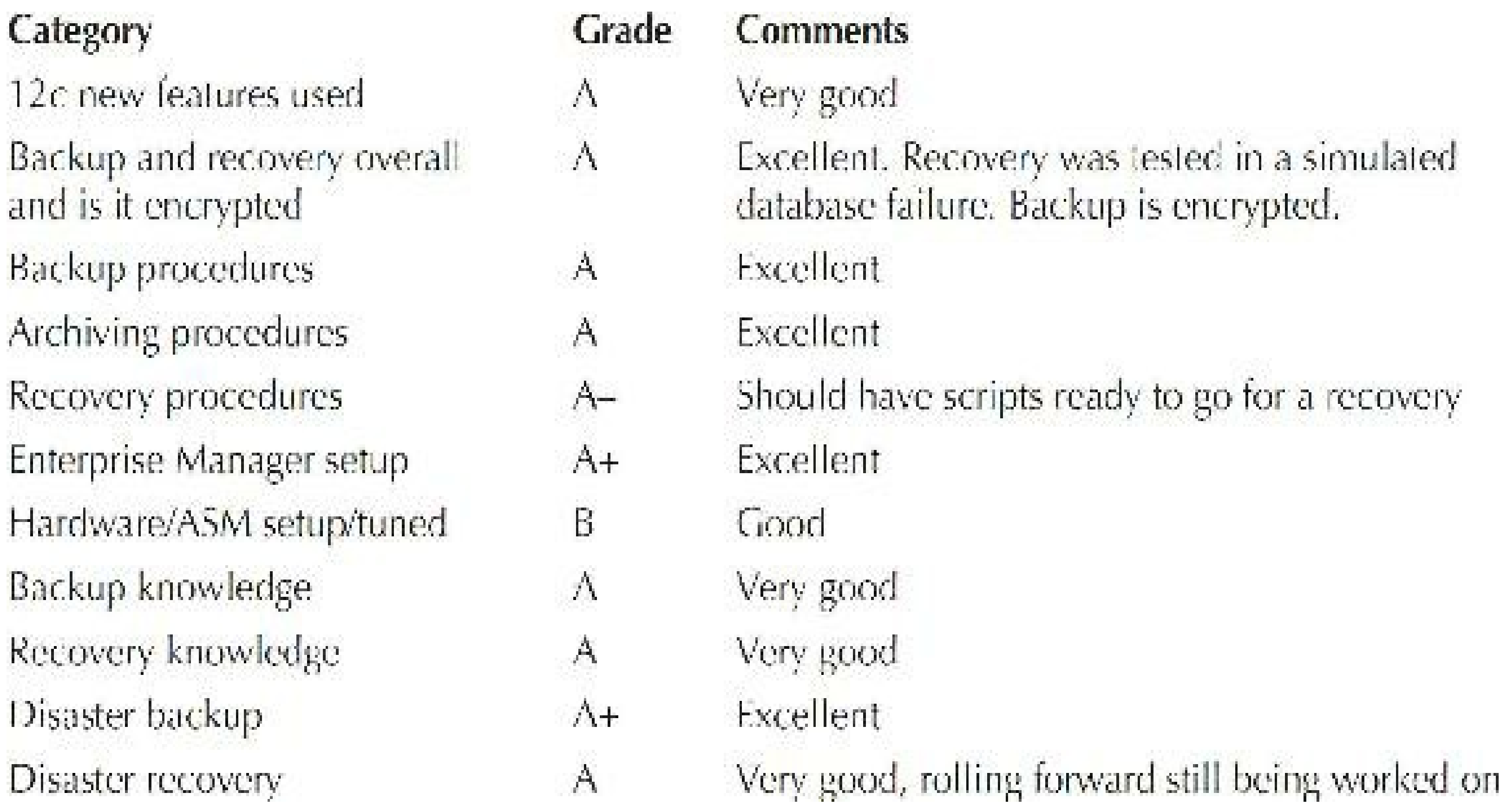
Backup- and Recovery-Related Information

The following are backup- and recovery-related questions and answers:

- Does the system require 7×24 use? **No, it is 6×24.**
- How fast will recovery need to be (on-disk backup)? **12-hour maximum.**
- Are there "standby" disks in case of failure? **No, four-hour turnaround from HP.**
- How much data is "backed up"; is it being "tape-striped" with parity? **Unknown.**
- Has the UPS been established? **Yes.**
- Are export files also taken? **No.**
- Are cold backup procedures in place? **Not applicable.**
- Are export procedures in place? **Needs improvement/Implement Data Pump compatibility for export/import control files (new in 11*g*).**
- Are hot backup procedures in place? **Excellent.**
- Is the backup encrypted? **No.**

- Is it possible to use encrypted backup to the cloud? **Yes.**
- Is the fast recovery area (FRA) sized properly? **Yes.**
- Are disaster recovery procedures in place? **Needs improvement (Data Guard suggested).**

The following is an example of some of the areas you may evaluate in a backup and recovery rating. Most Oracle DBA books evaluate features like these in greater depth. The layout should be identical to your system review.



Category	Grade	Comments
12c new features used	A	Very good
Backup and recovery overall and is it encrypted	A	Excellent. Recovery was tested in a simulated database failure. Backup is encrypted.
Backup procedures	A	Excellent
Archiving procedures	A	Excellent
Recovery procedures	A–	Should have scripts ready to go for a recovery
Enterprise Manager setup	A+	Excellent
Hardware/ASM setup/tuned	B	Good
Backup knowledge	A	Very good
Recovery knowledge	A	Very good
Disaster backup	A+	Excellent
Disaster recovery	A	Very good, rolling forward still being worked on

Naming Conventions and/or Standards and Security Information Questions

The following are naming convention, standards-related, or security-related questions and answers:

- Have you reviewed naming conventions being used? **Excellent**
- Have you checked file protections on key Oracle files? **Poor**
- Have you checked database security procedures, including info shared in the cloud? **Poor**
- Have you checked password procedures? **Poor**
- Have you reviewed the Oracle security information that exists at www.oracle.com/security and the security information that you can find at the following link: http://www.oracle.com/technetwork/topics/security/articles/index.html? **Not complete**

DBA Knowledge Rating

Having all DBAs reviewed by an impartial expert is paramount to identifying and improving their skills. Often, the primary DBA is too busy to attend training sessions or improve their skills on new versions of Oracle. Assessing DBAs helps identify their strengths and weaknesses. This process will fail if this review is used against a person. It *must* be used with the goal of identifying and improving skills.

Category	Rating
DBA knowledge overall	A
Oracle 12c new features	A
Oracle Enterprise Manager	A+
Oracle architecture/PDBs	A–
Oracle objects/memory areas	B+
Oracle internals	B+
Oracle initialization parameters	B+
Oracle query tuning	A
Oracle database tuning	A
Oracle backup	A
Oracle recovery	A
Oracle ASM/hardware	B–
Oracle utilities	A
Operating system	B+

TIP

Reviewing a DBA's ability should be done only if the review is used as a means of improving the DBA's skills. Reviewing a person is a very sensitive issue and must be done by someone who has the goal of improvement in mind first and foremost. Critical knowledge for 12c includes the ability to use pluggable databases and the In-Memory column store, and the ability to review where the public cloud might be used (if at all).

Other Items to Consider in Your TPI and System Review

As I stated earlier, my goal in this chapter is to give the most basic barometer as a starting guide.

There are many things here that may or may not be important to your specific system. Following are some items that I also think may be important to consider in the system review that you develop and the TPI that you customize for your system:

- Are you effectively using ASM in your storage architecture?
- Do you have appropriate flashback technology implemented (including flashback PDB) as a means of accelerated recovery and high availability? No query is slower than the one accessing a system that is down!
- Are statistics being collected often enough (or too often)? Are they being collected too often on tables that are generally static? Is everything automated correctly?
- Have you used AWR and ADDM (see Chapters 5 and 14 for more information) to diagnose and fix potential problems?
- Has using Enterprise Manager Cloud Control made you faster at deploying new nodes and diagnosing RAC issues?
- Do you understand how to leverage the cloud and have you *investigated* leveraging the public cloud for use/nonuse? Are you leveraging big data, encrypted cloud backups, offsite storage and developer cloud systems?
- Are you testing new hardware in the public cloud instead of first buying it?
- Have you consolidated databases to a multitenant system leveraging pluggable databases?
- Do you have a sufficient test and development system to ensure proper testing before moving code to production? Can you test in the public cloud to save time, money, and effort?
- Have you set initialization parameters effectively that need minimum settings such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, PGA_AGGREGATE_LIMIT, JAVA_POOL_SIZE, and INMEMORY_SIZE? Have you investigated the use of MEMORY_TARGET?
- Do you have an encrypted backup, or could your system potentially face downtime, causing severe delays in production performance? Once again, no query is slower than the one accessing a system that is down!
- Are you ready for the next hardware upgrade? Have you considered Real Application Testing or testing on Oracle Cloud? Have you investigated future hardware return on investment (ROI), such as Violin Memory or other flash memory arrays, Oracle Exadata, Exalogic, or Exadata Storage Expansion Rack?

Tips Review

- Measuring your EPI (Education Performance Index) can be helpful in identifying educational improvements that might be beneficial.
- Measuring your SPI (System Performance Index) can be helpful in identifying overall system improvements that might be beneficial.

- Measuring your MPI (Memory Performance Index) can be helpful in identifying potential memory allocation and usage improvements that could benefit your system, especially with 12*c* IM.
- Measuring your DPI (Disk Performance Index) can be helpful in identifying potential disk improvements that might benefit your systems, especially with PDBs and ASM.
- Measuring your TPI (Total Performance Index) can be helpful in identifying bottlenecks; it is a simple barometer of your overall system performance and may help you find areas needing improvement.
- Have your system reviewed on an annual basis by an outside party or, at the minimum, by someone inside your company.
- A system review should always include immediate action items. This ensures that the time needed for improvements will be allocated.
- Reviewing a DBA's ability should be done only if the review is used as a means of improving the DBA's skills. Reviewing a person is a very sensitive issue and must be done by someone who has the goal of improvement in mind first and foremost in mind. Critical knowledge for 12*c* includes the ability to use pluggable databases and the In-Memory column store, and the ability to review where the public cloud might be used (if at all).
- If you can't effectively monitor your own system, then contract someone who can. The cost of maintaining a database is usually far less than the cost of downtime when problems occur. With the advent of Oracle Cloud, it's easier to monitor from an outside party.
- Include 12*c* new features (covered throughout this book) in your items to review as needed.

References

Maurice Aelion, Dr. Oleg Zhooravlev, and Arie Yuster, *Tuning Secrets from the Dark Room of the DBA*.

Memory Performance Index, Disk Performance Index, Education Performance Index, Total Performance Index, MPI, DPI, EPI, SPI and TPI (Copyright TUSC/RJN 1998–2016).

Oracle Database New Features Guide, versions 11*g* and 12*c* (Oracle Corporation).

Oracle Database SQL Language Reference, versions 11*g* and 12*c* (Oracle Corporation).

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CHAPTER 16

Monitor the System Using Unix Utilities (DBA)

Part of being able to solve performance problems includes being able to use operating system utilities effectively. Using the correct utilities to find CPU, memory, and disk I/O issues is crucial to identifying where performance problems exist. Today's DBAs and system managers increasingly include performance management as part of their duties. This chapter focuses on a few key and basic commands that will help you look at Oracle. It is meant for DBAs who are not as familiar with Unix or Linux.

Basically, two main categories of activities are needed for system management. The first, accounting and monitoring, consists of tools such as accounting logs, software monitors, hardware monitors, or manual logs to monitor system usage, workload, performance, availability, and reliability. Accounting and monitoring help system administrators perform load balancing and control resource usage. The second category, performance analysis, consists of using the monitored data to determine what system tuning is required and, by predicting future workload, when upgrading is required. In a broad sense, *system performance* refers to how well the computer resources accomplish the work they are supposed to do. This chapter gives you the utilities you need to accomplish both of these objectives.

Because the system utilities are part of Unix and vary from vendor to vendor, this chapter draws its details from one vendor and makes brief mention of other vendors. Including the details from Solaris, Linux, HP-UX, and AIX would take up too much space. Oracle is dedicated to Linux, most recently with Oracle Linux with Unbreakable Enterprise Linux Kernel. Oracle also is dedicated to Solaris with the acquisition of Sun Microsystems and has announced that Exadata and Exalogic will run on both Oracle Linux and Solaris. SAP has certified a version of Oracle Linux and has also decided to certify SAP on Exadata.

Unix/Linux Utilities

This chapter focuses on tips related to Unix and Linux utilities and shell scripts that can be used to find problems as well as gather statistics for monitoring. Tips covered in this chapter include:

- Using the `sar` command to monitor CPU usage
- Using `sar` and `vmstat` to monitor paging/swapping
- Using the `sar` command to monitor disk I/O problems

- Finding the worst user on the system using the `top` command
- Using the `uptime` command to monitor the CPU load
- Using the `mpstat` command to identify CPU bottlenecks
- Combining `ps` with selected V$ views
- Using `iostat` to identify disk I/O bottlenecks
- Determining shared memory usage using `ipcs`
- Monitoring system load using `vmstat`
- Monitoring disk free space
- Monitoring network performance

Using the sar Command to Monitor CPU Usage

The `sar` command has many different switches that you can set to display different pieces of performance information. With the `-u` switch, `sar` can be used to monitor CPU utilization. The `sar` utility is an effective way to see a quick snapshot of how much the CPU is "bogged down" or utilized (100 percent is not a good thing). Run this utility on a regular basis to get a baseline for your system, enabling you to identify when your system is running poorly. The `sar` command has the following benefits:

- Provides great information that you can use for performance tuning and monitoring
- Logs to a disk file (but does not provide per-process information)
- Requires low overhead to run
- Is found on most Unix and Linux platforms

sar –u (Check for CPU Bogged Down)

With the `-u` switch, you can use `sar` to monitor CPU utilization. Of the two numbers following the switch for `sar` (in the following example the switch is `-u`), the first displays the number of seconds between `sar` readings, and the second is the number of times you want `sar` to run. Here is a sample report on HP-UX showing CPU utilization (the default):

Column	Description
%usr	Percent of CPU running in user mode
%sys	Percent of CPU running in system mode
%wio	Percent of CPU running idle with a process waiting for block I/O
%idle	Percent of CPU that is idle

```
# sar -u 10 8
                %usr     %sys      %wio      %idle
11:55:53        80        14         3          3
11:56:03        70        14        12          4
11:56:13        72        13        21          4
11:56:23        76        14         6          3
11:56:33        73        10        13          4
11:56:43        71         8        17          4
11:56:53        67         9        20          4
11:57:03        69        10        17          4

Average         73        11        13          4
```

A low %idle time could point to which processes are using the most CPU or an underpowered CPU. Use the `ps` or `top` command (discussed later in this chapter) to find a CPU-intensive job. A poorly written query requiring a large amount of disk access can also cause a large amount of CPU usage as well.

In the following `sar` output, the cause for concern is the large values being returned for %wio (waiting for block I/O) versus actual heavy CPU usage:

```
# sar -u 5 4

                %usr     %sys      %wio      %idle
14:29:58          20        20        60          0
14:30:03          17        23        60          0
14:30:08          19        14        67          0
14:30:13          22        11        67          0
Average           21        16        64          0
```

This list shows a high %wio time, pointing toward a disk contention problem. The `iostat` command (discussed later in this chapter) can be used to pinpoint disk contention.

TIP
Use the `sar -u` command to see a quick snapshot of how much work the CPU is doing and whether the CPU is overwhelmed. Run `sar` on a regular basis to get a baseline for your system so you can identify when your system is running poorly. However, at times low CPU idle time can also be an I/O issue, not a CPU issue.

Here are some things to look for in `sar`'s output:

- Low CPU idle times
- High percentage of time spent waiting on I/O or %wio > 10
- Bottlenecks with %sys > 15, which could indicate that swapping, paging, or backups are causing a bottleneck
- Abnormally high %usr, which could be due to applications not being tuned properly or CPU overutilization

The sar –d Command (Find I/O Problems)

The `sar -d` command reports the activity of block devices on the system for each disk or tape drive. This command helps identify heavily accessed disks and unbalanced disk I/O. Disk-striping software frequently can help in cases where the majority of disk access goes to a handful of disks. When a large amount of data is making heavy demands on one disk or one controller, striping distributes the data across multiple disks and controllers. When the data is striped across multiple disks, accesses to it are averaged over all the I/O controllers and disks, thus optimizing overall disk throughput. Some disk-striping software also provides support for Redundant Array of Inexpensive Disks (RAID) and the ability to keep one disk in reserve as a *hot standby* (that is, a disk that can be automatically rebuilt and used when one of the production disks fails). When thought of in this manner, RAID can be a very useful feature in terms of performance because a system that has been crippled by hard drive failure will be viewed by your user community as having pretty bad performance.

This information may seem obvious, but it is important to overall system performance. Frequently, the answer to disk performance simply rests on matching the disk architecture to system use. On Linux, the `sar -d` command does not return as much information, so you might want to use the `iostat` command instead. Here are some examples using `sar -d` to find disk I/O issues:

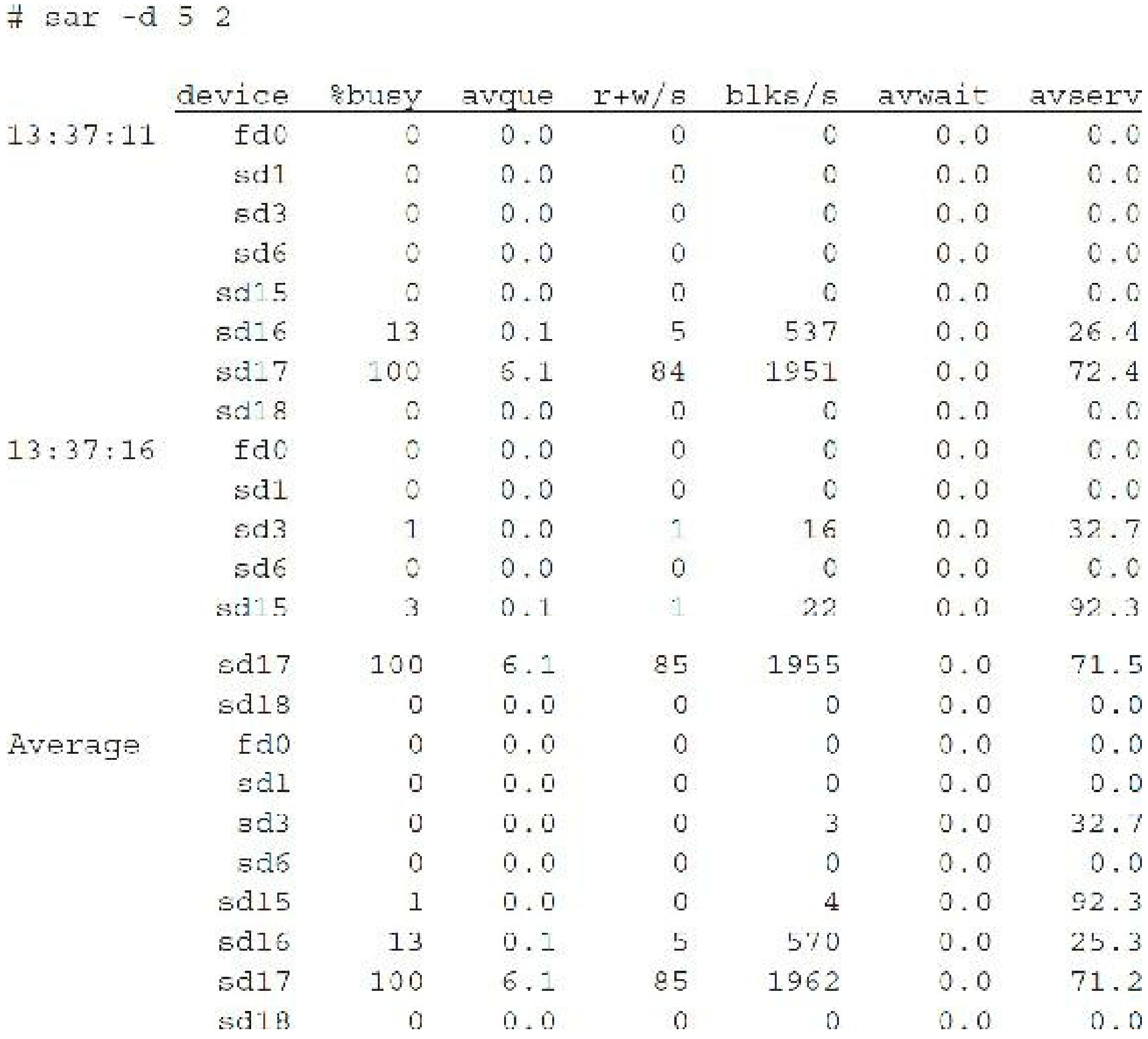
```
# sar -d

09:34:54   device    %busy   avque    r+w/s   blks/s   avwait   avserv
09:34:59   c0t6d0     0.60    0.50        1        6     3.84     5.38
           c3t6d0     0.20    0.50        1        6     3.85     3.76
           c7t0d0     0.20    0.50        4       50     2.60     0.89
           c7t0d2     8.78   21.61      270     4315    10.39     1.77
           c7t0d3     8.78   21.82      267     4273    10.77     1.80
           c7t0d4    23.15    0.50      252    13019     5.06     1.51
           c7t0d5     0.60    0.50        1       19     6.15     6.48
09:35:04   c0t6d0     2.60    0.50       16      140     5.04     1.69
           c3t6d0     0.40    0.50        1        7     1.12     9.02
           c7t0d0     1.60    1.23       10      152     6.01     5.30
           c7t0d1     2.40    1.07       10      155     5.45     6.31
           c7t0d2     0.80   19.38       15      234    10.02     1.71
           c7t0d3     0.40   21.89       12      198    10.89     1.85
           c7t0d4    24.60    0.50      274    10357     5.04     1.22
```

Things to watch for in the `sar -d` output include the following:

- %busy on a device that is greater than 50 percent
- If avwait is greater than avserv
- Unbalanced disk I/O load

Here's an example using `sar-d` that shows a disk I/O bottleneck. A high %busy and high avque indicates a disk I/O bottleneck. Consider the following output, where disk sd17 is a big problem (it is 100 percent busy). If this condition persisted, an analysis of disk sd17 should lead to a reorganization of information from sd17 to a less-used disk. The `sar` command allows two significant numerical inputs (as shown next): the first is the number of seconds between running `sar`, and the second is how many times to run it (less than 5 indicates a five-second interval and 2 indicates two repetitions).



```
# sar -d 5 2

          device  %busy   avque   r+w/s   blks/s   avwait   avserv
13:37:11    fd0       0     0.0       0        0      0.0      0.0
            sd1       0     0.0       0        0      0.0      0.0
            sd3       0     0.0       0        0      0.0      0.0
            sd6       0     0.0       0        0      0.0      0.0
            sd15      0     0.0       0        0      0.0      0.0
            sd16     13     0.1       5      537      0.0     26.4
            sd17    100     6.1      84     1951      0.0     72.4
            sd18      0     0.0       0        0      0.0      0.0
13:37:16    fd0       0     0.0       0        0      0.0      0.0
            sd1       0     0.0       0        0      0.0      0.0
            sd3       1     0.0       1       16      0.0     32.7
            sd6       0     0.0       0        0      0.0      0.0
            sd15      3     0.1       1       22      0.0     92.3

            sd17    100     6.1      85     1955      0.0     71.5
            sd18      0     0.0       0        0      0.0      0.0
Average     fd0       0     0.0       0        0      0.0      0.0
            sd1       0     0.0       0        0      0.0      0.0
            sd3       0     0.0       0        3      0.0     32.7
            sd6       0     0.0       0        0      0.0      0.0
            sd15      1     0.0       0        4      0.0     92.3
            sd16     13     0.1       5      570      0.0     25.3
            sd17    100     6.1      85     1962      0.0     71.2
            sd18      0     0.0       0        0      0.0      0.0
```

Tuning Disk-Bound Systems

Faster disks, disk cache, and flash take care of many disk-bound issues for larger customers, but I have a few points in this section for smaller customers without that luxury. Conceptually, upgrading disk systems is fairly easy. Get faster disks, get faster controllers, and get more disks. The problem is predicting how much of an improvement you can expect from a given upgrade. If the system is truly spindle bound, and the load is parallelizable such that adding more disks is practical, this route is almost always the best way to go. When a straightforward upgrade path exists, no more likely or predictable way to improve a system's I/O exists than to increase the number of disks. The problem is that a straightforward path for this sort of upgrade isn't always obvious.

For example, assume you have one state-of-the-art disk on its own controller storing sendmail's message queue, and the system has recently started to slow down. There are two ways to add a second disk effectively to a sendmail system. First, you could add the disk as its own filesystem and use multiple queues to divide the load between the disks. This upgrade will work, but it will become more difficult to maintain and potentially unreliable if it is repeated too many times. Second, you could perform a more hardware-centric solution, upgrading to either create a hardware RAID system, install a software RAID system to stripe the two disks together, or add NVRAM (*nonvolatile RAM*—retains its contents even when power is lost) to accelerate the disk's performance. With any of these solutions, upgrading the filesystem might also become necessary. None of these steps is a trivial task, and there's no way to be nearly as certain about the ultimate effect on performance with the addition of so many variables.

Obviously, you can't add disks without considering the potential effect on the I/O controller. Some systems have limits that restrict the number of controllers that can be made available to the operating system. Although I rarely push the limits of controller throughput with a small number of disks because e-mail operations are so small and random, adding so many disks on a system that you run out of chassis space in which to install controller cards is possible.

Any time a system has I/O problems, do not make the mistake of quickly dismissing the potential benefits of running a high-performance filesystem. This solution is usually inexpensive and effective, and where available, it can offer the best bang for the buck in terms of speed improvement. If I am asked to specify the hardware for an e-mail server, in situations where I have complete latitude in terms of hardware vendors, I know I can get fast disks, controllers, RAID systems, and processors for any operating system. The deciding factor for the platform then usually amounts to which high-performance file systems are supported. This consideration is that important.

If a RAID system is already in use, performance might potentially be improved by rethinking its setup. If the storage system is running out of steam using RAID 5 but has plenty of disk space, perhaps going to RAID 0+1 will improve performance and increase the box's hardware life. If the system is having problems with write bandwidth, lowering the number of disks per RAID group and, therefore, having a greater percentage of the disk space devoted to parity may help. Using some of your unused space is certainly preferable to buying a new storage system. Changing the configuration of the storage system is especially worth considering if it wasn't set up by someone who really understands performance tuning.

If a RAID system has been set up suboptimally, you may be able to improve its performance by upgrading. Vendors often provide upgrade solutions to their RAID systems that can improve their throughput, both in terms of hardware components and the software that manages the system.

Lastly, to save money, the system might have originally included insufficient NVRAM or read cache. Performance might improve dramatically if you increase the NVRAM.

You can also use `tunefs/tune2fs` to help with disk issues. (On AIX, use `chfs`.) The `tunefs/tune2fs` command lists the current characteristics of a file system (careful—some commands cannot be run on an active system, so check your documentation for more information before running these):

```
tunefs -v .../rdsk/c0txdx
```

To set *minfree* (the percentage of reserved filesystem blocks) to 5 percent, use the following command (be careful, however; setting this could increase the overhead for file writes and reduce the file system's ability to avoid fragmentation):

```
tunesfs -m 5 /dev/dsk/c2d5s0
```

To change rotational delay from 1 to 0 (generally the default set with newfs and mkfs is 0, which should make tuning this with `tunefs` unnecessary):

```
tunefs -d 0 /dev/rdsk/c0txd0
```

Refer to Chapter 3 for additional information on tuning disk I/O at the database level.

The sar –b Command (Check the Buffer Cache)

The `sar -b` command reports on the system's buffer cache activities (*not* the Oracle buffer cache). It gives you the number of transfers per second between system buffers and block devices. The main parameters to look for are as follows:

- Read cache: %rcache > 90%, indicating the potential for bad disk I/O
- Write cache: %wcache < 70%, likewise indicating the potential for bad disk I/O

```
sar -b

9:48:44      bread/s lread/s %rcache bwrit/s lwrit/s %wcache pread/s pwrit/s
09:48:49     437     422           0 404     413           2       0       0
09:48:54     604     858          30 617     630           2       0       0
09:48:59     259     451          20 431     479          10       0       0
09:49:04     676     750          10 671     633           0       0       0
09:49:09     369     577          36 473     511           7       0       0

Average      450     612          20 519     533           3       0       0
```

To look deeper into the buffer cache operation, consider a typical HP processor module. It consists of a CPU, a cache, a transaction look-aside buffer (TLB), and a coprocessor. These components are connected together with buses, and the processor module itself is connected to the system bus. The cache is a very high-speed memory unit. Typical access times are 10–20 nanoseconds (ns), compared to RAM, which is typically 80–90 ns. The cache can be accessed in one CPU cycle. Its contents and instructions and data that was recently or is anticipated to be used by the CPU are stored here. The TLB is used to translate virtual addresses into physical addresses. It’s a high-speed cache whose entries consist of pairs of recently used virtual addresses and their associated physical addresses. The coprocessor is a specialized piece of hardware that does complex mathematical numerical instructions. For memory management in Unix, *vhand* is the paging daemon. The buffer cache, as you can see from the HP example, is a pool of memory designed to decrease file access time. Here are some other noteworthy buffer cache characteristics:

- The buffer cache can have a fixed state.
- The default system uses dynamic size allocation.
- The buffer cache can increase performance of disk reads and writes.
- Data is flushed from the buffer cache by the Sync process.

The sar –q Command (Check the Run Queue and Swap Queue Lengths)

The `sar -q` command reports on the system’s run queue lengths and swap queue lengths. On Linux, it also gives the average load numbers. The `-q` switch gives the length of the run queue (runq-sz), the percentage of time the run queue was occupied (%runocc), the length of the swap queue (swpq-sz), and the percentage of time the swap queue was occupied (%swpocc); the smaller these numbers, the better. You need to compare `sar -q` to `sar -w` data to see if the runq-sz is greater than 4 or the %swpocc is greater than 5, which signals a potential issue.

```
sar -q

10:00:18 runq-sz %runocc swpq-sz %swpocc
10:00:23     0.0       0     0.0       0
10:00:28     0.0       0     0.0       0
10:00:33     0.0       0     0.0       0
10:00:38     0.0       0     0.0       0
10:00:43     1.0       5     0.0       0

Average      1.0       1     0.0       0
```

Using the sar and vmstat Commands to Monitor Paging/Swapping

A quick way to determine if any swapping activity has occurred since the system started is to issue the command `vmstat -s`. Having a non-zero value in the swp/in and swp/out columns is a good indicator of a possible problem. You can delve into more detail using the `sar` command, which you can also use to check for system paging and swapping. Depending on the system, any paging and swapping could be a sign of trouble. In a virtual memory system, paging is when users who *are not* currently active are moved from memory to disk (a small issue). Swapping is when users who *are* currently active are moved to disk due to insufficient memory (very large issue). Swapping and paging could easily take an entire book due to the depth of the subject. Simple and fast commands to get a general picture of the state of your system are covered in this chapter.

Using sar –p to Report Paging Activities

The following table describes the fields displayed with the `sar -p` command. On Linux, use `sar -B`. On AIX, use `sar -r`.

Field	Description
atch/s	Page faults per second that are satisfied by reclaiming a page currently in memory (per second); (if the field name is faults/s on Linux with a `-B`)
pgin/s	Page-in requests per second
ppgin/s	Pages paged in per second
pflt/s	Page faults from protection errors per second (illegal access to page) or "copy-on-writes"
vflt/s	Address translation page faults per second (valid page not in memory)
slock/s	Faults per second caused by software lock requests requiring physical I/O

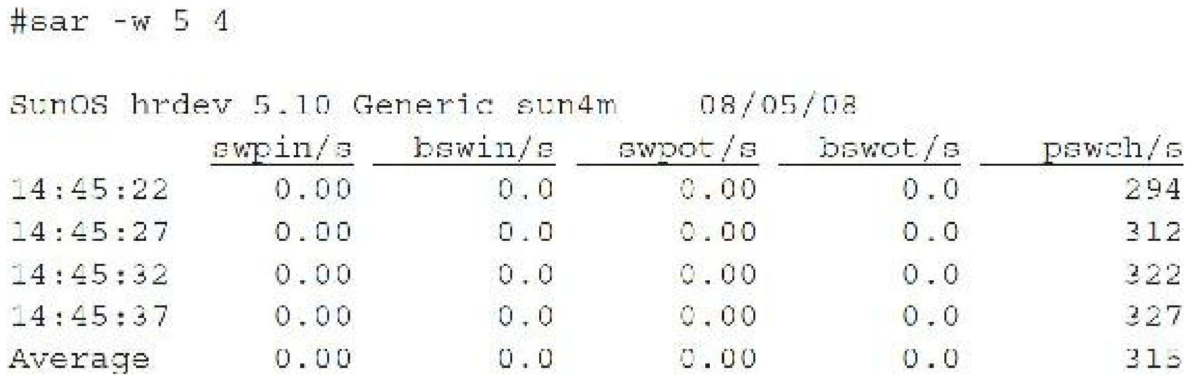
```
#sar -p 5 4

             atch/s    pgin/s   ppgin/s    pflt/s    vflt/s   slock/s
14:37:41      13.15     20.12    179.08     11.16      2.19     58.57
14:37:46      34.33     20.56    186.23      4.19      1.40     57.49
14:37:51      22.36     19.56    151.30      2.20      0.00     60.88
14:37:56      21.75     22.36    147.90      1.80      0.00     60.28
Average       27.37     20.11    161.81      7.58      8.14     60.85
```

The key statistic to look for is an inordinate number of page faults of any kind. A high value usually indicates a high degree of paging. Remember that paging is not nearly as bad as swapping, but as paging increases, swapping will soon follow. You can review the daily reports over a period of time to see if paging is steadily increasing during a specific time frame. The command `sar -p` without any time intervals shows you the paging statistics from the entire day if you have enabled periodic automatic monitoring.

Using sar –w to Report Swapping and Switching Activities

The `sar` command with the `-w` switch shows swapping activity. On Linux, use the `-w` switch. On AIX, you have only paging, not swapping. The `sar-w` command displays the swpin/s, swpot/s, bswin/s, and bswot/s fields, which are the number of transfers and number of 512-byte units transferred for swapins and swapouts (including initial loading of some programs). The field pswch/s shows context switches that occur per second. pswch/s should be less than 50. Examine swapping activity closely if swpot/s rises above 0.



```
#sar -w 5 4

SunOS hrdev 5.10 Generic sun4m    08/05/08
            swpin/s    bswin/s    swpot/s    bswot/s    pswch/s
14:45:22       0.00        0.0       0.00        0.0        294
14:45:27       0.00        0.0       0.00        0.0        312
14:45:32       0.00        0.0       0.00        0.0        322
14:45:37       0.00        0.0       0.00        0.0        327
Average        0.00        0.0       0.00        0.0        315
```

A high count for process switching points toward a memory deficiency because actual process memory is being paged. Swapping is not a problem in the preceding example.

Using sar –r to Report Free Memory and Free Swap

The following command line and output illustrate the `sar` command with the `-r` switch:

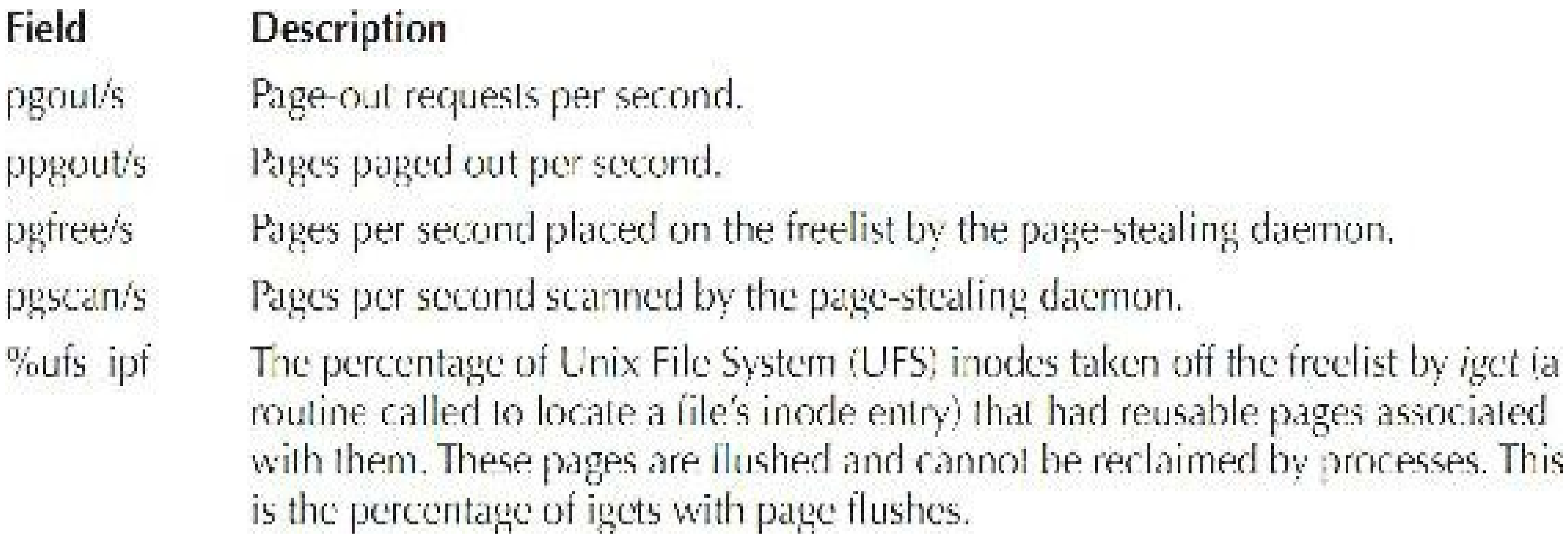
```
# sar -r 5 4

                 freemem    freeswap
14:45:21         517        1645911
14:45:26         294        1645907
14:45:36         378        1645919
14:45:41         299        1642633
Average          367        1644597
```

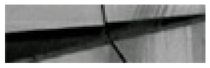
When freemem (*free memory*—listed here in 512-byte blocks) falls below a certain level, the system starts to page. If it continues to fall, the system then starts to swap out processes—a sign of a rapidly degrading system. Look for processes taking an extreme amount of memory, or else an excessive number of processes. On Linux and HP-UX, use `vmstat`.

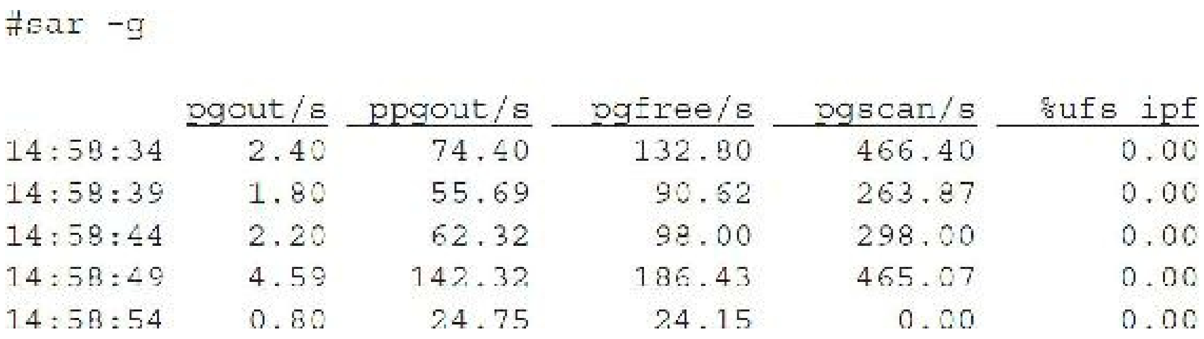
Using sar –g to Report Paging Activities

The following table describes the fields displayed with the `-g` switch. On Linux, use `sar -B`. On AIX, use `sar -r`.



Field	Description
pgout/s	Page-out requests per second.
ppgout/s	Pages paged out per second.
pgfree/s	Pages per second placed on the freelist by the page-stealing daemon.
pgscan/s	Pages per second scanned by the page-stealing daemon.
%ufs ipf	The percentage of Unix File System (UFS) inodes taken off the freelist by *iget* (a routine called to locate a file's inode entry) that had reusable pages associated with them. These pages are flushed and cannot be reclaimed by processes. This is the percentage of igets with page flushes.





```
#sar -g

            pgout/s  ppgout/s   pgfree/s   pgscan/s   %ufs ipf
14:58:34      2.40     74.40     132.80     466.40       0.00
14:58:39      1.80     55.69      90.62     263.87       0.00
14:58:44      2.20     62.32      98.00     298.00       0.00
14:58:49      4.59    142.32     186.43     465.07       0.00
14:58:54      0.80     24.75      24.15       0.00       0.00
```

A high ppgout value (pages being moved out of memory) points toward a memory deficiency.

Using sar –wpgr to Report on Memory Resources

More information about the system's utilization of memory resources can be obtained by using `sar –wpgr` (this combines the previously listed switches):

```
% sar -wpgr 5 5

07:42:30 swpin/s pswin/s swpot/s bswot/s pswch/s
          atch/s  pgin/s ppgin/s  pflt/s  vflt/s slock/s
          pgout/s ppgout/s pgfree/s pgscan/s %s5ipf
          freemem freeswp
07:42:35    0.00     0.0    0.00     0.0     504
            0.00     0.00   0.00     0.00    6.20   11.78
            0.00     0.00   0.00     0.00    0.00
           33139   183023
...
Average     0.00     0.0    0.00     0.0     515
Average     0.00     0.32   0.40     2.54    5.56   16.83
Average     0.00     0.00   0.00     0.00    0.00
Average    32926 183015
```

Check for page-outs (pgout/s means page-out requests per second; ppgout/s means page-out pages per second), and watch for their consistent occurrence. Look for a high incidence of address translation faults (vflt/s). Check for swap-outs (swpot/s). Occasional swap-outs may not be a cause for concern, as some number of them is normal (for example, inactive jobs). However, consistent swap-outs are usually bad news, indicating that the system is very low on memory and is probably sacrificing active jobs. If you find evidence of memory shortages in any of these, you can use `ps` to look for memory-intensive jobs.

TIP
Use the `sar` command to monitor and evaluate memory use and the potential need for additional memory. Paging is generally the movement of inactive processes from memory to disk. A high degree of paging is generally the predecessor to swapping. Swapping is the movement of active processes from memory to disk. If swapping starts to escalate, your system begins the downward "death spiral." Fixing memory hogs or adding memory is the correct solution.

What's a Good Idle Percentage for the CPU?

The optimum idle percentage depends on the system size and variation in time accessed. For instance, a system that is accessed with heavy CPU usage for short periods of time may have an 80 percent average CPU idle time. In contrast, a system with very small jobs, but many of them, may have the same 80 percent average CPU idle time. In 12*c*, consolidating systems by using multitenant databases usually results in the idle percentage being much higher and the heavy usage periods being much lower (by averaging all systems into one). The idle percentage is not as important as what is available when you run a job that must complete immediately (and is very important to the business). A 50-percent idle CPU may be a problem for the company with a large CPU-bound job that must complete quickly, whereas a 10-percent idle CPU may be more than enough for a company that has a very small job (requiring little CPU) that must complete quickly. Oracle generally attempts to use the entire available CPU to complete a job.

I have found it helpful to run `sar` at regularly scheduled intervals throughout the day. The overhead of running `sar` is minimal, and it can be a great help in determining what was happening on your system last week when the problem actually started occurring. You have the ability to keep information in report format for 30 days by default. The following entries in crontab produce a snapshot of the system state every 20 minutes during working hours:

```
20,40 8-17 * * 1-5 /usr/lib/sa/sa1
```

The next entry produces a report of important activities throughout the workday:

```
5 18 * * 1-5 /usr/lib/sa/sa2 -s 8:00 -e 18:01 -i 1200 -A
```

To access the report at any time, simply type **sar** with the appropriate switches and you will see output for each sampling period. For further information, see your man pages for "sar," "sa1," and "sa2."

TIP
In 12c, consolidating systems by using multitenant databases usually results in the CPU idle percentage being much higher and the heavy CPU usage periods being much lower (by averaging all systems into one). Using pluggable databases to average out the load on a single multitenant system can be very effective!

CPU Scheduler and Context Switching

The goal in tuning is to keep the CPU as busy as possible so it uses all available resources allotted to get things done faster. The five major process states are as follows:

- **SRUN** The process is running or runnable.
- **SSLEEP** The process is waiting for an event in memory or on the swap device.
- **SZOMB** The process has released all system resources except for the process table. This is

the final process state.

- **SIDL** The process is being set up via `fork` and/or `exec`.
- **SSTOP** The process has been stopped by job control or by process tracing and is waiting to continue.

The CPU scheduler handles context switches and interrupts. In multiprocessing environments, a *context switch* is when one process is suspended from execution on the CPU, its current state is recorded, and another process starts its execution. Obviously, in computer processing environments, the goal is good CPU and computer system component design in order to reduce context switch management overhead, or to have a processing load that works more efficiently and does not require too many context switches. Context switching occurs when any of the following occur:

- A time slice expires
- A process exits
- A process puts itself to sleep
- A process puts itself in a stopped state
- A process returns from user mode from a system call but is no longer the most eligible process to run
- A real-time priority process becomes ready to run

Checking Oracle CPU Utilization Within Oracle

This section explains how to examine the processes running in Oracle. V$SYSSTAT shows Oracle CPU usage for all sessions. The statistic "CPU used by this session" actually shows the aggregate CPU used by all sessions. V$SESSTAT shows Oracle CPU usage per session. You can use this view to see which particular session is using the most CPU.

For example, if you have eight CPUs, then, for any given minute in real time, you have eight minutes of CPU time available. On Windows and Unix-based systems, this can be either user time or system mode time ("privileged" mode, in Windows). If your process is not running, it is waiting. CPU utilized by all systems may, therefore, be greater than one minute per interval.

At any given moment, you know how much time Oracle has utilized *on* the system. So if eight minutes are available and Oracle uses four minutes of that time, then you know that 50 percent of all CPU time is used by Oracle. If your process is not consuming that time, then some other process is. Return to the system to discover what process is using up the CPU. Identify the process, determine why it is using so much CPU, and see if you can tune it. If the CPU_COUNT initialization parameter is manually set to 4 for an instance running on an eight-CPU system, that could also explain why it was only using up to 50 percent of the CPU resources. By default, an instance has CPU_COUNT set to the number of physical CPUs (or cores) on the server, but this parameter can be changed.

The major areas to check for Oracle CPU utilization are

- Reparsing SQL statements

- Inefficient SQL statements
- Read consistency
- Scalability limitations within the application
- Latch contention

Finding the Worst User on the System Using the top Command

The `top` command shows a continuous display of the most active processes. DBAs and operations experts often run this (or similar utilities) at the first sign of system performance issues. This display automatically updates itself on the screen every few seconds. The first lines give general system information, while the rest of the display is arranged in order of decreasing current CPU usage (the worst user is on "top"). If your system does not have `top` installed, it is commonly available from http://sunfreeware.com or various other sources on the Web. Simply do a web search for **"top program download"** and you should be rewarded with multiple locations from which to download the program. On AIX, the command is `topas`. On Solaris, both `prstat` and `top` are available.

```
# top

Cpu states:  0.0% idle, 81.0% user, 17.7% kernel,  0.8% wait,  0.5% swap
Memory: 765M real, 12M free, 318M swap, 1586M free swap

PID    USERNAME  PRI  NICE   SIZE    RES  STATE   TIME    WCPU     CPU  COMMAND
23626  psoft     -25     2   208M  4980K  cpu     1:20  22.47%  99.63%  oracle
15819  root      -15     4  2372K   716K  sleep  22:19   0.61%   3.81%  pmon
20434  oracle     33     0   207M  2340K  sleep   2:47   0.23%   1.14%  oracle
20404  oracle     33     0    93M  2300K  sleep   2:28   0.23%   1.14%  oracle
23650  root       33     0  2052K  1584K  cpu     0:00   0.23%   0.95%  top
23625  psoft      27     2  5080K  3420K  sleep   0:17   1.59%   0.38%  sqr
23554  root       27     2  2288K  1500K  sleep   0:01   0.06%   0.38%  br2.1.adm
15818  root       21     4  6160K  2416K  sleep   2:05   0.04%   0.19%  proctool
  897  root       34     0  8140K  1620K  sleep  55:46   0.00%   0.00%  Xsun
20830  psoft      -9     2  7056K  2748K  sleep   7:14   0.67%   0.00%  PSRUN
20854  psoft      -8     2   208M  4664K  sleep   4:21   0.52%   0.00%  oracle
  737  oracle     23     0  3844K  1756K  sleep   2:56   0.00%   0.00%  tnslsnr
 2749  root       28     0  1512K   736K  sleep   1:03   0.00%   0.00%  lpNet
18529  root       14    10  2232K  1136K  sleep   0:56   0.00%   0.00%  xlock
    1  root       33     0   412K   100K  sleep   0:55   0.00%   0.00%  init
```

The preceding display shows the top user to be psoft with a PID (Process ID) of 23626 (this output may be slightly different on your system). This user is using 99.63 percent of one CPU. If this output persisted for any length of time, finding out *who* this is and *what* he or she is doing would be imperative! I will show how to link this back to an Oracle user employing the `ps` command and querying the V$ views later in this chapter.

TIP

Use the `top` command to find the worst user on the system at a given point in time (the `kill` command usually follows for many DBAs). If the worst query lasts only a short period of time, it may not be a problem; but if it persists, additional investigation may be necessary.

Monitoring Tools

There are GUI monitoring tools available (Oracle Cloud Control comes to mind) on most platforms that either come bundled with the software or are available on the Internet. The Task Manager and "perfmon" are available on Windows; sdtprocess and Management Console are available for later versions of Solaris (once again http://sunfreeware.com has a plethora of free tools); nmon (within `topas` command) is available for AIX; and tools like Superdome Support Management Station (SMS), glance, and HP Servicecontrol Manager are available for HP. When using any tools, remember to manage system performance with the following guidelines:

- Measure performance continuously.
- Assess systems and applications.
- Select the tool to use.
- Monitor.
- Troubleshoot issues that arise.
- Remove bottlenecks.
- Optimize applications.
- Plan for future workloads.

You will also find it worthwhile to remember to always use basic tuning guidelines:

- Do not tune at random except to solve an emergency.
- Measure before and after you tune.
- Tune one area at a time, and only change one thing at a time.
- Always use at least two tools when possible to evaluate tuning decisions.
- Know when to say stop!

Using the uptime Command to Monitor CPU Load

The `uptime` command is an excellent utility for quickly viewing the CPU load averages for the past 1, 5, and 15 minutes. The `uptime` command also displays how long the system has been running (the *uptime*) and the number of users on the system. You want to look at the load average. This is the number of jobs in the CPU run queue for the last 1, 5, and 15 minutes. Note that this is not the percentage of CPU being used.

```
# uptime
  3:10pm  up 5 day(s), 19:04,  2 users,  load average: 2.10, 2.50, 2.20
```

I have found that a system with an average run queue of 2–3 is acceptable. If you add the following script to your cron table to run every hour, your average system load will be e-mailed to you every two hours:

```
{uptime; sleep 120; uptime; sleep 120; uptime;} | mailx -s uptime
you@company.com
```

TIP
Use `cron` and `uptime` to have your system load e-mailed to you on a regular basis. See your Unix manual for any specific syntax when using these commands.

Using the mpstat Command to Identify CPU Bottlenecks

The `mpstat` command is a tool on Solaris, Linux, and AIX that reports per-processor statistics in tabular form. When using the `mpstat` command, you set the time interval between reports and the number of times `mpstat` should repeat. Each row of the table represents the activity of one processor. The first table shows the summary of activity since boot time. Pay close attention to the smtx measurement, which indicates the number of times the CPU failed to obtain a mutex (mutual exclusion lock). Mutex stalls waste CPU time and degrade multiprocessor scaling. In the example that follows, there are four processors numbered 0–3, and a system that is heading toward disaster is displayed (this output is specific to Solaris).

```
# mpstat 10 5

CPU minf mjf xcal intr ithr csw icsw migr smtx srw sysc1 usr sys wt  idl
0   1    0   0    110  9    75  2    2    9    0   302   4   4   11  81
1   1    0   0    111  109  72  2    2    11   0   247   3   4   11  82
2   1    0   0    65   63   73  2    2    9    0   317   4   5   10  81
3   1    0   0    2    0    78  2    2    9    0   337   4   5   10  81
CPU minf mjf xcal intr ithr csw icsw migr smtx srw sysc1 usr sys wt  idl
0   2    8   0    198  12   236 113  35   203  60  1004  74  26  0   0
1   1    17  0    371  286  225 107  39   194  48  1087  60  40  0   0
2   0    22  0    194  82   267 127  38   227  49  1197  63  37  0   0
3   0    14  0    103  0    218 107  35   188  46  1075  71  29  0   0
CPU minf mjf xcal intr ithr csw icsw migr smtx srw sysc1 usr sys wt  idl
0   17   22  0    247  12   353 170  26   199  21  1263  54  46  0   0
1   8    14  0    406  265  361 165  27   200  25  1242  53  47  0   0
2   6    15  0    408  280  306 151  23   199  24  1229  56  44  0   0
3   10   19  0    156  0    379 174  28   163  27  1104  63  37  0   0
CPU minf mjf xcal intr ithr csw icsw migr smtx srw sysc1 usr sys wt  idl
0   0    19  0    256  12   385 180  24   446  19  1167  48  52  0   0
1   0    13  0    416  279  341 161  24   424  20  1376  45  55  0   0
2   0    13  0    411  290  293 144  22   354  15  931   54  46  0   0
3   0    14  0    140  0    320 159  22   362  14  1312  58  42  0   0
CPU minf mjf xcal intr ithr csw icsw migr smtx srw sysc1 usr sys wt  idl
0   23   15  0    264  12   416 194  31   365  25  1146  52  48  0   0
1   20   10  0    353  197  402 184  29   341  25  1157  41  59  0   0
2   24   5   0    616  486  360 170  30   376  20  1363  41  59  0   0
3   20   9   0    145  0    352 165  27   412  26  1359  50  50  0   0
```

TIP

If the smtx column for the `mpstat` *output is greater than 200, you are heading toward CPU bottleneck problems.*

Combining ps with Selected V$ Views

Which process is using the most CPU? The following `ps` Unix command lists the top nine CPU users (much like the `top` command in "Finding the Worst User on the System Using the top Command," earlier in this chapter):

```
ps -e -o pcpu,pid,user,args | sort -k 3 -r | tail

%CPU   PID    USER      COMMAND
0.3    1337   oracle    oraclePRD
0.3    4888   oracle    oraclePRD (LOCAL=NO)
0.4    3      root      fsflush
0.4    1333   psoft     PSRUN PTPUPRCS
0.4    3532   root      ./pmon
0.4    4932   oracle    oraclePRD (LOCAL=NO)
0.4    4941   oracle    oraclePRD (LOCAL=NO)
2.6    4943   oracle    oraclePRD (LOCAL=NO)
16.3   4699   oracle    oraclePRD
```

This command lists the %CPU used, the process ID (PID), the Unix username, and the command that was executed. If the top user was an Oracle user, you could then get the information on the process from Oracle using the queries listed next. You do this by passing the system PID obtained from the `ps` command into the following queries:

```
-- ps_view.sql
col username format a15
col osuser    format a10
col program   format a20
set verify off
select      a.username, a.osuser, a.program, spid, sid, a.serial#
from        v$session a, v$process b
where       a.paddr  =  b.addr
and         spid       = '&spid';

-- ps_sql.sql
set verify off
column username format a15
column sql_text   format a60
undefine sid
undefine serial#
accept sid prompt 'sid: '
accept serial prompt 'serial#: '
select      'SQL Currently Executing: '
from        dual;

select      b.username, a.sql_text
from        v$sql a, v$session b
where       b.sql_address       = a.address
and         b.sql_hash_value = a.hash_value
and         b.sid        = &sid
and         b.serial# = '&serial';
```

```
select    'Open Cursors:'
from      dual;

select    b.username, a.sql_text
from      v$open_cursor a, v$session b
where     b.sql_address       = a.address
and       b.sql_hash_value = a.hash_value
and       b.sid       = &sid
and       b.serial# = '&serial';
```

The following output shows an example that identifies the top CPU user utilizing the previously described commands and scripts:

```
$ ps -e -o pcpu,pid,user,args | sort -k 3 -r | tail

%CPU   PID    USER      COMMAND
0.4    650    nobody    /opt/SUNWsymon/sbin/sm_logscand
0.4    3242   oracle    ora_dbwr_DM6
0.4    3264   oracle    ora_dbwr_DMO
0.4    3316   oracle    ora_dbwr_CNV
0.4    4383   oracle    ora_dbwr_QAT
0.5    3      root      fsflush
0.8    654    root      /opt/SUNWsymon/sbin/sm_krd -i 10
1.7    652    root      /opt/SUNWsymon/sbin/sm_configd -i 10
3.6    4602   oracle    oracleCNV (LOCAL=NO)

$ sqlplus system/manager
SQL> @ps_view
Enter value for pid: 4602
```

Note that I use 4602 as the input, as it is the PID for the worst CPU from the `ps` command:

```
old   4:          and spid='&pid'
new   4:          and spid='4602'

USERNAME   OSUSER    PROGRAM                 SPID     SID     SERIAL#
DBAENT     mag       sqlplus@hrtest          4602      10         105

SQL> @ps_sql
sid: 10
serial#: 105
```

Note that I use 10 as the SID and 105 as the serial#, as they were the values retrieved in the preceding query (PS_VIEW.SQL):

```
'SQLCURRENTLYEXECUTING:'
------------------------
SQL Currently Executing:
old   5: and b.sid=&sid
new   5: and b.sid=10
old   6: and b.serial#='&serial'
new   6: and b.serial#='105'

USERNAME    SQL TEXT
DBAENT      select sum(bytes),sum(blocks) from dba_segments

'OPENCURSORS:'
Open Cursors:
old   5: and b.sid=&sid
new   5: and b.sid=10
old   6: and b.serial#='&serial'
new   6: and b.serial#='105'

USERNAME    SQL TEXT
DBAENT      select sum(bytes),sum(blocks) from dba segments
```

Putting it all together (setting headings off), you get

```
DBAENT      mag      sqlplus@hrtest       4602     10         105
SQL Currently Executing:
DBAENT      select sum(bytes),sum(blocks) from dba segments
Open Cursors:
DBAENT      select sum(bytes),sum(blocks) from dba segments
```

If you had a problem with users executing ad hoc queries and received problem queries that showed up in this result on a regular basis, you could add an automated `kill` command at the end to automate your job completely.

TIP
Combine operating system utilities with Oracle utilities to find problematic users quickly and effectively.

CPU/Memory Monitoring Tool (Task Manager) on

Windows

Task Manager can be used to monitor CPU and memory use under Windows. You can also select the columns to display in Task Manager, one of which is the process ID. However, because Oracle uses threaded processes, I did not find this feature useful in mapping to Oracle session IDs.

Using the iostat Command to Identify Disk I/O Bottlenecks

You can also use the `iostat` command to identify a disk bottleneck. The `iostat` command reports terminal and disk I/O activity, as well as CPU utilization. The first line of the output is for everything since booting the system, whereas each subsequent line shows only the prior interval specified.

Depending on the flavor of Unix, this command has several options (*switches*). The most useful switches are usually `-d` (transfers per second by disk), `-x` (extended statistics), `-D` (reads and writes per second by disk), `-t` (terminal or tty), and `-c` (CPU load). The basic format for this is:

```
iostat [option] [disk] [interval] [count]
```

Using the `-d` switch, you can list the number of kilobytes transferred per second for specific disks, the number of transfers per second, and the average service time in milliseconds. This displays I/O only; it doesn't distinguish between read and writes.

Using iostat –d for Disk Drives sd15, sd16, sd17, and sd18

The output that follows shows that sd17 is severely overloaded compared to the other drives. Moving information from sd17 to one of the other drives would be a good idea if this information is representative of disk I/O on a consistent basis.

```
# iostat -d sd15 sd16 sd17 sd18 5 5

     sd15                sd16                   sd17                 sd18
 Kps  tps  serv  Kps  tps  serv   Kps   tps   serv  Kps  tps  serv
   1    0    53   57    5   145    19     1     89    0    0    14
 140   14    16    0    0     0   785    31     21    0    0     0
   8    1    15    0    0     0   814    36     18    0    0     0
  11    1    82    0    0    26   818    36     19    0    0     0
   0    0     0    1    0    22   856    37     20    0    0     0
```

Using iostat –D

The `-D` switch reports the reads per second, writes per second, and percentage disk utilization:

```
% iostat -D sd15 sd16 sd17 sd18 5 5

          sd15                sd16                sd17                sd18
 rps   wps   util  rps   wps    util  rps   wps    util  rps   wps   util
   0     0    0.3    4     0    6.2     1     1     1.0    0     0    0.0
   0     0    0.0    0    35   90.6   237     0    97.8    0     0    0.0
   0     0    0.0    0    24   84.7   218     0    98.2    0     0    0.0
   0     0    0.0    0    34   88.3   230     0    98.2    0     0    0.0
   0     2    4.4    0    37   91.3   225     0    97.7    0     0    0.0
```

This shows that the activity on sd17 is entirely read activity, whereas the activity on sd16 is strictly write activity. Both drives are at a peak level of utilization, and I may also have I/O problems. These statistics were gathered during a backup of sd17 to sd16. Your system should never look this bad!

Using iostat –x

Using the `-x` switch reports extended disk statistics for all disks. This combines many of the switches mentioned previously.

```
extended disk statistics
disk    r/s   w/s   Kr/s    Kw/s   wait   actv   svc_t   %w   %b
fd0     0.0   0.0    0.0     0.0    0.0    0.0     0.0    0    0
sd1     0.0   0.2    0.0    23.2    0.0    0.0    37.4    0    1
sd3     0.0   1.2    0.0     8.4    0.0    0.0    31.3    0    1
sd6     0.0   0.0    0.0     0.0    0.0    0.0     0.0    0    0
sd15    0.0   1.6    0.0    12.8    0.0    0.1    93.3    0    3
sd16    0.0   5.8    0.0   315.2    0.0    0.1    25.0    0   15
sd17   73.0   2.8  941.1   117.2    0.0    6.9    90.8    0  100
sd18    0.0   0.0    0.0     0.0    0.0    0.0     0.0    0    0
```

```
extended disk statistics
disk     r/s    w/s    Kr/s     Kw/s    wait    actv    svc_t   %w   %b
fd0      0.0    0.0    0.0      0.0     0.0     0.0      0.0    0    0
sd1      0.0    0.0    0.0      0.0     0.0     0.0      0.0    0    0
sd3      0.0    0.0    0.0      0.0     0.0     0.0      0.0    0    0
sd6      0.0    0.0    0.0      0.0     0.0     0.0      0.0    0    0
sd15     0.0    0.0    0.0      0.0     0.0     0.0      0.0    0    0
sd16     0.0    4.6    0.0    257.6     0.0     0.1     26.4    0   12
sd17    69.0    3.2  993.6    179.2     0.0     7.6    105.3    0  100
sd18     0.0    0.0    0.0      0.0     0.0     0.0      0.0    0    0
```

Once again, disks sd16 and sd17 are problems that I need to investigate and monitor further.

Combining iostat –x with Logic in a Shell Script

The script in this section takes the `iostat -x` output, sorts it by the busy field (%b), and prints out the ten busiest disks for the listed interval. Some options for this script are listed here, followed by the script example and output:

- This is the `diskbusy` script built on 1/1/2009:
  - The shell is running in `!/bin/ksh`.
  - This script gets an `iostat -x` listing and sorts it by %b field.
- Change `print $10` to sort by a different field.
- Change to `iostat -x 5 5` to get a different interval and count (5 seconds/5 times).
- Change `tail` to `tail -20` to get the top 20 busiest disks only.

```
iostat -x | awk '/^disk/'
iostat -x 5 5|grep -v '^  ' |grep -v '^disk'| awk '{
          print $10 ", " $0
          }' $* |
sort -n |
awk -F, '{
          print $2
          }' |
tail
```

Running the preceding shell script, I receive this output:

```
# ./diskbusy

 disk     r/s     w/s    Kr/s    Kw/s   wait    actv    svc t    %w   %b
  sd6     0.0     0.0     0.0     0.0    0.0     0.0      0.0     0    0
  sd3     0.2     0.6     0.2     2.0    0.0     0.0      8.1     0    1
  sd6     0.1     0.0     2.0     0.0    0.0     0.0    176.3     0    1
  sd1     3.0     0.1    11.9    10.4    6.0     1.9   2555.3     3    3
  sd17    3.4     0.7    37.4    17.2    0.0     0.2     54.6     0    4
  sd16    4.1     0.8    38.6    26.0    0.0     0.6    129.5     0    6
  sd17   99.0    14.2   790.8   795.2    0.0     3.6     31.4     0   99

sd17  100.0     14.0  798.8  784.0    0.0    3.5    30.8    0  100
sd17   95.0     14.2  760.0  772.8    0.0    3.6    32.7    0  100
sd17   95.5     14.0  764.3  762.7    0.0    3.5    31.6    0  100
```

In the preceding example, I run `iostat` five times and the top ten busiest disks are displayed over all five runs. The disk sd17 is listed five times because it hits the combined top ten all five times that `iostat` is run.

TIP
Use the `sar` and `iostat` commands to find potential disk I/O problem areas. Utilizing the capabilities of shell scripting with these commands embedded can further enhance these commands.

Using the ipcs Command to Determine Shared Memory

Another helpful memory command that you can use to monitor the Oracle SGA is the `ipcs` command. The `ipcs` command displays the size of each shared memory segment for the SGA. If there is not enough memory for the entire SGA to fit in a contiguous piece of memory, the SGA will be built in noncontiguous memory segments. In the event of an instant crash, the memory might not be released. If this happens to you, note that the `ipcrm` command removes the segments (`ipcrm -m` for memory segments and `ipcrm -s` for semaphore segments). Use `ipcs -b` on Solaris and `ipcs -a` on Linux, HP-UX, and AIX.

```
# ipcs -b

Shared Memory:
m     204  0x171053d8  --rw-r-----   oracle     dba     65536
m     205  0x1f1053d8  --rw-r-----   oracle     dba 100659200
m     206  0x271053d8  --rw-r-----   oracle     dba   1740800
Semaphores:
s 393218  00000000    --ra-r-----   oracle     dba   300
```

In the preceding example, the SGA is built in three noncontiguous segments (making up the 100M+ SGA). The instance is then shut down and started with a smaller SGA (so the SGA is made up of contiguous pieces of memory). After the SGA has been lowered to 70M, I again issue the `ipcs` command:

```
# ipcs -b

Shared Memory:
m   4403 0x0f1053d8 --rw-r-----   oracle      dba 71118848
Semaphores:
s 393218 00000000   --ra-r-----   oracle      dba   300
```

Fitting the entire SGA into a single shared memory segment is generally preferable because of the overhead that can be required to track more than one segment and the time required to switch back and forth between those segments. You can increase the maximum size of a single shared memory segment by increasing the SHMMAX setting in the `/etc/system` file (or `/etc/sysctl.conf` depending on version). See the Oracle installation documentation for more specific information for your platform. On Solaris 10, the setting of the shared memory parameters moved to resource control, so if you modify the `/etc/system` file, any changes you make are ignored. Lastly, if you configure Hugepages, then the memory is pulled from a pool, and semaphores are not used. AMM requires the use of semaphores, so if you set MEMORY_TARGET (see Chapter 4 for setting the initialization parameters), you cannot use Hugepages.

TIP
Use the `ipcs` command to see if your SGA is built using multiple noncontiguous pieces of memory. A database crash can cause this to be problematic by not releasing the memory. Use the `ipcrm` command (only if the SGA pieces are not released after a database crash) to then remove the SGA pieces from memory. Do not issue the `ipcrm` command with a running database.

Using the vmstat Command to Monitor System Load

The `vmstat` command is a conglomeration of many of the other commands listed in this chapter. The advantage of `vmstat` is you get to see everything at once. The problem with `vmstat` is that you get to see everything at once and must evaluate it.

The `vmstat` command shows you these sets of processes:

r	Processes that are currently running
b	Processes that are able to run but are waiting on a resource
w	Processes that are able to run but have been swapped out

It additionally offers this information about CPU usage:

us	Percentage of user time for normal and priority processes
sy	Percentage of system time
id	Percentage of idle time

```
#vmstat 5 3

procs         memory                     page                   disk            faults            cpu
r  b  w   swap     free   re    mf   pi  po  fr  de  sr   s0 s1 s6 s9    in    sy       cs   us  sy id
19 2  0  1372992  26296  0     2   363   0   0   0   0   70 31  0  0   703  4646      662  64  36  0
23 3  0  1372952  27024  0    42   287   0   0   0   0   66 22  0  0   778  4619      780  63  37  0
16 4  0  1381236  36276  0    43   290   0   0   0   0   59 23  0  0  1149  4560     1393  56  44  0
```

Having any process in the b or w column is usually a sign of a problem system (the preceding system has a problem if this continues). If processes are blocked from running, the CPU is likely to be overwhelmed or a device is hung. The CPU idle time that is displayed in the preceding example is 0. Clearly the system is overwhelmed, as processes are blocked and people are waiting to get CPU time. On the reverse side, if the idle time is high, you may not be using your system to its full capacity (not balancing activities efficiently) or the system may be oversized for the task. I like to see an idle time of 5–20 percent for a static (not adding new users) system.

Be aware that as the amount of time the system is waiting on I/O requests increases, the amount of idle time on the CPU decreases. This is because system resources have to be expended to track those waiting I/O requests. I mention this to make sure that you take a look at the whole picture before making a decision. Eliminating an I/O bottleneck may free up significant amounts of CPU time. Time spent tracking I/O is reflected as `sy` or system time in the `vmstat` output.

In the CPU columns of the report, the `vmstat` command summarizes the performance of multiprocessor systems. If you have a two-processor system and the CPU load is reflected as 50 percent, that doesn't necessarily mean that both processors are equally busy. Rather, depending on the multiprocessor implementation, it may indicate that one processor is almost completely busy and the next is almost idle. The first column of `vmstat` output also has implications for multiprocessor systems. If the number of runnable processes is not consistently greater than the number of processors, it is less likely that you can get significant performance increases by adding more CPUs to your system.

You can also use the `vmstat` command to view system paging and swapping. The po (page-out) and pi (page-in) values indicate the amount of paging that is occurring on your system. A small amount of paging is acceptable during a heavy usage cycle but should not occur for a prolonged period of time. On most systems, paging will occur during Oracle startup.

TIP
Use the `vmstat` command to find blocked processes (users waiting for CPU time) and also for

paging or swapping problems. The `vmstat` command is a great way to see many of the `sar` options in one screen.

Monitoring Disk Free Space

Often DBAs, especially those without in-house system administrators, need to monitor disk free space closely. For example, if the filesystem containing your archived redo logs fills, all activity on your database can instantly come to a halt! What follows is a script that allows you to monitor disk free space easily; it sends an e-mail message to you if there is an issue. I would schedule this script to run about every 15 minutes. Scheduling a program to run at specified intervals is usually done through the `cron` process. You add or remove entries with the command `crontab -e`. This command should open your `crontab` file in a vi editor. Here's an example that checks disk free space every 15 minutes:

```
0,15,30,45 * * * * /usr/local/bin/diskfreespace.sh
```

This script runs the `diskfreespace.sh` program every 15 minutes, every day. For further information about scheduling programs via `cron`, refer to your system's man pages on "crontab." The command to view the man page (help page) for `crontab` is `man crontab` from the Unix prompt.

Finally, here is an example script to check file system free space on your host; it then sends an e-mail message to you if there is less than 5 percent free space. You can edit this script for more or less free space by changing `$PERC -gt 95` to, for example, `$PERC -gt 90`. This alerts you when the system has less than 10 percent free space. Note that this script is designed for Linux and will run unmodified on Solaris. To run it on HP-UX, change the command `df -kl` to `df -kP`.

```
#!/bin/sh
# script name: diskfreespace.sh
#
#
df -kl | grep -iv filesystem | awk '{ print $6" "$5}' | while read LINE; do
        PERC `echo $LINE | awk '{ print $2 }'`
        if [[ $PERC > 95 ]]; then
          echo "`date` - ${LINE} space used on `hostname` " | mailx -s "${LINE} on
`hostname` at ${CLIENT} is almost full" rich@tusc.com
        fi
        done
```

The df Command

One of the biggest and most frequent problems that systems have is running out of disk space, particularly in /tmp or /usr. There is no magic answer to the question, "How much space should be allocated to these directories?" but a good rule of thumb is between 1500K and 3000K for /tmp and roughly twice that for /usr (with larger systems these values need to be larger yet, especially for /tmp). Other filesystems should have about 5 or 10 percent of the system's available capacity. The `df` command shows the free disk space on each disk that is mounted. The `-k` option displays the information about each filesystem in columns, with the allocations in KB. On HP-UX, use `bdf`.

```
% df -k

Filesystem           kbytes    used    avail capacity  Mounted on
/dev/dsk/c0t0d0s0     38111   21173    13128    62%    /
/dev/dsk/c0t0d0s6    246167  171869    49688    78%    /usr
/proc                     0       0        0     0%    /proc
fd                        0       0        0     0%    /dev/fd
swap                 860848     632   860216     0%    /tmp
/dev/dsk/c0t0d0s7    188247   90189    79238    53%    /home
/dev/dsk/c0t0d0s5    492351  179384   263737    40%    /opt
qs:/home/prog/met     77863   47127    22956    67%    /home/met
```

From this display, you can see the following information (all entries are in KB):

Column	Description
kbytes	Total size of usable space in file system (size is adjusted by allotted head room)
used	Space used
avail	Space available for use
capacity	Percentage of total capacity used
Mounted on	Mount point

The usable space has been adjusted to take into account a 10-percent reserve head room adjustment and thus reflects only 90 percent of actual capacity. The percentage shown under capacity is, therefore, used space divided by the adjusted usable space.

The du Command

Once you know that you need space, `du` (disk usage) is a nice command to find out who's hogging the space. Here are some nice `du` commands you can use to find the sizes of current directories within a mount:

```
du -sk * | sort -n  (compute in 1K blocks)
du -sh * | sort -n  (human readable - report values in K,G, etc.)
```

Here is a version of the same command that ensures you remain in that single filesystem and don't travel to other filesystems. For instance, if you run the following in /, it will show you only the subdirectories and files in /, and won't go into other filesystems like /opt or /tmp.

```
du -xk . | sort -nr | more
```

Monitoring Network Performance with netstat

One way to check for network loading is to use `netstat` without any parameters:

```
% netstat

TCP
   Local Address        Remote Address    Swind Send-Q Rwind Recv-Q  State
-------------------- -------------------- ----- ------ ----- ------ -------
AAA1.1023            bbb2.login            8760      0  8760      0 ESTABLISHED
AAA1.listen          Cccc.32980            8760      0  8760      0 ESTABLISHED
AAA1.login           Dddd.1019             8760      0  8760      0 ESTABLISHED
AAA1.32782           AAA1.32774           16384      0 16384      0 ESTABLISHED
...
```

In the report, the important field is send-q, which indicates the depth of the send queue for packets. If the numbers in send-q are large and increasing across several of the connections, the network is probably bogged down.

Corrective Network Actions

If you suspect that there are problems with the integrity of the network itself, you must try to determine where the faulty piece of equipment is. If the problem is that the network is extremely busy, thus increasing collisions, time-outs, retransmissions, and so on, you may need to redistribute the workload more appropriately. By partitioning and segmenting the network nodes into subnetworks that more clearly reflect the underlying workloads, you can maximize overall network performance. Installing additional network interfaces in your gateway and adjusting the addressing on the gateway to reflect the new subnetworks accomplishes this. Altering your cabling and implementing some of the more advanced intelligent hubs may be needed as well. By reorganizing your network, you maximize the amount of bandwidth that is available for access to the local subnetwork. Make sure systems that regularly perform NFS mounts of each other are on the same subnetwork.

If you have an older network and are having to rework your network topology, consider replacing the older coax-based networks with the more modern twisted-pair types, which are generally more reliable and flexible. Make sure the workload is on the appropriate machine(s). Use the machine with the best network performance to do its proper share of network file service tasks. Check your network for diskless workstations. These require large amounts of network resources to boot up, swap, page, etc. With the cost of local storage decreasing constantly, it is getting harder to believe that diskless workstations are still cost-effective when compared to regular workstations. Consider upgrading the workstations so they support users locally, or at least minimize their use of the network.

If your network server has been acquiring more clients, check its memory and its kernel buffer allocations for proper sizing. If the problem is that I/O-intensive programs are being run over the network, work with the users to determine what can be done to make that requirement a local, rather than a network, one. Educate your users to make sure they understand when they are using the network appropriately and when they are being wasteful with this valuable resource.

Modifying the Configuration Information File

Solaris uses the `/etc/system` file for modification of kernel-tunable variables. The basic format is this:

```
set parameter = value
```

It can also have this format:

```
set [module:]variablename = value
```

The `/etc/system` file can also be used for other purposes (for example, to force modules to be loaded at boot time, to specify a root device, and so on). The `/etc/system` file is used for permanent changes to the operating system values. Temporary changes can be made using `adb` (Android Debug Bridge) kernel debugging tools. The system must be rebooted for the changes to become active using `/etc/system`. Once you have made your changes to this file, you can recompile to make a new Unix kernel. The command is `mkkernel -s` system. This new kernel, called `vmunix.test`, is placed in the `/stand/build` directory. Next, you move the present `stand/system` file to `/stand/system.prev`; then you can move the modified file `/stand/build/system` to `/stand/system`. Then you move the currently running kernel `/stand/vmunix` to `/stand/vmunix.prev`, and then move the new kernel, `/stand/build/vmunix.test`, into place in `/stand/vmunix` (i.e., `mv /stand/build/vmunix.test /stand/vmunix`). The final step is to reboot the machine to make your changes take effect.

Other Factors That Affect Performance

Good performance is difficult to define. Two common, but different and not necessarily equivalent, measures are used for performance. *Response time* is the time between the instant the user presses the enter key and the time the system provides a response. *Throughput* is the number of transactions accomplished in a fixed period of time. Of the two measures, throughput is the better measure of how much work is actually getting accomplished. Response time is more visible and, therefore, used more frequently; it is a better measurement for meeting the system's business objectives. Some people don't look at everything when tuning. Remember to check all of these:

- **All hardware** Are the CPUs fast enough and are there enough of them? How much memory is there; is it enough?
- **Operating system and application software** Is the system configured correctly for the current environment?
- **People** Are people trained sufficiently on the system and applications to optimize their productivity?
- **Changes** What changes in workload and user requirements can be expected to occur?

A resource is a bottleneck if the size of a request exceeds the available resource. A *bottleneck* is a limitation of system performance due to the inadequacy of the hardware or software component or the system's organization.

Tuning a CPU System

- Upgrade to faster or more processors.
- Upgrade the system with a larger data/instruction cache.
- Spread applications across multiple systems and disks.
- Run long batch jobs during off-peak hours whenever possible.
- `nice` (a command that changes the priority of a process) unimportant applications.
- Lock frequently used processes in memory.
- Turn off system accounting.
- Optimize the applications.

Tuning Memory-Bound Systems

- Add physical memory.
- Add flash.
- Use diskless workstations rather than X-terms.
- Reduce MAXDSIZ.
- Reduce the use of memory locking.
- Identify programs with memory leaks.
- Tune the applications.
- Reduce the size of the kernel drivers and subsystems.
- Reduce the size of the buffer cache.

Disk Tuning

- Add disk drives.
- Add disk channels.
- Use faster disks or add flash.
- Use striping.
- Use mirroring.
- Balance I/O across multiple spindles.
- Dedicate a disk section to an application.
- Use raw disk I/O.
- Increase the system buffer cache.
- Increase the kernel table sizes.
- Use the `tunefs` and `tune NFS` commands.

Volume Manager Factors That Can Affect Performance

- File system parameters
- Fragmentation
- Mirroring
- Scheduling
- Spindles
- Strictness
- Striping
- Workload
- Work type

Other Sources to Improve Performance

Another tool worth investigating is the Oracle Cluster Health Monitor (CHM). You can use it to track operating system resources on each node. CHM tracks every process and device level continuously. You can set thresholds, which when they are hit, set off an alert. Historical information can also be replayed. For more information see www.oracle.com/technetwork/database/enterprise-edition/ipd-overview-130032.pdf.

Oracle ORION Calibration Tool is another tool that you can use to create a representative workload that stresses a storage array in the same manner as your production application. Orion issues I/Os against raw disks using the same libraries an Oracle database would issue. It can also help you fine-tune the storage array for a production application. For more information see https://docs.oracle.com/database/121/TGDBA/pfgrf_iodesign.htm#TGDBA015.

Lastly, please see My Oracle Support (Metalink) Note 224176.1 for additional information on using operating system commands to diagnose Oracle Performance issues.

Tips Review

- Use the `sar -u` command to see a quick snapshot of how much work the CPU is doing and whether the CPU is overwhelmed. Run `sar` on a regular basis to get a baseline for your system so you can identify when your system is running poorly. However, at times low CPU idle time can also be an I/O issue, not a CPU issue.
- Use the `sar` command to monitor and evaluate memory use and the potential need for additional memory. *Paging* is generally the movement of inactive processes from memory to disk. A high degree of paging is generally the predecessor to swapping. *Swapping* is the movement of active processes from memory to disk. If swapping starts to escalate, your system begins the downward "death spiral." Fixing memory hogs or adding memory is the correct solution.
- In 12*c*, consolidating systems by using multitenant databases usually results in the CPU idle percentage being much higher and the heavy CPU usage periods being much lower (by averaging all systems into one). Using pluggable databases to average out the load on a single multitenant system can be very effective!
- Use the `top` command to find the worst user on the system at a given point in time. (the `kill` command usually follows for many DBAs). If the worst query lasts only a short period of time, it may not be a problem; but if it persists, additional investigation may be necessary.
- Use `cron` and `uptime` to have your system load e-mailed to you on a regular basis. See your Unix manual for any specific syntax when using these commands.
- If the smtx column for the `mpstat` output is greater than 200, you are heading toward CPU bottleneck problems.
- Combine operating system utilities with Oracle utilities to find problematic users quickly and effectively.
- Use the `sar` and `iostat` commands to find potential disk I/O problem areas. Utilizing the capabilities of shell scripting with these commands embedded can further enhance these commands.
- Use the `ipcs` command to see if your SGA is built using multiple noncontiguous pieces of memory. A database crash can cause this to be problematic by not releasing memory. Use the `ipcrm` command (only if the SGA pieces are not released after a database crash) to then remove the SGA pieces from memory. Do *not* issue the `ipcrm` command with a running database.
- Use the `vmstat` command to find blocked processes (users waiting for CPU time) and also for paging or swapping problems. The `vmstat` command is a great way to see many of the `sar`

options in one screen.

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APPENDIX A

Key Initialization Parameters (DBA)

Oracle 12*c* Release 2 has 412 different documented and 4237 different undocumented initialization (`init.ora/spfile.ora`) parameters. This means you have a total of 4649 initialization parameters to play with; you can do a `count(*)` of X$KSPPI for the total number of parameters both documented and undocumented (you need to be SYS to access the X$ tables). A count of V$PARAMETER gives you a count of only the documented parameters. When I refer to the undocumented parameters, I am referring to parameters that start with an underscore (_), although some of them are actually even documented. There are also several parameters that I call documented (no "_" in front of them), but they are not really documented, only externalized or available for use, usually for backward compatibility. Even these numbers vary slightly on different versions of Oracle and platforms. The initialization parameters vary (in both name and number) according to the database version and release used. Run the queries listed in this appendix (accessing the V$PARAMETER view and the X$KSPPI table) on your version of the database to get the number of parameters and details for your specific version.

Tips covered in this appendix include the following:

- Desupported and deprecated initialization parameters
- Top 25 documented initialization parameters with descriptions and suggested settings
- Top 20 documented initialization parameters that you better not forget (option dependent)
- Top 13 undocumented initialization parameters (Shhh!)
- Bonus 11 undocumented initialization parameters (mostly Exadata)
- Complete listing of documented initialization parameters (412 in 12*c*R2)
- Query for undocumented initialization parameters (4237 in 12*c*R2)

Since every system is set up differently, my top 25 may not be the same as your top 25 (so feel free to write in this book as if it were yours). Hopefully, this appendix will give you a place to start until someone writes the 1000-page book on *all* of the initialization parameters. Please refer to Chapter 4 for a detailed look at the most important initialization parameters.

Obsoleted/Desupported Initialization Parameters

The following are *some* of the Oracle 12*c*R2 obsoleted/desupported initialization parameters (query V$OBSOLETE_PARAMETER for the full list of 154 obsolete parameters). Obsolete means these parameters are gone, although they sometimes become undocumented parameters, which means that they have an underscore (_) in front of them.

- DDL_WAIT_FOR_LOCKS
- DRS_START
- GC_FILES_TO_LOCKS
- DB_BLOCK_LRU_LATCHES (undocumented parameter with default of 8)
- _KGL_LATCH_COUNT (shows as both obsolete and undocumented; default of 0)
- MAX_COMMIT_PROPAGATION_DELAY
- PLSQL_NATIVE_LIBRARY_DIR
- PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT
- ROW_LOCKING (undocumented parameter with default of ALWAYS)
- SQL_VERSION

Deprecated Initialization Parameters

The following are Oracle 12*c*R2 deprecated initialization parameters. You can use these for backward compatibility, but they are probably going away in the future. To list the deprecated parameters for a given version, run the following SQL statement (note that 23 records were returned for this query in 12*c*R2, versus 26 in 12*c*R1), although some of these were deprecated in the past as noted in the list):

```
select name
from   v$parameter
where  isdeprecated = 'TRUE';
```

- ACTIVE_INSTANCE_COUNT
- BACKGROUND_DUMP_DEST (replaced in 11.1 by DIAGNOSTIC_DEST)
- BUFFER_POOL_KEEP (replaced in 9*i* with DB_KEEP_CACHE_SIZE)
- BUFFER_POOL_RECYCLE (replaced in 9*i* with DB_RECYCLE_CACHE_SIZE)
- COMMIT_WRITE (as of 12.2, use COMMIT_LOGGING and COMMIT_WAIT)
- CURSOR_SPACE_FOR_TIME (as of 11.1)
- FAST_START_IO_TARGET (replaced in 9*i* with FAST_START_MTTR_TARGET)
- INSTANCE_GROUPS (as of 11.1)

- LOCK_NAME_SPACE (as of 10.1)
- LOG_ARCHIVE_START (as of 11.2)
- PARALLEL_ADAPTIVE_MULTI_USER (as of 12.2)
- PLSQL_DEBUG (as of 11.1)
- PLSQL_V2_COMPATIBILITY (as of 11.1)
- RDBMS_SERVER_DN (as of 12.2)
- REMOTE_OS_AUTHENT (as of 11.1)
- RESOURCE_MANAGER_CPU_ALLOCATION (as of 11.1)
- SEC_CASE_SENSITIVE_LOGON (as of 12.1)
- SERIAL_REUSE (as of 10.2)
- SQL_TRACE (as of 10.2)
- STANDBY_ARCHIVE_DEST (as of 11.1)
- USER_DUMP_DEST (as of 11.1, replaced by DIAGNOSTIC_DEST)
- UTL_FILE_DIR (as of 12.1)

Top 25 Initialization Parameters

The following list is *my* list of the top 25 most important initialization parameters, in order of importance. Your top 25 may vary somewhat from my top 25 because everyone has a unique business, unique applications, and unique experiences.

1. **MEMORY_TARGET** This is the initialization parameter setting for all of the memory allocated to *both* the PGA and SGA combined (new in as of 11*g*). Setting MEMORY_TARGET enables Automatic Memory Management, so Oracle allocates memory for you based on system needs, but you can also set minimum values for key parameters. MEMORY_TARGET is used for everything that SGA_TARGET was used for but now additionally includes the PGA (especially important as MEMORY_TARGET now includes the important area PGA_AGGREGATE_TARGET). Important parameters such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, LARGE_POOL_SIZE, and JAVA_POOL_SIZE are all set automatically when you set MEMORY_TARGET. Setting minimum values for important initialization parameters in your system is also a *very* good idea.
2. **MEMORY_MAX_TARGET** This is the maximum memory allocated for Oracle and the maximum value to which MEMORY_TARGET can be set.
3. **DB_CACHE_SIZE** Initial memory allocated to data cache or memory used for data itself. This parameter doesn't need to be set if you set MEMORY_TARGET or SGA_TARGET, but setting a value for this as a minimum setting is a good idea. Your goal should always be toward a memory resident database or at least toward getting all data that will be queried in memory.

4. **SHARED_POOL_SIZE** Memory allocated for data dictionary and for SQL and PL/SQL statements. The query itself is put in memory here. This parameter doesn't need to be set if you set MEMORY_TARGET, but setting a value for this as a minimum is a good idea. Note that SAP recommends setting this to 400M. Also note that the Result Cache gets its memory from the shared pool and is set with the RESULT_CACHE_SIZE and RESULT_CACHE_MODE (FORCE/AUTO/MANUAL) initialization parameters. Lastly, an important note since 11*g* is that this parameter now includes some SGA overhead (12M worth) that it previously did not (in 10*g*). Set this 12M higher than you did in 10*g*!
5. **INMEMORY_SIZE** The In-Memory column store resides in this area, which is separate from the buffer cache used to store data in memory. Tables, tablespaces, partitions, and other objects can have single columns stored in this memory area in a compressed fashion. This allows for much faster analytics (like summing an individual column). Oracle builds indexes to make this even faster based on ranges of values. Also, INMEMORY_QUERY should be set to ENABLED (the default). Additional INMEMORY settings are described in Chapter 4.
6. **SGA_TARGET** If you use Oracle's Automatic Shared Memory Management, this parameter is used to determine the size of your data cache, shared pool, large pool, and Java pool automatically (see Chapter 4 for more information). Setting this to 0 disables it. This parameter doesn't need to be set if you set MEMORY_TARGET, but you may want to set a value for this as a minimum setting for the SGA if you've calibrated it in previous versions. The SHARED_POOL_SIZE, LARGE_POOL_SIZE, JAVA_POOL_SIZE, and DB_CACHE_SIZE are all set automatically based on this parameter (or MEMORY_TARGET if used). INMEMORY_SIZE is also included in this number.
7. **PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT** The _TARGET is a soft memory cap for the total of all users' PGAs. This parameter doesn't need to be set if you set MEMORY_TARGET, but setting a value as a minimum setting is a good idea. Note that SAP specifies to set this to 20 percent of available memory for OLTP and 40 percent for OLAP. The _LIMIT sets the upper limit that is allowed (the hard memory cap).
8. **SGA_MAX_SIZE** Maximum memory that SGA_TARGET can be set to. This parameter doesn't need to be set if you set MEMORY_TARGET, but you may want to set a value if you use SGA_TARGET.
9. **OPTIMIZER_MODE** FIRST_ROWS, FIRST_ROWS_*n*, or ALL_ROWS. Although RULE/CHOOSE are definitely desupported and obsolete and people are often scolded for even talking about it, I was able to set the mode to RULE in 11*g*R2. Consider the following error I received when I set OPTIMIZER_MODE to a mode that doesn't exist (SUPER_FAST):
   ```
   SQL> alter system set optimizer_mode=super_fast

   ERROR:
   ORA-00096: invalid value SUPER_FAST for parameter optimizer_mode, must be from
   among first_rows_1000, first_rows_100, first_rows_10, first_rows_1, first_rows,
   all_rows, choose, rule
   ```
10. **SEC_MAX_FAILED_LOGIN_ATTEMPTS** If the user fails to enter the correct password after this many tries (new as of 11*g*) the server process drops the connection and the server process is terminated. The default is 3 (consider increasing this value for *less* secure systems). A similar parameter in my top 25 list in the prior edition included

SEC_CASE_SENSITIVE_LOGON, which was new as of 11*g*, but is deprecated as of 12.1. Be careful if you're still using this parameter in 11*g* (fix case issues with passwords by ensuring passwords can be lower, upper, or mixed case before you upgrade to 12*c*!).

11. **CURSOR_SHARING** Converts literal SQL to SQL with bind variables, reducing parse overhead. The default is EXACT. Consider setting it to FORCE after research (see Chapter 4 for more information).
12. **OPTIMIZER_USE_INVISIBLE_INDEXES** The default is FALSE to ensure invisible indexes are *not* used by default (new as of 11*g*). Set this parameter to TRUE to use *all* of the indexes and to check which ones might have been set incorrectly to be invisible; this could be a helpful tuning exercise, or it could also bring the system to a halt, so only use it in development.
13. **OPTIMIZER_USE_PENDING_STATISTICS** The default is FALSE to ensure pending statistics are *not* used, whereas setting this to TRUE enables all pending statistics to be used (new as of 11*g*).
14. **OPTIMIZER_INDEX_COST_ADJ** Coarse adjustment between the cost of an index scan and the cost of a full table scan. Set between 1 and 10 to force index use more frequently. Setting this parameter to a value between 1 and 10 pretty much guarantees index use, however, even when not appropriate, so be careful because it is highly dependent on the index design and implementation being correct. Please note that if you are using Oracle Applications 11*i*, setting OPTIMIZER_INDEX_COST_ADJ to any value other than the default (100) is not supported (see Metalink Note 169935.1). I've seen a benchmark where this was set to 200. Also, see bug 4483286. SAP suggests that you *not* set it for OLAP, but set it to 20 for OLTP.
15. **DB_FILE_MULTIBLOCK_READ_COUNT** For full table scans to perform I/O more efficiently, this parameter reads the given number of blocks in a single I/O. The default value is 128 in 11*g*R2, but it is usually noted *not* to change this from the default.
16. **LOG_BUFFER** Server processes making changes to data blocks in the buffer cache generate redo data into the log buffer. SAP says to use the default, whereas Oracle Applications sets it to 10M. I've seen benchmarks with it set over 100M.
17. **DB_KEEP_CACHE_SIZE** Memory allocated to the keep pool or an additional data cache that you can set up outside the buffer cache for very important data that you don't want pushed out of the cache.
18. **DB_RECYCLE_CACHE_SIZE** Memory allocated to a recycle pool or an additional data cache that you can set up outside the buffer cache and in addition to the keep cache described in item 17. Usually, DBAs set this up for ad hoc user query data with poorly written queries.
19. **OPTIMIZER_USE_SQL_PLAN_BASELINES** The default is TRUE, which means Oracle uses these baselines if they exist (new as of 11*g*). Note that Stored Outlines are deprecated (discouraged but they still work) in 11*g*, as they are replaced with SQL Plan Baselines.
20. **OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES** The default is FALSE, which means that Oracle does not capture them by default, but if you create some, it will use them as stated in the previous parameter (new as of 11*g*).
21. **LARGE_POOL_SIZE** Total blocks in the large pool allocation for large PL/SQL and a few other Oracle options less frequently used.

22. **STATISTICS_LEVEL** Used to enable advisory information and optionally keep additional OS statistics to refine optimizer decisions. TYPICAL is the default.
23. **JAVA_POOL_SIZE** Memory allocated to the JVM for Java stored procedures.
24. **JAVA_MAX_SESSIONSPACE_SIZE** Upper limit on memory that is used to keep track of the user session state of Java classes.
25. **OPEN_CURSORS** Specifies the size of the private area used to hold (open) user statements. If you get an "ORA-01000: maximum open cursors exceeded," you may need to increase this parameter, but make sure you are *closing* cursors that you no longer need. Prior to 9.2.0.5, these open cursors were also cached and, at times, caused issues (ORA-4031) if OPEN_CURSORS was set too high. As of 9.2.0.5, SESSION_CACHED_CURSORS now controls the setting of the PL/SQL cursor cache. Do *not* set the parameter SESSION_CACHED_CURSORS as high as you set OPEN_CURSORS, or you may experience ORA-4031 or ORA-7445 errors. SAP recommends setting this to 2000; Oracle Applications has OPEN_CURSORS at 600 and SESSION_CACHED_CURSORS at 500.

TIP
Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly before implementing those changes in a production environment.

Top 20 Initialization Parameters Not to Forget

This section details some other important initialization parameters. However, these parameters may be important only in certain cases or only if you are using a certain feature or version of Oracle:

1. **CONTROL_FILES** The location of your control files. You should have at least three copies.
2. **COMPATIBLE** Set this to the correct version, or you'll miss things in the new version. Set to at least 12.2.0.0.0 for 12cR2.
3. **OPTIMIZER_FEATURES_ENABLE** If this is not set, you are missing out on new features. My 12.2 system had this set to 12.2.0.1, but the version that I was on was 12.2.0.0.2.
4. **OPTIMIZER_ADAPTIVE_FEATURES** The default is TRUE. You should not change this unless you want to turn this off (not advisable). Two related parameters are OPTIMIZER_ADAPTIVE_REPORTING_ONLY, which is set to FALSE by default and used to only report on Adaptive Use (for testing). OPTIMIZER_INMEMORY_AWARE should also stay at the default of TRUE when using INMEMORY.
5. **AUDIT_TRAIL** The default is set to DB in 12*c*R2. This parameter enables auditing for many major commands, including CREATE, ALTER, GRANT, and AUDIT.
6. **DIAGNOSTIC_DEST** Trace, Alert, and Core Dump files are now in a new location. The DIAGNOSTIC_DEST specifies the root directory where these files are located. A basic

example on how this works is to set the DIAGNOSTIC_DEST to a location (/u01/app/oracle), for example. The corresponding locations for the dump files become *DIAGNOSTIC_DEST*\DIAG\RDBMS\*dbname**instname**trace* (note that I have PDBs):

- background_dump_dest = /u01/app/oracle/diag/rdbms/cdb1/cdb1/trace
- user_dump_dest = /u01/app/oracle/diag/rdbms/cdb1/cdb1/trace
- core_dump_dest = /u01/app/oracle/diag/rdbms/cdb1/cdb1/cdump
- Alert files go to /u01/app/oracle/diag/rdbms/cdb1/cdb1/cdump

7. **UNDO_MANAGEMENT** Set this to AUTO (default) for automatic undo management.
8. **UNDO_TABLESPACE** Set this to the tablespace to use for undo management (UNDOTBS1 is the default).
9. **UNDO_RETENTION** The UNDO retention time in seconds (900 is the default).
10. **SPFILE** This gives the location of the binary SPFILE used for startup. You can create a readable PFILE with the command "`CREATE PFILE='`*`path_and_name`*`' FROM SPFILE='`*`path and name`*`';`" and you can create an SPFILE from a PFILE or from MEMORY. You can also do a *startup* (using the SPFILE) or do a `startup pfile=`... to use a given PFILE (`initSID.ora` or any name you specify). The SPFILE is in the ORACLE_HOME\dbs directory. Chapter 4 has additional information.
11. **DB_BLOCK_SIZE** Default block size for the database. A smaller block size reduces contention by adjacent rows, but a larger block size lowers the number of I/Os needed to pull back more records. A larger block size also helps in range scans where the blocks desired are sequentially stored. An 8K block size is used for most applications and is the default.
12. **CLUSTER_DATABASE** You must set this to FALSE for single instance. With pluggable databases, there are now CDB_CLUSTER and CDB_CLUSTER_NAME parameters.
13. **UTL_FILE_DIR** Set to use the UTL_FILE package. Note that in 11*g*, the UTL_FILE package no longer opens a file if it is a symbolic link (created to close a known security hole). This parameter is deprecated in 12*c* and is unset (try to move away from this).
14. **LOG_CHECKPOINT_INTERVAL** Checkpoint frequency (in OS blocks—most OS blocks are 512 bytes) at which Oracle performs a database write of all dirty (modified) blocks to the datafiles in the database. Oracle also performs a checkpoint if more than one-quarter of the data buffers are dirty in the db cache and also on any log switch. The LGWR (log writer) also updates the SCN in the control files and datafiles with the SCN of the checkpoint.
15. **FAST_START_MTTR_TARGET** Bounds time to complete a crash recovery. This is the time (in seconds) that the database takes to perform crash recovery of a single instance. If you set this parameter, LOG_CHECKPOINT_INTERVAL should *not* be set to 0. If you don't set this parameter, you can still see your estimated MTTR (mean time to recovery) by querying V$INSTANCE_RECOVERY for ESTIMATED_MTTR.
16. **RECOVERY_PARALLELISM** Recover using the Parallel Query option for a faster recovery.
17. **MAX_SHARED_SERVERS** Upper limit on shared servers when using shared servers.
18. **LICENSE_MAX_SESSIONS and LICENSE_MAX_USERS** These limit concurrent and

named users (default is 0).

19. **LICENSE_SESSIONS_WARNING** Here, you specify at which session+1 you get a license warning (default is 0).
20. **CELL_OFFLOAD_PROCESSING** The default is TRUE (several other CELL parameters to consider include CELL_OFFLOAD_COMPACTION, CELL_OFFLOAD_DECRYPTION, CELL_OFFLOAD_PARAMETERS, CELL_OFFLOAD_PLAN_DISPLAY, and CELL_OFFLOAD_PROCESSING), which means that Smart Scans are set to be ON for Exadata (if you are using it). (*Exadata only*.)

TIP
Oracle includes some excellent options. Unfortunately, some of them do not work unless you have the initialization parameter set correctly.

Top 13 Undocumented Initialization Parameters (As I See It)

The following list is *my* list of the top 13 undocumented initialization parameters in order of importance. Your top 13 may vary somewhat, depending on your need for one of these parameters. Although the following warning describes well the risks associated with using these parameters, I note that the fastest RAC TPC (Transaction Processing Council) benchmark uses 17 undocumented parameters, as do many of the TPC benchmarks that I've seen.

CAUTION
These 13 parameters are not supported by Oracle, and I do not recommend using them on a production system. Use them only if directed by Oracle Support and if you have thoroughly tested them on your crash-and-burn system (and your closest friend has been using them for years). Undocumented initialization parameters can lead to database corruption (although some of them can get your database back up when it becomes corrupted).

1. **_ALLOW_RESETLOGS_CORRUPTION** This parameter saves you when you have corrupted redo logs. It allows the database to open with the datafiles at different SCN synchronization levels. This means some datafiles may contain changes that other datafiles do not (like the RBS or UNDO tablespace). This parameter may allow you to get to your data, but there is no easy way to determine if the data that is available after using this parameter is logically consistent. Regardless of data consistency, the DBA has to rebuild the database afterward. Failure to do so results in multiple ORA-600 errors occurring within the database at a later time.

2. **_CORRUPTED_ROLLBACK_SEGMENTS** Setting this parameter can be a means of last resort when you have corrupted ROLLBACK segments, which you can list with this parameter to be skipped. The _CORRUPTED_ROLLBACK_SEGMENTS parameter can force the database open after a failed recovery, but at a very high cost. _CORRUPTED_ROLLBACK_SEGMENTS allows the database to open by assuming every transaction in the ROLLBACK segments is a complete, committed transaction. This leads to logical corruption throughout the database and can easily corrupt the data dictionary. An example would be where you transfer money from one bank to another. The transaction would only be complete if you can verify that all parts of it are complete. In Oracle, when creating a table, think of all the individual dictionary objects that are updated: fet$, uet$, tab$, ind$, col$, etc. By setting this parameter, you allow table creation to succeed, even if only fet$ was updated, but not uet$, or even if tab$ was updated, but not col$. Use it when you have no other means of recovery and export/import/rebuild soon after.

CAUTION
These first two parameters do not always work or may corrupt the database so badly that you cannot perform once the database is open. If they are used and do not work, then Oracle Support cannot do anything to salvage the database if the DBA breaks down and calls Support, but the DBA can do several things before using these parameters that will allow other recovery methods to be used afterward. So if you must use these parameters, please ensure that you use them with the help of Oracle Support. One good reason to use Oracle Support in this effort is the fact that the _ALLOW_RESETLOGS_CORRUPTION parameter is problematic, often requiring an event to be set as well, to get the database open.

3. **_HASH_JOIN_ENABLED** Enables/disables hash joining if you have the memory needed. The default value is TRUE.
4. **_IN_MEMORY_UNDO** Makes in-memory undo for top-level transactions (Oracle's IMU really messed up my block-level tuning presentation as blocks in memory became more complex). The default is TRUE. Some applications have you set this to FALSE, so please check your application carefully for this parameter. This is one of the things that makes Oracle fast, so be careful changing this parameter!
5. **_TRACE_FILES_PUBLIC** This parameter allows users to see the trace output without giving them major privileges elsewhere. The default is FALSE; both Oracle and SAP set this to TRUE.
6. **_FAST_FULL_SCAN_ENABLED** This allows fast full index scans if only the index is needed. The default is TRUE, but Oracle Applications often recommends this be set to FALSE.
7. **_KSMG_GRANULE_SIZE** This is the granule size multiple for SGA granule pieces of memory such as SHARED_POOL_SIZE and DB_CACHE_SIZE.
8. **_HASH_MULTIBLOCK_IO_COUNT** Number of blocks that a hash join will read/write at once.

9. **_INDEX_JOIN_ENABLED** Used to enable/disable the use of index joins. Default is TRUE.
10. **_OPTIMIZER_ADJUST_FOR_NULLS** Adjust selectivity for null values. Default is TRUE.
11. **_TRACE_POOL_SIZE** Trace pool size in bytes.
12. **_B_TREE_BITMAP_PLANS** Enables the use of bitmap plans for tables with only b-tree indexes. The default is TRUE, but many applications recommend setting this to FALSE.
13. **_UNNEST_SUBQUERY** Enables the unnesting of correlated or complex subqueries. The default is TRUE.

TIP
Undocumented initialization parameters can corrupt your database! Some of them can help you salvage a corrupted database. Try to use these only when all other choices have failed and with the help of Oracle Support.

Here are five additional initialization parameters that you can use for latch contention:

1. **_KGL_LATCH_COUNT** Number of library cache latches (set this to the next prime number higher than 2*CPU). Setting this parameter too high (>66) causes ORA-600 errors (bug 1381824). KGL stands for Kernel Generic Library or the Library Cache portion of the shared pool (there is also a Dictionary Cache portion). Many *KGL* undocumented parameters are available for debugging and improving shared pool performance. Be careful with this one as it shows up in obsolete parameters, but still shows as undocumented as well.
2. **_LOG_SIMULTANEOUS_COPIES** The number of redo copy latches (or simultaneous copies allowed into the redo log buffer). Redo records are written to the redo log buffer requiring the redo copy latch when changes are made. Use this parameter to reduce the contention on multi-CPU systems (default is 2).
3. **_DB_BLOCK_HASH_BUCKETS** Must be prime (set to next prime number higher than 2*Cache buffers) in versions 9*i* and 10*g* (there is an algorithm change in 11*g*). This parameter should not be a problem or need to be set as of 10*g*. On my system, this value was set to a default of 1048576 when there were only 332930 db block buffers (certainly eliminating hash chain issues). A _DB_BLOCK_HASH_LATCHES parameter (set to 32768, by default, in my system) is also available. My system is just under 7G MEMORY_TARGET.
4. **_DB_BLOCK_MAX_CR_DBA** The maximum number of consistent read (CR) blocks for a given database block address (DBA). The default is 6 (six copies maximum of a CR block). Before this parameter was set, large use applications updating many rows within the same block caused so many CR versions that there were incredible issues with latches on the hash chain looking for the correct version of a given block (see the previous parameter for related information).
5. **_SPIN_COUNT** Determines how often the processor takes a new request (reduces CPU time-outs). Also determines how many times a process tries to get a latch until it goes to sleep (when it is a willing-to-wait latch). Many processes spinning to get a latch can cost a lot of

CPU, so be careful if you increase this value. In Oracle 7, this parameter was called the _LATCH_SPIN_COUNT. The default is 1.

Bonus 11 Undocumented Initialization Parameters

Here are 11 more undocumented parameters that are mostly new as of Oracle 11*g*R2 that I think are worth looking into, but that I've not personally tested too much (other than the INIT_SQL_FILE parameter, which I've added to the bottom of the list; it is well worth reading through).

1. **_KCFIS_STORAGEIDX_DISABLED** Don't use storage index optimization on storage cells if this is set to TRUE. The default is FALSE. (*Exadata only*.)
2. **_BLOOM_FILTER_ENABLED** Set to TRUE by default. With Exadata, bloom filters are used for join filtering with smart scans. _BLOOM_PRUNING_ENABLED also has a default of TRUE. Set these to FALSE to disable. (*Exadata only*.)
3. **_COLUMN_COMPRESSION_FACTOR** Set to 0 by default.
4. **_IMU_POOLS** Located in the memory UNDO pools. The default is 3.
5. **_NESTED_LOOP_FUDGE** The default is 100 (probably means 100 percent, similar to OPTIMIZER_INDEX_COST_ADJ, but I've not tested it).
6. **_OPTIMIZER_MAX_PERMUTATIONS** The default is 2000 (seems high to me, but I've not tested it). This parameter determines the optimizer's maximum permutations per query block. (Note that 183 hidden parameters starting with _OPTIMIZER% are available.)
7. **_PGA_MAX_SIZE** The maximum size of PGA for *one* process. Must be prime (set to next prime number greater than 2*Cache buffers) in version 9*i* and 10*g* (there is an algorithm change in 12*c*; mine was set to around the PGA_AGGREGATE_TARGET). This parameter should not be a problem or need to be set as of 10*g*.
8. **_OPTIMIZER_IGNORE_HINTS** The default is FALSE. Could be a way to check if you really need all of those hints you've put in over the years.
9. **_ALLOW_READ_ONLY_CORRUPTION** The default is FALSE. This allows read-only open even if the database is corrupt. Careful with this parameter; consult Oracle Support.
10. **_OPTIM_PEEK_USER_BINDS** The default is TRUE, which allows Oracle to peek at the user's bind variable. Setting this FALSE when peeking is not favorable can lead to *huge* performance gains since Oracle peeks and uses the *same* plan that is *not* optimized for the next bind. Related to this is OPTIMIZER_ADAPTIVE_CURSOR_SHARING, which has a default of TRUE but is also often set to FALSE.
11. **_INIT_SQL_FILE** This SQL file (and its location) is executed upon database creation (usually `sql.bsq`, very interesting to read if you have a long night available). It is in the $ORACLE_HOME\rdbms\admin directory by default.

The hidden parameters are used mainly by the Oracle development group. The implementation of hidden parameters can change from release to release, even when you only applied a patch to your database. Because they are not documented and *not supported*, they may not work as you expect, or as is described here. For a query that gives you a complete listing of all undocumented parameters, their default values, and descriptions, see the section "Listing of Undocumented Initialization Parameters (X$KSPPI/X$KSPPCV)," later in this chapter.

Listing of Documented Initialization Parameters (V$PARAMETER)

The following query retrieves the listing that follows on 12*c*R2 (412 rows returned on Linux). This particular query was run on 12.2.0.0.2.

```
Col name format a33
Col value for a10
Col ismodified for a5
Col description for a28 word_wrapped

select      name, value, ismodified,  description
from        v$parameter
order by    name;
```

The following listing contains the output for this query and includes the parameter names, values, whether the parameter can be modified, and a brief description.

```
NAME                              VALUE      ISMOD DESCRIPTION
--------------------------------- ---------- ----- ----------------------------
DBFIPS_140                        FALSE      FALSE Enable use of
                                                   crypographic libraries
                                                   in FIPS mode, public

O7_DICTIONARY_ACCESSIBILITY       FALSE      FALSE Version 7 Dictionary
                                                   Accessibility Support
```

```
active_instance_count                          FALSE number of active
                                                     instances in the
                                                     cluster database

adg_imc_enabled                     TRUE       FALSE Enable IMC support on
                                                     ADG

allow_deprecated_rpcs               YES        FALSE Allow deprecated TTC
                                                     RPCs

allow_global_dblinks                FALSE      FALSE LDAP lookup for DBLINKS
allow_group_access_to_sga           FALSE      FALSE Allow read access for
                                                     SGA to users of Oracle
                                                     owner group

approx_for_aggregation              FALSE      FALSE Replace exact
                                                     aggregation with
                                                     approximate aggregation

approx_for_count_distinct           FALSE      FALSE Replace count distinct
                                                     with approx count distinct

approx_for_percentile               none       FALSE Replace percentile_*
                                                     with approx_percentile

aq_tm_processes                     1          FALSE number of AQ Time
                                                     Managers to start

archive_lag_target                  0          FALSE Maximum number of
                                                     seconds of redos the
                                                     standby could lose

asm_diskgroups                                 FALSE disk groups to mount
                                                     automatically

asm_diskstring                                 FALSE disk set locations for
                                                     discovery

asm_io_processes                    0          FALSE number of I/O processes
                                                     in the ASM IOSERVER
                                                     instance

asm_power_limit                     1          FALSE number of parallel
                                                     relocations for disk
                                                     rebalancing

asm_preferred_read_failure_groups              FALSE preferred read failure
                                                     groups
```

```
audit_file_dest                    /u01/app/o FALSE Directory in which
                                   racle/admi       auditing files are to
                                   n/orcl/adu       reside
                                   mp

audit_sys_operations               TRUE       FALSE enable sys auditing
audit_syslog_level                            FALSE Syslog facility and
                                                    level

audit_trail                        DB         FALSE enable system auditing
awr_snapshot_time_offset           0          FALSE Setting for AWR
                                                    Snapshot Time Offset

background_core_dump               partial    FALSE Core Size for
                                                    Background Processes

background_dump_dest               /u01/app/o FALSE Detached process dump
                                   racle/prod       directory
                                   uct/12.2.0
                                   /dbhome_1/
                                   rdbms/log

backup_tape_io_slaves              FALSE      FALSE BACKUP Tape I/O slaves
bitmap_merge_area_size             1048576    FALSE maximum memory allow
                                                    for BITMAP MERGE

blank_trimming                     FALSE      FALSE blank trimming
                                                    semantics parameter

buffer_pool_keep                              FALSE Number of database
                                                    blocks/latches in keep
                                                    buffer pool

buffer_pool_recycle                           FALSE Number of database
                                                    blocks/latches in
                                                    recycle buffer pool

cdb_cluster                        FALSE      FALSE if TRUE startup in CDB
                                                    Cluster mode

cdb_cluster_name                   orcl       FALSE CDB Cluster name
cell_offload_compaction            ADAPTIVE   FALSE Cell packet compaction
                                                    strategy

cell_offload_decryption            TRUE       FALSE enable SQL processing
                                                    offload of encrypted
                                                    data to cells

cell_offload_parameters                       FALSE Additional cell offload
                                                    parameters
```

```
cell_offload_plan_display          AUTO       FALSE Cell offload explain
                                                    plan display

cell_offload_processing            TRUE       FALSE enable SQL processing
                                                    offload to cells

cell_offloadgroup_name                        FALSE Set the offload group
                                                    name

cellmemory_clause_default                     FALSE Default cellmemory
                                                    clause when no DDL
                                                    specified

circuits                                      FALSE max number of circuits
client_result_cache_lag            3000       FALSE client result cache
                                                    maximum lag in
                                                    milliseconds

client_result_cache_size           0          FALSE client result cache max
                                                    size in bytes

clonedb                            FALSE      FALSE clone database
cluster_database                   FALSE      FALSE if TRUE startup in
                                                    cluster database mode

cluster_database_instances         1          FALSE number of instances to
                                                    use for sizing cluster
                                                    db SGA structures

cluster_interconnects                         FALSE interconnects for RAC
                                                    use

commit_logging                                FALSE transaction commit log
                                                    write behaviour

commit_point_strength              1          FALSE Bias this node has
                                                    toward not preparing in
                                                    a two-phase commit

commit_wait                                   FALSE transaction commit log
                                                    wait behaviour

commit_write                                  FALSE transaction commit log
                                                    write behaviour

common_user_prefix                 C##        FALSE Enforce restriction on
                                                    a prefix of a Common
                                                    User/Role/Profile name
```

```
compatible                           12.2.0.0.0 FALSE Database will be
                                                      completely compatible
                                                      with this software
                                                      version

connection_brokers                   ((TYPE=DED FALSE connection brokers
                                     ICATED)(BR       specification
                                     OKERS=1)),
                                      ((TYPE=EM
                                     ON)(BROKER
                                     S=1))

control_file_record_keep_time        7          FALSE control file record
                                                      keep time in days

control_files                        /u02/app/o FALSE control file names list
                                     racle/orad
                                     ata/orcl/c
                                     ontrol01.c
                                     tl, /u03/a
                                    pp/oracle/
                                    fast_recov
                                    ery_area/o
                                    rcl/contro
                                    l02.ctl

control_management_pack_access       DIAGNOSTIC FALSE declares which
                                     +TUNING          manageability packs are
                                                      enabled

core_dump_dest                       /u01/app/o FALSE Core dump directory
                                     racle/diag
                                     /rdbms/orc
                                     l/orcl/cdu
                                     mp

cpu_count                            1          FALSE number of CPUs for this
                                                      instance

create_bitmap_area_size              8388608    FALSE size of create bitmap
                                                      buffer for bitmap index

create_stored_outlines                          FALSE create stored outlines
                                                      for DML statements

cursor_bind_capture_destination      memory+dis FALSE Allowed destination for
                                     k                captured bind variables
```

```
cursor_invalidation                IMMEDIATE  FALSE default for DDL cursor
                                                    invalidation semantics

cursor_sharing                     EXACT      FALSE cursor sharing mode
cursor_space_for_time              FALSE      FALSE use more memory in
                                                    order to get faster
                                                    execution

data_guard_sync_latency            0          FALSE Data Guard SYNC latency
data_transfer_cache_size           0          FALSE Size of data transfer
                                                    cache

db_16k_cache_size                  0          FALSE Size of cache for 16K
                                                    buffers

db_2k_cache_size                   0          FALSE Size of cache for 2K
                                                    buffers

db_32k_cache_size                  0          FALSE Size of cache for 32K
                                                    buffers

db_4k_cache_size                   0          FALSE Size of cache for 4K
                                                    buffers

db_8k_cache_size                   0          FALSE Size of cache for 8K
                                                    buffers

db_big_table_cache_percent_target  0          FALSE Big table cache target
                                                    size in percentage

db_block_buffers                   0          FALSE Number of database
                                                    blocks cached in memory

db_block_checking                  FALSE      FALSE header checking and
                                                    data and index block
                                                    checking

db_block_checksum                  TYPICAL    FALSE store checksum in db
                                                    blocks and check during
                                                    reads

db_block_size                      8192       FALSE Size of database block
                                                    in bytes

db_cache_advice                    ON         FALSE Buffer cache sizing
                                                    advisory

db_cache_size                      0          FALSE Size of DEFAULT buffer
                                                    pool for standard block
                                                    size buffers
```

```
db_create_file_dest                  /u02/app/o FALSE default database
                                     racle/orad       location
                                     ata

db_create_online_log_dest_1                     FALSE online log/controlfile
                                                      destination #1

db_create_online_log_dest_2                     FALSE online log/controlfile
                                                      destination #2

db_create_online_log_dest_3                     FALSE online log/controlfile
                                                      destination #3

db_create_online_log_dest_4                     FALSE online log/controlfile
                                                      destination #4

db_create_online_log_dest_5                     FALSE online log/controlfile
                                                      destination #5

db_domain                                       FALSE directory part of
                                                      global database name
                                                      stored with CREATE
                                                      DATABASE

db_file_multiblock_read_count        128        FALSE db block to be read
                                                      each IO

db_file_name_convert                            FALSE datafile name convert
                                                      patterns and strings
                                                      for standby/clone db

db_files                             200        FALSE max allowable # db
                                                      files

db_flash_cache_file                             FALSE flash cache file for
                                                      default block size

db_flash_cache_size                  0          FALSE flash cache size for
                                                      db_flash_cache_file

db_flashback_retention_target        1440       FALSE Maximum Flashback
                                                      Database log retention
                                                      time in minutes.

db_index_compression_inheritance     NONE       FALSE options for table or
                                                      tablespace level
                                                      compression inheritance
```

```
db_keep_cache_size                   0          FALSE Size of KEEP buffer
                                                      pool for standard block
                                                      size buffers

db_lost_write_protect                NONE       FALSE enable lost write
                                                      detection

db_name                              orcl       FALSE database name specified
                                                      in CREATE DATABASE

db_performance_profile                          FALSE Database performance
                                                      category

db_recovery_file_dest                /u03/app/o FALSE default database
                                     racle/fast       recovery file location
                                     _recovery_
                                     area

db_recovery_file_dest_size           2621440000 FALSE database recovery files
                                     0                size limit

db_recycle_cache_size                0          FALSE Size of RECYCLE buffer
                                                      pool for standard block
                                                      size buffers

db_securefile                        PREFERRED  FALSE permit securefile
                                                      storage during lob
                                                      creation

db_ultra_safe                        OFF        FALSE Sets defaults for other
                                                      parameters that control
                                                      protection levels

db_unique_name                       orcl       FALSE Database Unique Name
db_unrecoverable_scn_tracking        TRUE       FALSE Track nologging SCN in
                                                      controlfile

db_writer_processes                  1          FALSE number of background
                                                      database writer
                                                      processes to start

dbwr_io_slaves                       0          FALSE DBWR I/O slaves
ddl_lock_timeout                     0          FALSE timeout to restrict the
                                                      time that ddls wait for
                                                      dml lock

default_sharing                      metadata   FALSE Default sharing clause
deferred_segment_creation            TRUE       FALSE defer segment creation
                                                      to first insert
```

```
dg_broker_config_file1               /u01/app/o FALSE data guard broker
                                     racle/prod       configuration file #1
                                     uct/12.2.0
                                     /dbhome_1/
                                     dbs/dr1orc
                                     l.dat

dg_broker_config_file2               /u01/app/o FALSE data guard broker
                                     racle/prod       configuration file #2
                                     uct/12.2.0
                                     /dbhome_1/
                                     dbs/dr2orc
                                     l.dat

dg_broker_start                      FALSE      FALSE start Data Guard broker
                                                      (DMON process)

diagnostic_dest                      /u01/app/o FALSE diagnostic base
                                     racle            directory

disable_pdb_feature                  0          FALSE Disable features
disk_asynch_io                       TRUE       FALSE Use asynch I/O for
                                                      random access devices

dispatchers                          (PROTOCOL= FALSE specifications of
                                     TCP) (SERV       dispatchers
                                     ICE=orclXD
                                     B)

distributed_lock_timeout             60         FALSE number of seconds a
                                                      distributed transaction
                                                      waits for a lock

dml_locks                            2076       FALSE dml locks - one for
                                                      each table modified in
                                                      a transaction

dnfs_batch_size                      4096       FALSE Max number of dNFS
                                                      asynch I/O requests
                                                      queued per session

dst_upgrade_insert_conv              TRUE       FALSE Enables/Disables
                                                      internal conversions
                                                      during DST upgrade

enable_ddl_logging                   FALSE      FALSE enable ddl logging
enable_dnfs_dispatcher               FALSE      FALSE Enable DNFS Dispatcher
enable_goldengate_replication        FALSE      FALSE goldengate replication
                                                      enabled
```

```
enable_pdb_isolation                 FALSE      FALSE Enables Pluggable
                                                      Database isolation
                                                      inside a CDB

enable_pluggable_database            FALSE      FALSE Enable Pluggable
                                                      Database

enabled_PDBs_on_standby              *          FALSE List of Enabled PDB
                                                      patterns

encrypt_new_tablespaces              CLOUD_ONLY FALSE whether to encrypt
                                                      newly created
                                                      tablespaces

event                                           FALSE debug event control -
                                                      default null string

exafusion_enabled                    1          FALSE Enable Exafusion
external_keystore_credential_locat              FALSE external keystore
ion                                                   credential location

fal_client                                      FALSE FAL client
fal_server                                      FALSE FAL server list
fast_start_io_target                 0          FALSE Upper bound on recovery
                                                      reads

fast_start_mttr_target               0          FALSE MTTR target in seconds
fast_start_parallel_rollback         LOW        FALSE max number of parallel
                                                      recovery slaves that
                                                      may be used

file_mapping                         FALSE      FALSE enable file mapping
fileio_network_adapters                         FALSE Network Adapters for
                                                      File I/O

filesystemio_options                 none       FALSE IO operations on
                                                      filesystem files

fixed_date                                      FALSE fixed SYSDATE value
gcs_server_processes                 0          FALSE number of background
                                                      gcs server processes to
                                                      start

global_names                         FALSE      FALSE enforce that database
                                                      links have same name as
                                                      remote database

global_txn_processes                 1          FALSE number of background
                                                      global transaction
                                                      processes to start
```

```
hash_area_size                     131072     FALSE size of in-memory hash
                                                    work area

heat_map                           OFF        FALSE ILM Heatmap Tracking
hi_shared_memory_address           0          FALSE SGA starting address
                                                    (high order 32-bits on
                                                    64-bit platforms)

hs_autoregister                    TRUE       FALSE enable automatic server
                                                    DD updates in HS agent
                                                    self registration

ifile                                         FALSE include file in
                                                    init.ora

inmemory_ado_enabled               FALSE      FALSE Enable inmemory ADO
inmemory_clause_default                       FALSE Default in-memory
                                                    clause for new tables

inmemory_expressions_capture       DISABLE    FALSE Controls detection of
                                                    frequently used costly
                                                    expressions

inmemory_expressions_usage         ENABLE     FALSE Controls which
                                                    In-Memory Expressions
                                                    are populated in-memory

inmemory_force                     DEFAULT    FALSE Force tables to be
                                                    in-memory or not

inmemory_max_populate_servers      0          FALSE maximum inmemory
                                                    populate servers

inmemory_query                     ENABLE     FALSE Specifies whether
                                                    in-memory queries are
                                                    allowed

inmemory_size                      0          FALSE size in bytes of
                                                    in-memory area

inmemory_trickle_repopulate_server 1          FALSE inmemory trickle
s_percent                                           repopulate servers
                                                    percent

inmemory_virtual_columns           MANUAL     FALSE Controls which
                                                    user-defined virtual
                                                    columns are stored
                                                    in-memory
```

```
instance_abort_delay_time            0          FALSE time to delay an
                                                      internal initiated
                                                      abort (in seconds)

instance_groups                                 FALSE list of instance group
                                                      names

instance_mode                        READ-WRITE FALSE indicates whether the
                                                      instance read-only or
                                                      read-write or
                                                      read-mostly

instance_name                        orcl       FALSE instance name supported
                                                      by the instance

instance_number                      0          FALSE instance number
instance_type                        RDBMS      FALSE type of instance to be
                                                      executed

instant_restore                      FALSE      FALSE instant repopulation of
                                                      datafiles

java_jit_enabled                     TRUE       FALSE Java VM JIT enabled
java_max_sessionspace_size           0          FALSE max allowed size in
                                                      bytes of a Java
                                                      sessionspace

java_pool_size                       0          FALSE size in bytes of java
                                                      pool

java_restrict                        none       FALSE Restrict Java VM Access
java_soft_sessionspace_limit         0          FALSE warning limit on size
                                                      in bytes of a Java
                                                      sessionspace

job_queue_processes                  1000       FALSE maximum number of job
                                                      queue slave processes

large_pool_size                      0          FALSE size in bytes of large
                                                      pool

ldap_directory_access                NONE       FALSE RDBMS's LDAP access
                                                      option

ldap_directory_sysauth               no         FALSE OID usage parameter
license_max_sessions                 0          FALSE maximum number of
                                                      non-system user
                                                      sessions allowed
```

```
license_max_users                    0          FALSE maximum number of named
                                                      users that can be
                                                      created in the database

license_sessions_warning             0          FALSE warning level for
                                                      number of non-system
                                                      user sessions

listener_networks                               FALSE listener registration
                                                      networks

local_listener                                  FALSE local listener
lock_name_space                                 FALSE lock name space used
                                                      for generating lock
                                                      names for standby/clone
                                                      database

lock_sga                             FALSE      FALSE Lock entire SGA in
                                                      physical memory

log_archive_config                              FALSE log archive config
log_archive_dest                                FALSE archival destination
                                                      text string

log_archive_dest_1                              FALSE archival destination #1
                                                      text string

log_archive_dest_10                             FALSE archival destination
                                                      #10 text string

log_archive_dest_11                             FALSE archival destination
                                                      #11 text string

log_archive_dest_12                             FALSE archival destination
                                                      #12 text string

log_archive_dest_13                             FALSE archival destination
                                                      #13 text string

log_archive_dest_14                             FALSE archival destination
                                                      #14 text string

log_archive_dest_15                             FALSE archival destination
                                                      #15 text string

log_archive_dest_16                             FALSE archival destination
                                                      #16 text string

log_archive_dest_17                             FALSE archival destination
                                                      #17 text string
```

```
log_archive_dest_18                              FALSE archival destination
                                                       #18 text string

log_archive_dest_19                              FALSE archival destination
                                                       #19 text string

log_archive_dest_2                               FALSE archival destination #2
                                                       text string

log_archive_dest_20                              FALSE archival destination
                                                       #20 text string

log_archive_dest_21                              FALSE archival destination
                                                       #21 text string

log_archive_dest_22                              FALSE archival destination
                                                       #22 text string

log_archive_dest_23                              FALSE archival destination
                                                       #23 text string

log_archive_dest_24                              FALSE archival destination
                                                       #24 text string

log_archive_dest_25                              FALSE archival destination
                                                       #25 text string

log_archive_dest_26                              FALSE archival destination
                                                       #26 text string

log_archive_dest_27                              FALSE archival destination
                                                       #27 text string

log_archive_dest_28                              FALSE archival destination
                                                       #28 text string

log_archive_dest_29                              FALSE archival destination
                                                       #29 text string

log_archive_dest_3                               FALSE archival destination #3
                                                       text string

log_archive_dest_30                              FALSE archival destination
                                                       #30 text string

log_archive_dest_31                              FALSE archival destination
                                                       #31 text string

log_archive_dest_4                               FALSE archival destination #4
                                                       text string
```

```
log_archive_dest_5                              FALSE archival destination #5
                                                      text string

log_archive_dest_6                              FALSE archival destination #6
                                                      text string

log_archive_dest_7                              FALSE archival destination #7
                                                      text string

log_archive_dest_8                              FALSE archival destination #8
                                                      text string

log_archive_dest_9                              FALSE archival destination #9
                                                      text string

log_archive_dest_state_1             enable     FALSE archival destination #1
                                                      state text string

log_archive_dest_state_10            enable     FALSE archival destination
                                                      #10 state text string

log_archive_dest_state_11            enable     FALSE archival destination
                                                      #11 state text string

log_archive_dest_state_12            enable     FALSE archival destination
                                                      #12 state text string

log_archive_dest_state_13            enable     FALSE archival destination
                                                      #13 state text string

log_archive_dest_state_14            enable     FALSE archival destination
                                                      #14 state text string

log_archive_dest_state_15            enable     FALSE archival destination
                                                      #15 state text string

log_archive_dest_state_16            enable     FALSE archival destination
                                                      #16 state text string

log_archive_dest_state_17            enable     FALSE archival destination
                                                      #17 state text string

log_archive_dest_state_18            enable     FALSE archival destination
                                                      #18 state text string

log_archive_dest_state_19            enable     FALSE archival destination
                                                      #19 state text string

log_archive_dest_state_2             enable     FALSE archival destination #2
                                                      state text string
```

```
log_archive_dest_state_20            enable     FALSE archival destination
                                                      #20 state text string

log_archive_dest_state_21            enable     FALSE archival destination
                                                      #21 state text string

log_archive_dest_state_22            enable     FALSE archival destination
                                                      #22 state text string

log_archive_dest_state_23            enable     FALSE archival destination
                                                      #23 state text string

log_archive_dest_state_24            enable     FALSE archival destination
                                                      #24 state text string

log_archive_dest_state_25            enable     FALSE archival destination
                                                      #25 state text string

log_archive_dest_state_26            enable     FALSE archival destination
                                                      #26 state text string

log_archive_dest_state_27            enable     FALSE archival destination
                                                      #27 state text string

log_archive_dest_state_28            enable     FALSE archival destination
                                                      #28 state text string

log_archive_dest_state_29            enable     FALSE archival destination
                                                      #29 state text string

log_archive_dest_state_3             enable     FALSE archival destination #3
                                                      state text string

log_archive_dest_state_30            enable     FALSE archival destination
                                                      #30 state text string

log_archive_dest_state_31            enable     FALSE archival destination
                                                      #31 state text string

log_archive_dest_state_4             enable     FALSE archival destination #4
                                                      state text string

log_archive_dest_state_5             enable     FALSE archival destination #5
                                                      state text string

log_archive_dest_state_6             enable     FALSE archival destination #6
                                                      state text string

log_archive_dest_state_7             enable     FALSE archival destination #7
                                                      state text string
```

```
log_archive_dest_state_8           enable     FALSE archival destination #8
                                                    state text string

log_archive_dest_state_9           enable     FALSE archival destination #9
                                                    state text string

log_archive_duplex_dest                       FALSE duplex archival
                                                    destination text string

log_archive_format                 %t_%s_%r.d FALSE archival destination
                                   bf               format

log_archive_max_processes          4          FALSE maximum number of
                                                    active ARCH processes

log_archive_min_succeed_dest       1          FALSE minimum number of
                                                    archive destinations
                                                    that must succeed

log_archive_start                  FALSE      FALSE start archival process
                                                    on SGA initialization

log_archive_trace                  0          FALSE Establish archivelog
                                                    operation tracing level

log_buffer                         3735552    FALSE redo circular buffer
                                                    size

log_checkpoint_interval            0          FALSE # redo blocks
                                                    checkpoint threshold

log_checkpoint_timeout             1800       FALSE Maximum time interval
                                                    between checkpoints in
                                                    seconds

log_checkpoints_to_alert           FALSE      FALSE log checkpoint
                                                    begin/end to alert file

log_file_name_convert                         FALSE logfile name convert
                                                    patterns and strings
                                                    for standby/clone db

max_dispatchers                               FALSE max number of
                                                    dispatchers

max_dump_file_size                 unlimited  FALSE Maximum size (in bytes)
                                                    of dump file
```

```
max_iops                             0           FALSE MAX IO per second
max_mbps                             0           FALSE MAX MB per second
max_shared_servers                               FALSE max number of shared
                                                       servers

max_string_size                      STANDARD    FALSE controls maximum size
                                                       of VARCHAR2, NVARCHAR2,
                                                       and RAW types in SQL

memory_max_target                    0           FALSE Max size for Memory
                                                       Target

memory_target                        0           FALSE Target size of Oracle
                                                       SGA and PGA memory

nls_calendar                                     FALSE NLS calendar system
                                                       name

nls_comp                             BINARY      FALSE NLS comparison
nls_currency                                     FALSE NLS local currency
                                                       symbol

nls_date_format                                  FALSE NLS Oracle date format
nls_date_language                                FALSE NLS date language name
nls_dual_currency                                FALSE Dual currency symbol
nls_iso_currency                                 FALSE NLS ISO currency
                                                       territory name

nls_language                         AMERICAN    FALSE NLS language name
nls_length_semantics                 BYTE        FALSE create columns using
                                                       byte or char semantics
                                                       by default

nls_nchar_conv_excp                  FALSE       FALSE NLS raise an exception
                                                       instead of allowing
                                                       implicit conversion

nls_numeric_characters                           FALSE NLS numeric characters
nls_sort                                         FALSE NLS linguistic
                                                       definition name

nls_territory                        AMERICA     FALSE NLS territory name
nls_time_format                                  FALSE time format
nls_time_tz_format                               FALSE time with timezone
                                                       format

nls_timestamp_format                             FALSE time stamp format
nls_timestamp_tz_format                          FALSE timestamp with timezone
                                                       format
```

```
noncdb_compatible                   FALSE      FALSE Non-CDB Compatible
object_cache_max_size_percent       10         FALSE percentage of maximum
                                                     size over optimal of
                                                     the user session's
                                                     object cache

object_cache_optimal_size           102400     FALSE optimal size of the
                                                     user session's object
                                                     cache in bytes

ofs_threads                         4          FALSE Number of OFS threads
olap_page_pool_size                 0          FALSE size of the olap page
                                                     pool in bytes

one_step_plugin_for_pdb_with_tde    FALSE      FALSE Facilitate one-step
                                                     plugin for PDB with TDE
                                                     encrypted data

open_cursors                        300        FALSE max # cursors per
                                                     session

open_links                          4          FALSE max # open links per
                                                     session

open_links_per_instance             4          FALSE max # open links per
                                                     instance

optimizer_adaptive_features         TRUE       FALSE controls adaptive
                                                     features

optimizer_adaptive_reporting_only   FALSE      FALSE use reporting only mode
                                                     for adaptive
                                                     optimizations

optimizer_capture_sql_plan_baselines FALSE     FALSE automatic capture of
                                                     SQL plan baselines for
                                                     repeatable statements

optimizer_dynamic_sampling          2          FALSE optimizer dynamic
                                                     sampling

optimizer_features_enable           12.2.0.1   FALSE optimizer plan
                                                     compatibility parameter

optimizer_index_caching             0          FALSE optimizer percent index
                                                     caching

optimizer_index_cost_adj            100        FALSE optimizer index cost
                                                     adjustment
```

```
optimizer_inmemory_aware           TRUE       FALSE optimizer in-memory
                                                    columnar awareness

optimizer_mode                     RULE       FALSE optimizer mode
optimizer_secure_view_merging      TRUE       FALSE optimizer secure view
                                                    merging and predicate
                                                    pushdown/movearound

optimizer_use_invisible_indexes    FALSE      FALSE Usage of invisible
                                                    indexes (TRUE/FALSE)

optimizer_use_pending_statistics   FALSE      FALSE Control whether to use
                                                    optimizer pending
                                                    statistics

optimizer_use_sql_plan_baselines   TRUE       FALSE use of SQL plan
                                                    baselines for captured
                                                    sql statements

os_authent_prefix                  ops$       FALSE prefix for auto-logon
                                                    accounts

os_roles                           FALSE      FALSE retrieve roles from the
                                                    operating system

outbound_dblink_protocols          ALL        FALSE Outbound DBLINK
                                                    Protocols allowed

parallel_adaptive_multi_user       FALSE      FALSE enable adaptive setting
                                                    of degree for multiple
                                                    user streams

parallel_degree_limit              CPU        FALSE limit placed on degree
                                                    of parallelism

parallel_degree_policy             MANUAL     FALSE policy used to compute
                                                    the degree of
                                                    parallelism
                                                    (MANUAL/LIMITED/AUTO/AD
                                                    APTIVE)

parallel_execution_message_size    16384      FALSE message buffer size for
                                                    parallel execution

parallel_force_local               FALSE      FALSE force single instance
                                                    execution

parallel_instance_group                       FALSE instance group to use
                                                    for all parallel
                                                    operations
```

```
parallel_max_servers              40         FALSE maximum parallel query
                                                   servers per instance

parallel_min_percent              0          FALSE minimum percent of
                                                   threads required for
                                                   parallel query

parallel_min_servers              4          FALSE minimum parallel query
                                                   servers per instance

parallel_min_time_threshold       AUTO       FALSE threshold above which a
                                                   plan is a candidate for
                                                   parallelization (in
                                                   seconds)

parallel_servers_target           16         FALSE instance target in
                                                   terms of number of
                                                   parallel servers

parallel_threads_per_cpu          2          FALSE number of parallel
                                                   execution threads per
                                                   CPU

pdb_file_name_convert                        FALSE PDB file name convert
                                                   patterns and strings
                                                   for create cdb/pdb

pdb_lockdown                                 FALSE pluggable database
                                                   lockdown profile

pdb_os_credential                            FALSE pluggable database OS
                                                   credential to bind

permit_92_wrap_format             TRUE       FALSE allow 9.2 or older wrap
                                                   format in PL/SQL

pga_aggregate_limit               2147483648 FALSE limit of aggregate PGA
                                                   memory for the instance
                                                   or PDB

pga_aggregate_target              262144000  FALSE Target size for the
                                                   aggregate PGA memory
                                                   consumed by the
                                                   instance

pga_aggregate_xmem_limit          0          FALSE limit of aggregate PGA
                                                   XMEM memory consumed by
                                                   the instance
```

```
plscope_settings                    IDENTIFIER FALSE plscope_settings
                                    S:NONE           controls the compile
                                                     time collection, cross
                                                     reference, and storage
                                                     of PL/SQL source code
                                                     identifier and SQL
                                                     statement data

plsql_ccflags                                  FALSE PL/SQL ccflags
plsql_code_type                     INTERPRETE FALSE PL/SQL code-type
                                    D

plsql_debug                         FALSE      FALSE PL/SQL debug
plsql_optimize_level                2          FALSE PL/SQL optimize level
plsql_v2_compatibility              FALSE      FALSE PL/SQL version 2.x
                                                     compatibility flag

plsql_warnings                      DISABLE:AL FALSE PL/SQL compiler
                                    L                warnings settings

pre_page_sga                        TRUE       FALSE pre-page sga for
                                                     process

processes                           300        FALSE user processes
processor_group_name                           FALSE Name of the processor
                                                     group that this
                                                     instance should run in.

query_rewrite_enabled               TRUE       FALSE allow rewrite of
                                                     queries using
                                                     materialized views if
                                                     enabled

query_rewrite_integrity             enforced   FALSE perform rewrite using
                                                     materialized views with
                                                     desired integrity

rdbms_server_dn                                FALSE RDBMS's Distinguished
                                                     Name

read_only_open_delayed              FALSE      FALSE if TRUE delay opening
                                                     of read only files
                                                     until first access

recovery_parallelism                0          FALSE number of server
                                                     processes to use for
                                                     parallel recovery
```

```
recyclebin                            on         FALSE recyclebin processing
redo_transport_user                              FALSE Data Guard transport
                                                       user when using
                                                       password file

remote_dependencies_mode              TIMESTAMP  FALSE remote-procedure-call
                                                       dependencies mode
                                                       parameter

remote_listener                                  FALSE remote listener
remote_login_passwordfile             EXCLUSIVE  FALSE password file usage
                                                       parameter

remote_os_authent                     FALSE      FALSE allow non-secure remote
                                                       clients to use
                                                       auto-logon accounts

remote_os_roles                       FALSE      FALSE allow non-secure remote
                                                       clients to use os roles

remote_recovery_file_dest                        FALSE default remote database
                                                       recovery file location
                                                       for refresh/relocate

replication_dependency_tracking       TRUE       FALSE tracking dependency for
                                                       Replication parallel
                                                       propagation

resource_limit                        TRUE       FALSE master switch for
                                                       resource limit

resource_manager_cpu_allocation       1          FALSE Resource Manager CPU
                                                       allocation

resource_manager_plan                 SCHEDULER[ FALSE resource mgr top plan
                                      0x4BEF]:DE
                                      FAULT_MAIN
                                      TENANCE_PL
                                      AN

result_cache_max_result               5          FALSE maximum result size as
                                                       percent of cache size

result_cache_max_size                 5373952    FALSE maximum amount of
                                                       memory to be used by
                                                       the cache

result_cache_mode                     MANUAL     FALSE result cache operator
                                                       usage mode
```

```
result_cache_remote_expiration       0          FALSE maximum life time (min)
                                                      for any result using a
                                                      remote object

resumable_timeout                    0          FALSE set resumable_timeout
rollback_segments                               FALSE undo segment list
sec_case_sensitive_logon             TRUE       FALSE case sensitive password
                                                      enabled for logon

sec_max_failed_login_attempts        3          FALSE maximum number of
                                                      failed login attempts
                                                      on a connection

sec_protocol_error_further_action    (DROP,3)   FALSE TTC protocol error
                                                      continue action

sec_protocol_error_trace_action      TRACE      FALSE TTC protocol error
                                                      action

sec_return_server_release_banner     FALSE      FALSE whether the server
                                                      retruns the complete
                                                      version information

serial_reuse                         disable    FALSE reuse the frame
                                                      segments

service_names                        orcl       FALSE service names supported
                                                      by the instance

session_cached_cursors               50         FALSE Number of cursors to
                                                      cache in a session.

session_max_open_files               10         FALSE maximum number of open
                                                      files allowed per
                                                      session

sessions                             472        FALSE user and system
                                                      sessions

sga_max_size                         1073741824 FALSE max total SGA size
sga_min_size                         0          FALSE Minimum, guaranteed
                                                      size of PDB's SGA

sga_target                           1073741824 FALSE Target size of SGA
shadow_core_dump                     partial    FALSE Core Size for Shadow
                                                      Processes

shared_memory_address                0          FALSE SGA starting address
                                                      (low order 32-bits on
                                                      64-bit platforms)
```

```
shared_pool_reserved_size            12373196   FALSE size in bytes of
                                                      reserved area of shared
                                                      pool

shared_pool_size                     0          FALSE size in bytes of shared
                                                      pool

shared_server_sessions                          FALSE max number of shared
                                                      server sessions

shared_servers                       1          FALSE number of shared
                                                      servers to start up

skip_unusable_indexes                TRUE       FALSE skip unusable indexes
                                                      if set to TRUE

smtp_out_server                                 FALSE utl_smtp server and
                                                      port configuration
                                                      parameter

sort_area_retained_size              0          FALSE size of in-memory sort
                                                      work area retained
                                                      between fetch calls

sort_area_size                       65536      FALSE size of in-memory sort
                                                      work area

spatial_vector_acceleration          FALSE      FALSE enable spatial vector
                                                      acceleration

spfile                               /u01/app/o FALSE server parameter file
                                     racle/prod
                                     uct/12.2.0
                                     /dbhome_1/
                                     dbs/spfile
                                     orcl.ora

sql92_security                       TRUE       FALSE require select
                                                      privilege for searched
                                                      update/delete

sql_trace                            FALSE      FALSE enable SQL trace
sqltune_category                     DEFAULT    FALSE Category qualifier for
                                                      applying hintsets

standby_archive_dest                 ?#/dbs/arc FALSE standby database
                                     h                archivelog destination
                                                      text string
```

```
standby_db_keep_sessions           FALSE      FALSE Keep session cross
                                                    standby role transition

standby_file_management            MANUAL     FALSE if auto then files are
                                                    created/dropped
                                                    automatically on
                                                    standby

star_transformation_enabled        FALSE      FALSE enable the use of star
                                                    transformation

statistics_level                   TYPICAL    FALSE statistics level
streams_pool_size                  0          FALSE size in bytes of the
                                                    streams pool

tape_asynch_io                     TRUE       FALSE Use asynch I/O requests
                                                    for tape devices

target_pdbs                        0          FALSE Parameter is a hint to
                                                    adjust certain
                                                    attributes of the CDB

temp_undo_enabled                  FALSE      FALSE is temporary undo
                                                    enabled

thread                             0          FALSE Redo thread to mount
threaded_execution                 FALSE      FALSE Threaded Execution Mode
timed_os_statistics                0          FALSE internal os statistic
                                                    gathering interval in
                                                    seconds

timed_statistics                   TRUE       FALSE maintain internal
                                                    timing statistics

trace_enabled                      TRUE       FALSE enable in memory
                                                    tracing

tracefile_identifier                          FALSE trace file custom
                                                    identifier

transactions                       519        FALSE max. number of
                                                    concurrent active
                                                    transactions

transactions_per_rollback_segment  5          FALSE number of active
                                                    transactions per
                                                    rollback segment
```

```
undo_management                     AUTO       FALSE instance runs in SMU
                                                     mode if TRUE, else in
                                                     RBU mode

undo_retention                      900        FALSE undo retention in
                                                     seconds

undo_tablespace                     UNDOTBS1   FALSE use/switch undo
                                                     tablespace

unified_audit_sga_queue_size        1048576    FALSE Size of Unified audit
                                                     SGA Queue

uniform_log_timestamp_format        TRUE       FALSE use uniform timestamp
                                                     formats vs pre-12.2
                                                     formats

use_dedicated_broker                FALSE      FALSE Use dedicated
                                                     connection broker

use_indirect_data_buffers           FALSE      FALSE Enable indirect data
                                                     buffers (very large SGA
                                                     on 32-bit platforms)

use_large_pages                     TRUE       FALSE Use large pages if
                                                     available
                                                     (TRUE/FALSE/ONLY)

user_dump_dest                      /u01/app/o FALSE User process dump
                                    racle/prod       directory
                                    uct/12.2.0
                                    /dbhome_1/
                                    rdbms/log

utl_file_dir                                   FALSE utl file accessible
                                                     directories list

workarea_size_policy                AUTO       FALSE policy used to size SQL
                                                     working areas
                                                     (MANUAL/AUTO)

xml_db_events                       enable     FALSE are XML DB events
                                                     enabled


412 rows selected.
```

Listing of Undocumented Initialization Parameters

(X$KSPPI/X$KSPPCV)

Using these parameters is not supported by Oracle, and I do not recommend using them on a production system. Use them only if you are directed to use them by Oracle Support *and* have thoroughly tested them on your crash-and-burn system. Undocumented initialization parameters can lead to database corruption (although a few of them can get your database back up when it becomes corrupted). Use at your own risk. The following query retrieves the undocumented parameters (4237 of them in 12*c*R2). No output is displayed due to space considerations.

```
Col name for a15
Col value for a15
Col value for a15
Col default1 for a15
Col desc1 for a30
select      a.ksppinm name, b.ksppstvl value, b.ksppstdf default1, a.ksppdesc
desc1
from        x$ksppi a, x$ksppcv b
where       a.indx = b.indx
and         substr(ksppinm,1,1) = '_'
order       by ksppinm;
```

TIP

Undocumented initialization parameters often show a glimpse of things coming in the next version of Oracle (or things going away from the last version). However, some of them don't work or could cause severe problems.

Additional Oracle Applications Notes

In Chapter 4 you received tips for sizing the Oracle Applications database. This section covers some additional notes about Oracle Applications, including tips related to concurrent managers, module-specific patches, Oracle E-Business Suite (EBS) modules, web server tuning, timeouts, and database initialization parameter sizing.

Concurrent Managers

There are multiple different ways concurrent managers (CMs) can be deployed in an EBS implementation. In the simple case of one application server running all the application tier processes, pay attention to all the default managers that are defined as part of the implementation. If the default seems to be high for a simple implementation, you can reduce the number of standard managers and create specialized managers with different work shifts. For example, you can assign Order Management–related batch jobs to a specialized manager that runs only in the night so that accidental execution of these programs during the peak hours can be avoided.

While reducing the standard managers, you can create custom "slow queue" and "fast queue" concurrent managers by defining two of those entries from the Concurrent Manager | Define screen by appropriately configuring the sleep time. For slow queues, set the sleep time to a higher number of seconds (160 seconds), and for fast queues, set the sleep time to a low value (30 seconds).

The other important parameter related to concurrent managers is the cache size, which determines how many requests a CM tries to execute upon each pass. If the cache size is set too low, then the CM is polling the queue table fnd_concurrent_requests too frequently. If it is set too high, then the CM is repeatedly trying to execute upon requests already serviced by another CM. The rule of thumb for tuning the cache size is

# of CM Processes * Desired Cache size per CM Process

For example, if you want to have 4 requests cached, then set the value to 200 for 50 target processes, and set it to 120 for 30 target processes.

The proper tuning of the sleep and cache size parameters will play a great role if and when parallel concurrent processing (PCP) is used along with the RAC databases. Parallel concurrent processing is a deployment option for larger environments where more than one application server is being used. In this setup, a primary node and a secondary node are defined for every concurrent manager queue. PCP is activated by tuning the AutoConfig variable appldcp. When the concurrent managers are started using `adcmctl.sh`, the internal concurrent manager is started on the primary node and will constantly poll the secondary node via tns. If it does not hear back from the other node, then concurrent managers would be failed to start in the primary node.

In RAC nodes where the interconnect bandwidth is low, an improper setting of the cache size and sleep time can cause "gc latch waits" in the database. Because these two parameters determine how often the SELECT FOR UPDATE query against fnd_concurrent_requests needs to be executed based on the STATUS_CODE and PHASE_CODE columns of this table, there could be hot blocks needed at the same time by various nodes across the RAC. The concurrency goes "critical" when Oracle RAC loses track of the current ownership of the block and is therefore not able to complete the block request from the other nodes (Dynamic Block Re-mastering—DRM). When multiple nodes require the same blocks of data/modified data for concurrency, you will run into "gc latch waits"—global cache concurrency waits that could bring down the entire EBS system to its knees.

In some implementations, either the development/implementation team or the DBA team tends to create custom triggers on the fnd_concurrent_requests table. Any trigger has an overhead of executing the code in it when it is fired. If you put that in the context of fnd_concurrent_requests having millions of rows with improper sleep time and cache values for the concurrent managers in a RAC environment, the gc latch waits issue would be even worse. So, if the triggers are not adding any value, disable them or revisit the purpose of why they were created in the first place. The same scenario of fnd_concurrent_requests and gc latches holds true for any other cohesive processes such as Pick, Release, Order, Import functionalities. By nature, these two can stress the "interconnect" by competing for the hot blocks in the Order Entry–related tables.

For very large environments, the concurrent managers can be tuned further by doing what is known as *CM affinity*. It is controlled by the AutoConfig variable s_cp_twotask in the concurrent manager nodes. This variable can be set to a specific tns value or to a CRS service value that can pin all of the manager's process from this particular concurrent manager to a specific instance in the RAC. There might be concurrent programs where the trace is enabled by default. *SELECT * FROM FND_CONCURRENT_PROGRAMS WHERE ENABLE_TRACE='Y'* can list all the concurrent programs for which trace is enabled. Revisit the list and take appropriate action. Usually for a specific issue, Oracle Support would ask you to turn on the trace, and people tend to forget to turn off the trace after the issue is resolved. Verify that the "Purge Concurrent Programs Request Logs" is scheduled to run. Frequency may vary depending on the site-specific and legislative requirements, but not running or running for anything more than 60 days would cause fnd_concurrent_requests and other related objects to grow substantially.

Workflow needs to be part of the discussion of concurrent managers. The Workflow Engine plays a major role in Oracle EBS. It has business events defined for various business functionalities that move the work from one place to the next. Work with the business analysts and/or functional folks to determine whether all the default business events are required for the current installation. There are numerous events that are turned on by default. When these events are on, they create workflow records in the Workflow tables, causing excessive growth in these tables. From time to time, run the EBS Workflow Analyzer Report as per "EBS Workflow (WF) Analyzer" (Doc ID 1369938.1). This HTML report will provide a clear picture of the state of the Workflow Engine, with different sections such as Workflow Administration, Workflow Footprint, Workflow Concurrent Programs, Workflow Notification Mailer, etc. Any check that's not passed needs to be looked into.

For example, if the Workflow Administration section shows there are a huge number of workflows that are in "stuck" status, they need to be cleaned up. Or if the Workflow Patch Levels section indicates patch levels are not up to the latest and greatest, these need to be worked on and cleaned up. Even after executing the recommendations from the Workflow Analyzer Report, if you see more volume in the WF tables, then consider adding dedicated WF agent listeners for sales orders/purchase orders and for generic deferred events to process heavy WF items through the Oracle Access Manager (OAM) screens. In addition, take a look at "Troubleshooting Workflow Data Growth Issues" (Doc ID 298550.1) for details on how to purge and delete the unwanted workflow data.

Applications—Finding Module-Specific Patches

There are module-specific performance issues and fixes available depending on what modules are being primarily used on your current production instances. However, there is a one-stop shop to find all the patches related to performance, from RDBMS to ATG to Financials and other major modules. This is documented in "Oracle E-Business Suite Recommended Performance Patches" (Doc ID 244040.1) and is very frequently updated for the newly identified and bug-fixed patches. If you are an Apps DBA, bookmark this page (it will come in handy at the time of need) and consult this document during the design/preparation stage of your next patching cycle.

Diagnostics Data Collection: EBS Analyzers

Over the years, EBS and its related support methodologies for day-to-day smooth operation have matured. As of this writing, there is an analyzer tool for most of the modules in EBS. Each of these tools is very valuable in terms of troubleshooting a module-specific problem, data discrepancy issues, an Accounts Payable (AP) problem, a concurrent manager issue, etc. Similar to the output described for the Workflow Analyzer Report in the “Concurrent Managers” section, all other analyzers produce a nice HTML-formatted report that can be used for in-house maintenance purposes or can be used at the time of troubleshooting or working with Oracle Support. The EBS analyzers are minimally invasive, and do not perform any INSERTs, UPDATEs, or DELETEs in the database. Instead, they just collect data to do a health check for a specific module. They review the overall footprint for a given module, review its configuration details, and provide recommendations based on best practices. Currently, the following analyzers are available to download from the Oracle Support website:

1. Workflow (WF) Analyzer
2. Concurrent Processing (CP) Analyzer
3. Reports & Printing Analyzer
4. Clone Log Parser Utility
5. Database Parameter Settings Analyzer
6. BI Publisher (BIP) Analyzer
7. Cash Management Transaction Analyzer
8. Oracle Receivables Adjustment Analyzer
9. Oracle Receivables AutoAccounting Analyzer
10. Oracle Receivables AutoInvoice Analyzer
11. Oracle Receivables Period Close Analyzer
12. Oracle Receivables Transaction Analyzer
13. R12: Master GDF Diagnostic (MGD) to Validate Data Related to Invoices, Payments, Accounting, Suppliers and EBTax
14. Payables Create Accounting Analyzer
15. Payables Period Close Analyzer
16. AP, AR, and EBTax Setup/Data Integrity Analyzer
17. Payables Trial Balance Analyzer
18. Oracle Payments (IBY) Funds Disbursement Analyzer
19. Oracle Public Sector Accounting (PSA) Data Validation Analyzer
20. Internet Expenses (OIE) Analyzer
21. Inventory Consignment Analyzer
22. Inventory Transaction Analyzer
23. Order Management Sales Order Analyzer
24. R12: Order Management (ONT) Analyzer Diagnostic Script

25. R12: Shipping Execution (WSH) Analyzer Diagnostic Script
26. V6.2: OTM Analyzer Script for Analysis and Performance Monitoring
27. R12: PO Approval Analyzer Diagnostic Script
28. iProcurement Item Analyzer
29. R12: Procurement Encumbrance Accounting Analyzer
30. R12: Procurement Accrual Reconciliation Analyzer
31. iProcurement Change Request Analyzer
32. Procure to Pay Analyzer
33. R11*i*/R12: ASCP Performance Analyzer Script
34. R11*i*/R12: ASCP Data Collections Analyzer Script for Setup and Performance Monitoring
35. V7.3.1: Demantra Performance and Setup Analyzer Script and Monitoring Tool
36. R12: Discrete LCM Integration Key Setup Analyzer
37. R12.1: OPM LCM Integration Key Setup Analyzer
38. Process Manufacturing (OPM) Actual Costing Analyzer
39. R12: SLA Unprocessed/Invalid Records Analyzer Diagnostic Script for cost management
40. Appraisal Analyzer
41. Payroll RetroPay Analyzer
42. HR Technical Analyzer
43. Oracle Time and Labor (OTL) Analyzer
44. Human Capital Management (HCM) Person Analyzer
45. Payroll Analyzer
46. Benefits (BEN) Analyzer
47. Channel Revenue Management (ChRM) SLA Unprocessed Transactions Analyze
48. Install Base Analyzer

The analyzers can be installed separately on an as-needed basis or can be downloaded as a bundle via the EBS Support Analyzer Bundle Menu Tool, a Perl-based menu system that you can download from Oracle Support Note 1939637.1.

Web Server Tuning

EBS 11*i* and R12.1.x run on Oracle Internet Application Server (iAS). Standard Apache performance tuning guidelines apply to these versions. You can enable verbose garbage collection methodologies, rotate the Apache logs for readability at certain sizes, increase/decrease the log levels, etc. The application is deployed based on the Java virtual machines (JVMs) for OACore, FormsGroup, oafm group, etc. These JVMs are the basic engines to serve the web traffic from the browsers/applications and can be tuned depending on the footprint of the installations. Oracle recommends one oacore JVM per 100 active/concurrent users. Typically, one CPU core can support one JVM, so if you have a dual quad core system (2*4=8 CPUs), it can support eight JVMs. But the numbers can vary according to the chip architecture. You can conservatively place four JVMs in a dual quad core system, or one JVM per two CPUs. On the other hand, the forms group can support up to 100 to 250 Oracle Forms users. But the number depends on what kind of forms the users are opening. More complex forms would require more resources. So, conservatively, we can say that one forms JVM can service around 125 Oracle Forms users.

Once you determine the active users in the EBS system, you can determine the number of JVMs required based on the given hardware according to the formulas in the previous paragraph. However, within a JVM, memory parameters play a crucial role in terms of garbage collection, minimum value of the starting footprint, and so on. The minimum and maximum memory per JVM are configurable. Some Java versions will not allow more than a 2GB footprint, but later versions from 1.6/1.7 onward allow a bigger footprint. So, the total memory needed should be calculated meticulously for a given web server so that the OS does not do excessive swapping.

For example, if you have two oacore JVMs with -Xmx1024M and one forms group with -Xmx1024M, that's 3GB of total memory requirement just for this particular web server. At the OS level, the server should have enough memory to support this configuration. For a larger environment, if you have more than a few hundred users—for example, if you are using Oracle EBS mainly for HCM with thousands of employees who would be using the iExpenses modules—then it is safe to assume that, at the expense report submitting deadlines, there would be around 500 concurrent users in the system. For this scenario, consider having more than one web/middle tier in a load-balanced environment. Each middle tier can have multiple oacore JVMs to support this kind of huge load. According to the expected end-user volume, the database-side processes/sessions parameters and other SGA-related memory parameters need to be increased/tuned as well.

All of the JVMs and their memory parameters are controlled by the AutoConfig variables oacore_nprocs, frmsrv_nprocs, forms_nprocs, oacore_jvm_start_options, oafm_jvm_start_options, and forms_jvm_start_option. Once these variables are properly adjusted in the context file, AutoConfig should be run for the new values to take effect.

Timeouts

There are numerous timeout variables that determine when to terminate an idle EBS connection. Timeout variables play an important role in the stability of an EBS system. Idle or runaway user connections will consume the resources on the web server JVMs, OS memory, database connections and database memory, and so forth. For larger environments, these variables need to be more carefully calibrated in order to avoid memory/CPU problems across the tech stack. These variables range from database to web server variables to application profiles. The following table was originally put forth by Greg Kitzmiller, and was later enhanced by TUSC. This is not complete by any means, but it is a good starting point on where and how to find out the actual values set across the tech stack of an EBS system.

Timeout Variable	Unit	Recom. Value	Metalink Notes	Comments
SQLNET.INBOUND_CONNECT_TIMEOUT	sec	60		Specifies the time for client to connect with the database server and provide necessary authentication information. If client fails to connect and complete authentication in the time specified, then the database server disconnects the connection. For slower networks, use a higher value, but not using this parameter at all will result in denial-of-service attacks where malicious clients can attempt to flood the database with a huge number of connect requests at the same time.
SQLNET.EXPIRE_TIME= 20	min	10		Specifies a time interval to send a probe and verify whether the client/server connections are still active. Keep it under the ICX: Session Timeout value. This will allow the database to clean up inactive DB sessions.

ICX: Session Timeout	min	30	ID 307149.1 ID 269884.1	Set by s_sesstimeout-self-service. This AutoConfig variable controls the ICX: Session Timeout profile and s_sesstimeout/s_oc4j_timeout from R12 onward. So, the actual value in the context file is specified in mille seconds but `afwebprf.sql` will convert this value into minutes and update the fnd_profile tables. You can manually update the profile from the apps but the next AutoConfig run will wipe out that settings. 30 minutes is the recommended value for a high performance system.
ICX: Limit Time	hrs	12	ID 269884.1	This profile controls the total time a forms session can be logged in. After this many number of hours you will get a pop-up warning window irrespective of the activity being done at that time.
ICX: Limit Connect	# of requests	2000	ID 269884.1	The maximum number of connection requests an user can make in a single session.
JTF_INACTIVE_SESSION_TIMEOUT	min	30		Should be the same as ICX: Session Timeout.
s_sesstimeout	ms	1800000	ID 307149.1 ID 269884.1	Sets initial value of ICX: Session Timeout. This should be set to default, which is 1800000. Anything higher can result in performance and out-of-memory errors.
s_f60time/s_formstime	min	5	ID 269884.1	Environment variable. The higher this variable is set, the longer the Forms processes will take to be cleaned up. Any dead connections older than 5 minutes would be cleaned up.

$OA_HTML/bin/ appsweb.cfg–Heartbeat	min	2	ID 269884.1	Forms client pings the server via a heartbeat message every 2 minutes by default. This heartbeat interval can be used to keep the connection alive if, e.g., the proxy or firewall has an inactivity timeout. If the server does not hear from the client for more than the heartbeat interval, it assumes that the client is gone and terminates that session. It should be less than s_f60time.
s_fmNetworkRetries	# of tries	30	ID 269884.1	Number of times the client should attempt to connect to the server if the network is interrupted.
s_oc4j_sesstimeout	min	30	ID 734077.1	Should match ICX: Session Timeout.
session.timeout	ms	600000	ID 307149.1 ID 1095629.1	$APACHE_TOP/Apache/Jserv/ etc/zone.properties; longer idle sessions will cause out-of-memory errors.

Database Initialization Parameter Sizing

This material is also part of Note 396009.1, and I think it is an excellent guideline! The following table should be used to size the relevant parameters to size the memory of an EBS database. See Chapter 4 for related information on this table.

Parameter Name	Development or Test Instance	11–100 Users	101–500 Users	501–1000 Users	1001–2000 Users
Processes	200	200	800	1200	2500
Sessions	400	400	1600	2400	5000
sga_target	1G	1G	2G	3G	14G
shared_pool_size (csp)	N/A	N/A	N/A	1800M	3000M
shared_pool_reserved_size (csp)	N/A	N/A	N/A	180M	300M
shared_pool_size (no csp)	400M	600M	800M	1000M	2000M
shared_pool_reserved_size (no csp)	40M	60M	80M	100M	100M
pga_aggregate_target	1G	2G	4G	10G	20G
Total Memory Required	~2 GB	~3 GB	~6 GB	~13 GB	~34 GB

Also part of Note 396009.1 are parameters from your database initialization parameters file that should be removed. Please see the note for that list. (My personal feeling is that some of these *should* be used to enhance performance, but many are not set because they feel that the DEFAULT is the correct setting … please test carefully!)

Top 10 Reasons *Not* to Write a Book

1. You like sleep and caffeine-enhanced water clogs your coffee maker.
2. You have enough trouble getting the time to read books, let alone write one.
3. You enjoy getting together with your family from time to time.
4. You’re tired of being the first one in the office (actually, you’ve been there all night).
5. Your hobby is golf and you never play.
6. You enjoy noticing the world around you rather than feeling a “purple haze all through your mind.”
7. Kevin Loney will write on that subject eventually … you’ll wait for his book.
8. You don’t want to “show off” how much you know … you’re far too humble.
9. Your PC is out of disk space already, although you’ve just loaded Windows 99.1415926.
10. You just got your *life* back after the last Oracle upgrade—no way!

TIP
Retirement is a good time to write a book, not during the fastest tech growth cycles in history (starting to get faster than pre-2000) followed by the Great Recession. Perhaps when the 2000-year bull market ends somewhere between 2018 and 2020 (good time to get out of the market in my opinion) that might be a better time.

Tips Review

- Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly *before* implementing those changes in a production environment.
- Oracle includes some excellent options. Unfortunately, some of them do *not* work unless you have the initialization parameter set correctly.
- Undocumented initialization parameters can corrupt your database! Some of them can help you salvage a corrupted database. Try to use these only when all other choices have failed and with the help of Oracle Support.
- Undocumented initialization parameters often show a glimpse of things coming in the next version of Oracle (or things going away from the last version). However, some of them don't work or could cause severe problems.
- Retirement is a good time to write a book, not during the fastest tech growth cycles in history (starting to get faster than pre-2000) followed by the Great Recession. Perhaps when the 2000-year bull market ends somewhere between 2018 and 2020 (good time to get out of the market in my opinion) that might be a better time.

References

Kevin Loney, *Oracle Database DBA Handbook* (McGraw-Hill).
Metalink Notes: 22908.1, 216205.1, 316889.1, 396009.1.
Various Oracle Support Notes and Documentation Manuals on Oracle Applications
Oracle Database Performance Tuning Guide, versions 11*g* and 12*c* (Oracle Corporation).

Thanks to Lucas Niemiec for testing the queries and providing the new listings for 11*g*R2. Thanks to Palani Kasi for new information on Oracle Applications. Thanks also to Brad Brown, Joe Trezzo, Randy Swanson, Sean McGuire, Greg Pucka, Mike Broullette, and Kevin Loney for their contributions to this chapter.

APPENDIX B

The V$ Views (DBA and Developer)

The V$ views are very helpful in analyzing database issues. There are 746 V$ views in 12*c*R2 (there were 525 in 11*g*R2). This appendix lists all views and creation scripts used to actually build the V$ and GV$ views. The V$ views vary in structure and number, depending on the database version and release used. Run the queries on your version of the database to get the number of views and structure for your specific version. The topics covered in this appendix include the following:

- Creation of V$ and GV$ views and X$ tables
- A list of all Oracle 12*c*R2 V$ views
- Oracle 12*c* script listing of the X$ tables used in the creation of the V$ views

NOTE
V$ to X$ and X$ to V$ cross-references can be found in Appendix C.

Creation of V$ and GV$ Views and X$ Tables

To understand the creation of X$ tables, knowing the V$ and data dictionary views can be crucial. And both are critical to comprehending fully the intricacies of Oracle. While knowledge of the views and tables is critical to your career, their creation has, however, remained somewhat of a vexing mystery. Figure 1 illustrates the creation of the underlying tables and the data dictionary views, whereas Figure 2 illustrates the creation of the X$ tables and the V$ views.

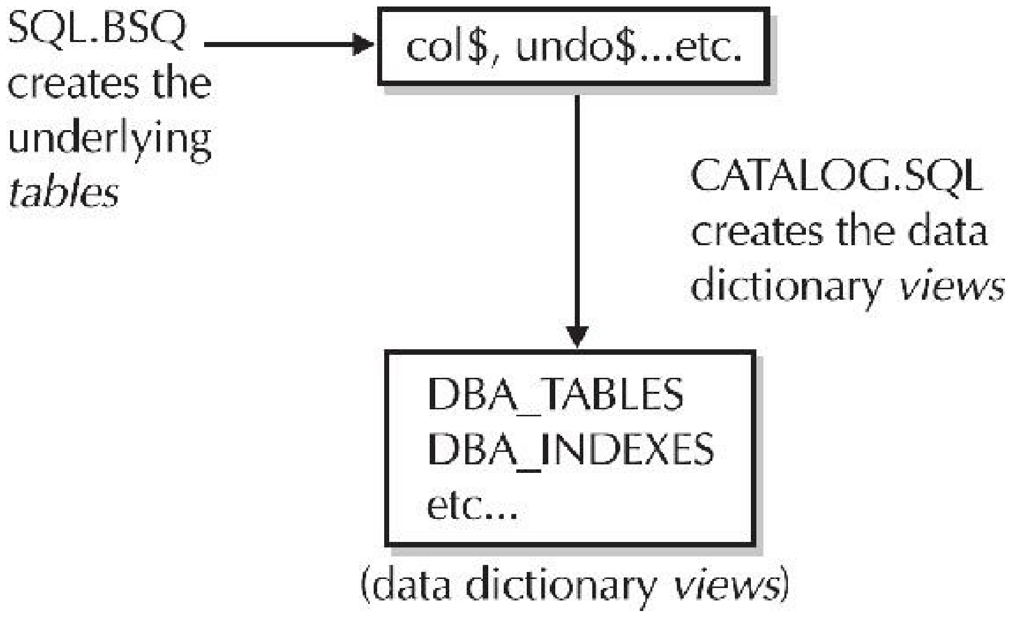
SQL.BSQ creates the underlying *tables*
col$, undo$...etc.
CATALOG.SQL creates the data dictionary *views*
DBA_TABLES
DBA_INDEXES
etc...
(data dictionary *views*)

FIGURE B-1. *Creation of the data dictionary views*

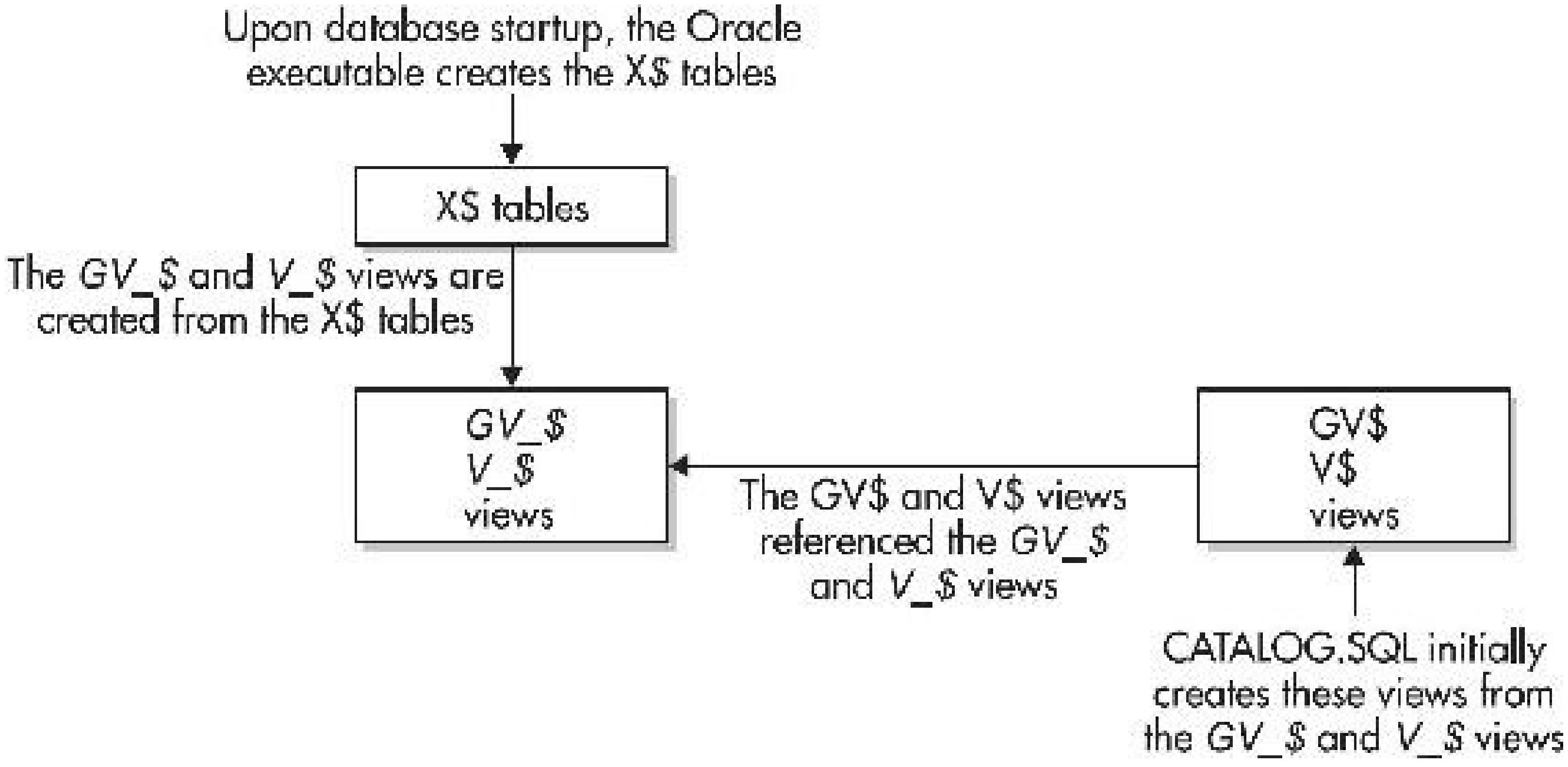
Upon database startup, the Oracle executable creates the X$ tables
X$ tables
The *GV_$* and *V_$* views are created from the X$ tables
GV_$
V_$
views
The GV$ and V$ views referenced the *GV_$* and *V_$* views
GV$
V$
views
CATALOG.SQL initially creates these views from the *GV_$* and *V_$* views

FIGURE B-2. *Creation of the X$ tables and the V$ views*

A List of Oracle 12*c* (12.2.0.0.1) GV$ Views

NOTE

The Oracle 12c V$ views are about the same as the GV$ views, minus the instance ID.

Here is the Oracle 12*c* query to obtain the listing of all the GV$ views (709 views):

```
set pagesize 1000

select    name
from      v$fixed_table
where     name like 'GV%'
order by  name;
```

A List of Oracle 12*c* (12.2.0.0.1) V$ Views

Here is the Oracle 12*c* query to get the listing of V$ views (746 views):

```
set pagesize 1000

select    name
from      v$fixed_table
where     name like 'V%'
order by  name;
```

The listing itself follows:

```
NAME
------------------------------------    ------------------------------
V$ACCESS                                 V$ASM_ACFS_SEC_REALM_GROUP
V$ACTIVE_INSTANCES                       V$ASM_ACFS_SEC_REALM_USER
V$ACTIVE_SERVICES                        V$ASM_ACFS_SEC_RULE
V$ACTIVE_SESSION_HISTORY                 V$ASM_ACFS_SEC_RULESET
V$ACTIVE_SESS_POOL_MTH                   V$ASM_ACFS_SEC_RULESET_RULE
V$ADVISOR_CURRENT_SQLPLAN                V$ASM_ALIAS
V$ADVISOR_PROGRESS                       V$ASM_ATTRIBUTE
V$ALERT_TYPES                            V$ASM_AUDIT_CLEANUP_JOBS
V$AQ1                                    V$ASM_AUDIT_CLEAN_EVENTS
V$AQ_BACKGROUND_COORDINATOR              V$ASM_AUDIT_CONFIG_PARAMS
V$AQ_BMAP_NONDUR_SUBSCRIBERS             V$ASM_AUDIT_LAST_ARCH_TS
V$AQ_CROSS_INSTANCE_JOBS                 V$ASM_CLIENT
V$AQ_DEQUEUE_TRANSACTIONS                V$ASM_DISK
V$AQ_JOB_COORDINATOR                     V$ASM_DISKGROUP
V$AQ_MESSAGE_CACHE                       V$ASM_DISKGROUP_SPARSE
V$AQ_MESSAGE_CACHE_ADVICE                V$ASM_DISKGROUP_STAT
V$AQ_MSGBM                               V$ASM_DISK_IOSTAT
V$AQ_NONDUR_REGISTRATIONS                V$ASM_DISK_IOSTAT_SPARSE
V$AQ_NONDUR_SUBSCRIBER                   V$ASM_DISK_SPARSE
V$AQ_NONDUR_SUBSCRIBER_LWM               V$ASM_DISK_SPARSE_STAT
V$AQ_NOTIFICATION_CLIENTS                V$ASM_DISK_STAT
V$AQ_OPT_CACHED_SUBSHARD                 V$ASM_ESTIMATE
V$AQ_OPT_INACTIVE_SUBSHARD               V$ASM_FILE
V$AQ_OPT_STATISTICS                      V$ASM_FILEGROUP
V$AQ_OPT_UNCACHED_SUBSHARD               V$ASM_FILEGROUP_FILE
V$AQ_REMOTE_DEQUEUE_AFFINITY             V$ASM_FILEGROUP_PROPERTY
V$AQ_SERVER_POOL                         V$ASM_FILESYSTEM
V$AQ_SHARDED_SUBSCRIBER_STAT             V$ASM_OPERATION
V$AQ_SUBSCRIBER_LOAD                     V$ASM_QUOTAGROUP
V$ARCHIVE                                V$ASM_TEMPLATE
V$ARCHIVED_LOG                           V$ASM_USER
V$ARCHIVE_DEST                           V$ASM_USERGROUP
V$ARCHIVE_DEST_STATUS                    V$ASM_USERGROUP_MEMBER
V$ARCHIVE_GAP                            V$ASM_VOLUME
V$ARCHIVE_PROCESSES                      V$ASM_VOLUME_STAT
V$ASH_INFO                               V$AW_AGGREGATE_OP
V$ASM_ACFSREPL                           V$AW_ALLOCATE_OP
V$ASM_ACFSREPLTAG                        V$AW_CALC
V$ASM_ACFSSNAPSHOTS                      V$AW_LONGOPS
V$ASM_ACFSTAG                            V$AW_OLAP
V$ASM_ACFSVOLUMES                        V$AW_SESSION_INFO
V$ASM_ACFS_ENCRYPTION_INFO               V$BACKUP
V$ASM_ACFS_SECURITY_INFO                 V$BACKUP_ARCHIVELOG_DETAILS
V$ASM_ACFS_SEC_ADMIN                     V$BACKUP_ARCHIVELOG_SUMMARY
V$ASM_ACFS_SEC_CMDRULE                   V$BACKUP_ASYNC_IO
V$ASM_ACFS_SEC_REALM                     V$BACKUP_COMPRESSION_PROGRESS
V$ASM_ACFS_SEC_REALM_FILTER              V$BACKUP_CONTROLFILE_DETAILS
```

V$BACKUP_CONTROLFILE_SUMMARY
V$BACKUP_COPY_DETAILS
V$BACKUP_COPY_SUMMARY
V$BACKUP_CORRUPTION
V$BACKUP_DATAFILE
V$BACKUP_DATAFILE_DETAILS
V$BACKUP_DATAFILE_SUMMARY
V$BACKUP_DEVICE
V$BACKUP_NONLOGGED
V$BACKUP_PIECE
V$BACKUP_PIECE_DETAILS
V$BACKUP_REDOLOG
V$BACKUP_SET
V$BACKUP_SET_DETAILS
V$BACKUP_SET_SUMMARY
V$BACKUP_SPFILE
V$BACKUP_SPFILE_DETAILS
V$BACKUP_SPFILE_SUMMARY
V$BACKUP_SYNC_IO
V$BGPROCESS
V$BH
V$BLOCKING_QUIESCE
V$BLOCK_CHANGE_TRACKING
V$BSP
V$BTS_STAT
V$BT_SCAN_CACHE
V$BT_SCAN_OBJ_TEMPS
V$BUFFERED_PUBLISHERS
V$BUFFERED_QUEUES
V$BUFFERED_SUBSCRIBERS
V$BUFFER_POOL
V$BUFFER_POOL_STATISTICS
V$CACHE
V$CACHE_LOCK
V$CACHE_TRANSFER
V$CALLTAG
V$CELL
V$CELL_CONFIG
V$CELL_CONFIG_INFO
V$CELL_DB
V$CELL_DB_HISTORY
V$CELL_DISK
V$CELL_DISK_HISTORY
V$CELL_GLOBAL
V$CELL_GLOBAL_HISTORY
V$CELL_IOREASON
V$CELL_IOREASON_NAME
V$CELL_METRIC_DESC
V$CELL_OFL_THREAD_HISTORY
V$CELL_OPEN_ALERTS
V$CELL_REQUEST_TOTALS
V$CELL_STATE
V$CELL_THREAD_HISTORY
V$CHANNEL_WAITS
V$CHUNK_METRIC
V$CIRCUIT
V$CLASS_CACHE_TRANSFER
V$CLASS_PING
V$CLEANUP_PROCESS
V$CLIENT_RESULT_CACHE_STATS
V$CLIENT_SECRETS
V$CLIENT_STATS
V$CLONEDFILE
V$CLUSTER_INTERCONNECTS
V$CODE_CLAUSE
V$COLUMN_STATISTICS
V$CONFIGURED_INTERCONNECTS
V$CONTAINERS
V$CONTEXT
V$CONTROLFILE
V$CONTROLFILE_RECORD_SECTION
V$CON_SYSMETRIC
V$CON_SYSMETRIC_HISTORY
V$CON_SYSMETRIC_SUMMARY
V$CON_SYSSTAT
V$CON_SYSTEM_EVENT
V$CON_SYSTEM_WAIT_CLASS
V$CON_SYS_TIME_MODEL
V$COPY_CORRUPTION
V$COPY_NONLOGGED
V$CORRUPT_XID_LIST
V$CPOOL_CC_INFO
V$CPOOL_CC_STATS
V$CPOOL_CONN_INFO
V$CPOOL_STATS
V$CR_BLOCK_SERVER
V$CURRENT_BLOCK_SERVER
V$DATABASE
V$DATABASE_BLOCK_CORRUPTION
V$DATABASE_INCARNATION
V$DATABASE_KEY_INFO
V$DATAFILE
V$DATAFILE_COPY
V$DATAFILE_HEADER
V$DATAGUARD_CONFIG
V$DATAGUARD_PROCESS
V$DATAGUARD_STATS
V$DATAGUARD_STATUS

V$DATAPUMP_JOB
V$DATAPUMP_SESSION
V$DBFILE
V$DBLINK
V$DB_CACHE_ADVICE
V$DB_OBJECT_CACHE
V$DB_PIPES
V$DB_TRANSPORTABLE_PLATFORM
V$DEAD_CLEANUP
V$DELETED_OBJECT
V$DETACHED_SESSION
V$DG_BROKER_CONFIG
V$DIAG_APP_TRACE_FILE
V$DIAG_CRITICAL_ERROR
V$DIAG_INFO
V$DIAG_OPT_TRACE_RECORDS
V$DIAG_SESS_OPT_TRACE_RECORDS
V$DIAG_SESS_SQL_TRACE_RECORDS
V$DIAG_SQL_TRACE_RECORDS
V$DIAG_TRACE_FILE
V$DIAG_TRACE_FILE_CONTENTS
V$DISPATCHER
V$DISPATCHER_CONFIG
V$DISPATCHER_RATE
V$DLM_ALL_LOCKS
V$DLM_CONVERT_LOCAL
V$DLM_CONVERT_REMOTE
V$DLM_LATCH
V$DLM_LOCKS
V$DLM_MISC
V$DLM_RESS
V$DLM_TRAFFIC_CONTROLLER
V$DML_STATS
V$DNFS_CHANNELS
V$DNFS_FILES
V$DNFS_SERVERS
V$DNFS_STATS
V$DYNAMIC_REMASTER_STATS
V$EDITIONABLE_TYPES
V$EMON
V$EMX_USAGE_STATS
V$ENABLEDPRIVS
V$ENCRYPTED_TABLESPACES
V$ENCRYPTION_KEYS
V$ENCRYPTION_WALLET
V$ENQUEUE_LOCK
V$ENQUEUE_STAT
V$ENQUEUE_STATISTICS
V$EVENTMETRIC
V$EVENT_HISTOGRAM
V$EVENT_HISTOGRAM_MICRO
V$EVENT_NAME
V$EVENT_OUTLIERS
V$EXADIRECT_ACL
V$EXECUTION
V$EXP_STATS
V$FALSE_PING
V$FAST_START_SERVERS
V$FAST_START_TRANSACTIONS
V$FILEMETRIC
V$FILEMETRIC_HISTORY
V$FILESPACE_USAGE
V$FILESTAT
V$FILE_CACHE_TRANSFER
V$FILE_HISTOGRAM
V$FILE_OPTIMIZED_HISTOGRAM
V$FILE_PING
V$FIXED_TABLE
V$FIXED_VIEW_DEFINITION
V$FLASHBACK_DATABASE_LOG
V$FLASHBACK_DATABASE_LOGFILE
V$FLASHBACK_DATABASE_STAT
V$FLASHBACK_TXN_GRAPH
V$FLASHBACK_TXN_MODS
V$FLASHFILESTAT
V$FLASH_RECOVERY_AREA_USAGE
V$FOREIGN_ARCHIVED_LOG
V$FS_FAILOVER_HISTOGRAM
V$FS_FAILOVER_OBSERVERS
V$FS_FAILOVER_STATS
V$FS_OBSERVER_HISTOGRAM
V$GCR_ACTIONS
V$GCR_LOG
V$GCR_METRICS
V$GCR_STATUS
V$GCSHVMASTER_INFO
V$GCSPFMASTER_INFO
V$GC_ELEMENT
V$GC_ELEMENTS_WITH_COLLISIONS
V$GES_BLOCKING_ENQUEUE
V$GES_DEADLOCKS
V$GES_DEADLOCK_SESSIONS
V$GES_ENQUEUE
V$GG_APPLY_COORDINATOR
V$GG_APPLY_READER
V$GG_APPLY_RECEIVER
V$GG_APPLY_SERVER
V$GLOBALCONTEXT

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V$GLOBAL_BLOCKED_LOCKS
V$GLOBAL_TRANSACTION
V$GOLDENGATE_CAPABILITIES
V$GOLDENGATE_CAPTURE
V$GOLDENGATE_MESSAGE_TRACKING
V$GOLDENGATE_PROCEDURE_STATS
V$GOLDENGATE_TABLE_STATS
V$GOLDENGATE_TRANSACTION
V$HANG_INFO
V$HANG_SESSION_INFO
V$HANG_STATISTICS
V$HEAT_MAP_SEGMENT
V$HM_CHECK
V$HM_CHECK_PARAM
V$HM_FINDING
V$HM_INFO
V$HM_RECOMMENDATION
V$HM_RUN
V$HS_AGENT
V$HS_PARAMETER
V$HS_SESSION
V$HVMASTER_INFO
V$IMEU_HEADER
V$IM_ADOELEMENTS
V$IM_ADOTASKDETAILS
V$IM_ADOTASKS
V$IM_COLUMN_LEVEL
V$IM_COL_CU
V$IM_HEADER
V$IM_IMECOL_CU
V$IM_SEGDICT
V$IM_SEGDICT_PIECEMAP
V$IM_SEGDICT_SORTORDER
V$IM_SEGDICT_VERSION
V$IM_SEGMENTS
V$IM_SEGMENTS_DETAIL
V$IM_SEG_EXT_MAP
V$IM_SMU_CHUNK
V$IM_SMU_HEAD
V$IM_TBS_EXT_MAP
V$IM_USER_SEGMENTS
V$INCMETER_CONFIG
V$INCMETER_INFO
V$INCMETER_SUMMARY
V$INDEXED_FIXED_COLUMN
V$INDEX_USAGE_INFO
V$INMEMORY_AREA
V$INMEMORY_XMEM_AREA
V$INSTANCE
V$INSTANCE_CACHE_TRANSFER
V$INSTANCE_LOG_GROUP
V$INSTANCE_PING
V$INSTANCE_RECOVERY
V$IOFUNCMETRIC
V$IOFUNCMETRIC_HISTORY
V$IOSTAT_CONSUMER_GROUP
V$IOSTAT_FILE
V$IOSTAT_FUNCTION
V$IOSTAT_FUNCTION_DETAIL
V$IOSTAT_NETWORK
V$IOS_CLIENT
V$IO_CALIBRATION_STATUS
V$IO_OUTLIER
V$IP_ACL
V$IR_FAILURE
V$IR_FAILURE_SET
V$IR_MANUAL_CHECKLIST
V$IR_REPAIR
V$JAVAPOOL
V$JAVA_LIBRARY_CACHE_MEMORY
V$JAVA_POOL_ADVICE
V$KERNEL_IO_OUTLIER
V$KEY_VECTOR
V$LATCH
V$LATCHHOLDER
V$LATCHNAME
V$LATCH_CHILDREN
V$LATCH_MISSES
V$LATCH_PARENT
V$LGWRIO_OUTLIER
V$LIBCACHE_LOCKS
V$LIBRARYCACHE
V$LIBRARY_CACHE_MEMORY
V$LICENSE
V$LISTENER_NETWORK
V$LOADISTAT
V$LOADPSTAT
V$LOBSTAT
V$LOCK
V$LOCKED_OBJECT
V$LOCKS_WITH_COLLISIONS
V$LOCK_ACTIVITY
V$LOCK_ELEMENT
V$LOCK_TYPE
V$LOG
V$LOGFILE
V$LOGHIST
V$LOGMNR_CONTENTS
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V$LOGMNR_DBA_OBJECTS
V$LOGMNR_DICTIONARY
V$LOGMNR_DICTIONARY_LOAD
V$LOGMNR_EXTENTS
V$LOGMNR_LATCH
V$LOGMNR_LOGFILE
V$LOGMNR_LOGS
V$LOGMNR_OBJECT_SEGMENTS
V$LOGMNR_PARAMETERS
V$LOGMNR_PROCESS
V$LOGMNR_SESSION
V$LOGMNR_STATS
V$LOGMNR_SYS_DBA_SEGS
V$LOGMNR_SYS_OBJECTS
V$LOGMNR_TRANSACTION
V$LOGSTDBY
V$LOGSTDBY_PROCESS
V$LOGSTDBY_PROGRESS
V$LOGSTDBY_STATE
V$LOGSTDBY_STATS
V$LOGSTDBY_TRANSACTION
V$LOG_HISTORY
V$MANAGED_STANDBY
V$MAPPED_SQL
V$MAP_COMP_LIST
V$MAP_ELEMENT
V$MAP_EXT_ELEMENT
V$MAP_FILE
V$MAP_FILE_EXTENT
V$MAP_FILE_IO_STACK
V$MAP_LIBRARY
V$MAP_SUBELEMENT
V$MAX_ACTIVE_SESS_TARGET_MTH
V$MEMORY_CURRENT_RESIZE_OPS
V$MEMORY_DYNAMIC_COMPONENTS
V$MEMORY_RESIZE_OPS
V$MEMORY_TARGET_ADVICE
V$METRIC
V$METRICGROUP
V$METRICNAME
V$METRIC_HISTORY
V$MTTR_TARGET_ADVICE
V$MUTEX_SLEEP
V$MUTEX_SLEEP_HISTORY
V$MVREFRESH
V$MYSTAT
V$NFS_CLIENTS
V$NFS_LOCKS
V$NFS_OPEN_FILES
V$NLS_PARAMETERS
V$NLS_VALID_VALUES
V$NONLOGGED_BLOCK
V$OBJECT_DEPENDENCY
V$OBJECT_DML_FREQUENCIES
V$OBJECT_PRIVILEGE
V$OBSOLETE_PARAMETER
V$OFFLINE_RANGE
V$OFSMOUNT
V$OFS_STATS
V$ONLINE_REDEF
V$OPEN_CURSOR
V$OPTIMIZER_PROCESSING_RATE
V$OPTION
V$OSSTAT
V$PARALLEL_DEGREE_LIMIT_MTH
V$PARAMETER
V$PARAMETER2
V$PARAMETER_VALID_VALUES
V$PASSWORDFILE_INFO
V$PATCHES
V$PDBS
V$PDB_INCARNATION
V$PERSISTENT_PUBLISHERS
V$PERSISTENT_QMN_CACHE
V$PERSISTENT_QUEUES
V$PERSISTENT_SUBSCRIBERS
V$PGASTAT
V$PGA_TARGET_ADVICE
V$PGA_TARGET_ADVICE_HISTOGRAM
V$PING
V$POLICY_HISTORY
V$PQ_SESSTAT
V$PQ_SLAVE
V$PQ_SYSSTAT
V$PQ_TQSTAT
V$PROCESS
V$PROCESS_GROUP
V$PROCESS_MEMORY
V$PROCESS_MEMORY_DETAIL
V$PROCESS_MEMORY_DETAIL_PROG
V$PROCESS_POOL
V$PROCESS_PRIORITY_DATA
V$PROPAGATION_RECEIVER
V$PROPAGATION_SENDER
V$PROXY_ARCHIVEDLOG
V$PROXY_ARCHIVELOG_DETAILS
V$PROXY_ARCHIVELOG_SUMMARY
V$PROXY_COPY_DETAILS

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V$PROXY_COPY_SUMMARY
V$PROXY_DATAFILE
V$PWFILE_USERS
V$PX_BUFFER_ADVICE
V$PX_INSTANCE_GROUP
V$PX_PROCESS
V$PX_PROCESS_SYSSTAT
V$PX_PROCESS_TRACE
V$PX_SESSION
V$PX_SESSTAT
V$QMON_COORDINATOR_STATS
V$QMON_SERVER_STATS
V$QMON_TASKS
V$QMON_TASK_STATS
V$QPX_INVENTORY
V$QUARANTINE
V$QUEUE
V$QUEUEING_MTH
V$RECOVERY_AREA_USAGE
V$RECOVERY_FILE_DEST
V$RECOVERY_FILE_STATUS
V$RECOVERY_LOG
V$RECOVERY_PROGRESS
V$RECOVERY_SLAVE
V$RECOVERY_STATUS
V$RECOVER_FILE
V$REDO_DEST_RESP_HISTOGRAM
V$REPLAY_CONTEXT
V$REPLAY_CONTEXT_LOB
V$REPLAY_CONTEXT_SEQUENCE
V$REPLAY_CONTEXT_SYSDATE
V$REPLAY_CONTEXT_SYSGUID
V$REPLAY_CONTEXT_SYSTIMESTAMP
V$REQDIST
V$RESERVED_WORDS
V$RESOURCE
V$RESOURCE_LIMIT
V$RESTORE_POINT
V$RESULT_CACHE_DEPENDENCY
V$RESULT_CACHE_DR
V$RESULT_CACHE_MEMORY
V$RESULT_CACHE_OBJECTS
V$RESULT_CACHE_RD
V$RESULT_CACHE_RR
V$RESULT_CACHE_STATISTICS
V$RESUMABLE
V$RFS_THREAD
V$RMAN_BACKUP_JOB_DETAILS
V$RMAN_BACKUP_SUBJOB_DETAILS
V$RMAN_BACKUP_TYPE
V$RMAN_COMPRESSION_ALGORITHM
V$RMAN_CONFIGURATION
V$RMAN_ENCRYPTION_ALGORITHMS
V$RMAN_OUTPUT
V$RMAN_STATUS
V$ROLLSTAT
V$ROWCACHE
V$ROWCACHE_PARENT
V$ROWCACHE_SUBORDINATE
V$RO_USER_ACCOUNT
V$RSRCMGRMETRIC
V$RSRCMGRMETRIC_HISTORY
V$RSRCPDBMETRIC
V$RSRCPDBMETRIC_HISTORY
V$RSRC_CONSUMER_GROUP
V$RSRC_CONSUMER_GROUP_CPU_MTH
V$RSRC_CONS_GROUP_HISTORY
V$RSRC_PDB
V$RSRC_PDB_HISTORY
V$RSRC_PLAN
V$RSRC_PLAN_CPU_MTH
V$RSRC_PLAN_HISTORY
V$RSRC_SESSION_INFO
V$RT_ADDM_CONTROL
V$RULE
V$RULE_SET
V$RULE_SET_AGGREGATE_STATS
V$SCHEDULER_INMEM_MDINFO
V$SCHEDULER_INMEM_RTINFO
V$SCHEDULER_RUNNING_JOBS
V$SECUREFILE_TIMER
V$SEGMENT_STATISTICS
V$SEGSPACE_USAGE
V$SEGSTAT
V$SEGSTAT_NAME
V$SERVICEMETRIC
V$SERVICEMETRIC_HISTORY
V$SERVICES
V$SERVICE_EVENT
V$SERVICE_REGION_METRIC
V$SERVICE_STATS
V$SERVICE_WAIT_CLASS
V$SERV_MOD_ACT_STATS
V$SESSION
V$SESSIONS_COUNT
V$SESSION_BLOCKERS
V$SESSION_CLIENT_RESULT_CACHE
V$SESSION_CONNECT_INFO
```

V$SESSION_CURSOR_CACHE
V$SESSION_EVENT
V$SESSION_FIX_CONTROL
V$SESSION_LONGOPS
V$SESSION_OBJECT_CACHE
V$SESSION_WAIT
V$SESSION_WAIT_CLASS
V$SESSION_WAIT_HISTORY
V$SESSMETRIC
V$SESSTAT
V$SESS_IO
V$SESS_TIME_MODEL
V$SES_OPTIMIZER_ENV
V$SGA
V$SGAINFO
V$SGASTAT
V$SGA_CURRENT_RESIZE_OPS
V$SGA_DYNAMIC_COMPONENTS
V$SGA_DYNAMIC_FREE_MEMORY
V$SGA_RESIZE_OPS
V$SGA_TARGET_ADVICE
V$SHADOW_DATAFILE
V$SHARED_POOL_ADVICE
V$SHARED_POOL_RESERVED
V$SHARED_SERVER
V$SHARED_SERVER_MONITOR
V$SORT_SEGMENT
V$SORT_USAGE
V$SPPARAMETER
V$SQL
V$SQLAREA
V$SQLAREA_PLAN_HASH
V$SQLCOMMAND
V$SQLFN_ARG_METADATA
V$SQLFN_METADATA
V$SQLPA_METRIC
V$SQLSTATS
V$SQLSTATS_PLAN_HASH
V$SQLTEXT
V$SQLTEXT_WITH_NEWLINES
V$SQL_BIND_DATA
V$SQL_BIND_METADATA
V$SQL_CS_HISTOGRAM
V$SQL_CS_SELECTIVITY
V$SQL_CS_STATISTICS
V$SQL_CURSOR
V$SQL_DIAG_REPOSITORY
V$SQL_DIAG_REPOSITORY_REASON
V$SQL_FEATURE
V$SQL_FEATURE_DEPENDENCY
V$SQL_FEATURE_HIERARCHY
V$SQL_HINT
V$SQL_JOIN_FILTER
V$SQL_MONITOR
V$SQL_MONITOR_SESSTAT
V$SQL_MONITOR_STATNAME
V$SQL_OPTIMIZER_ENV
V$SQL_PLAN
V$SQL_PLAN_MONITOR
V$SQL_PLAN_STATISTICS
V$SQL_PLAN_STATISTICS_ALL
V$SQL_REDIRECTION
V$SQL_REOPTIMIZATION_HINTS
V$SQL_SHARED_CURSOR
V$SQL_SHARED_MEMORY
V$SQL_WORKAREA
V$SQL_WORKAREA_ACTIVE
V$SQL_WORKAREA_HISTOGRAM
V$SSCR_SESSIONS
V$STANDBY_EVENT_HISTOGRAM
V$STANDBY_LOG
V$STATISTICS_LEVEL
V$STATNAME
V$STATS_ADVISOR_ACTIONS
V$STATS_ADVISOR_FINDINGS
V$STATS_ADVISOR_RATIONALES
V$STATS_ADVISOR_RECS
V$STATS_ADVISOR_RULES
V$STREAMS_APPLY_COORDINATOR
V$STREAMS_APPLY_READER
V$STREAMS_APPLY_SERVER
V$STREAMS_CAPTURE
V$STREAMS_MESSAGE_TRACKING
V$STREAMS_POOL_ADVICE
V$STREAMS_POOL_STATISTICS
V$STREAMS_TRANSACTION
V$SUBCACHE
V$SUBSCR_REGISTRATION_STATS
V$SYSAUX_OCCUPANTS
V$SYSMETRIC
V$SYSMETRIC_HISTORY
V$SYSMETRIC_SUMMARY
V$SYSSTAT
V$SYSTEM_CURSOR_CACHE

```
V$SYSTEM_EVENT
V$SYSTEM_FIX_CONTROL
V$SYSTEM_PARAMETER
V$SYSTEM_PARAMETER2
V$SYSTEM_PARAMETER4
V$SYSTEM_RESET_PARAMETER
V$SYSTEM_RESET_PARAMETER2
V$SYSTEM_WAIT_CLASS
V$SYS_OPTIMIZER_ENV
V$SYS_REPORT_REQUESTS
V$SYS_REPORT_STATS
V$SYS_TIME_MODEL
V$TABLESPACE
V$TEMPFILE
V$TEMPFILE_INFO_INSTANCE
V$TEMPORARY_LOBS
V$TEMPSTAT
V$TEMPUNDOSTAT
V$TEMP_CACHE_TRANSFER
V$TEMP_EXTENT_MAP
V$TEMP_EXTENT_POOL
V$TEMP_PING
V$TEMP_SPACE_HEADER
V$THREAD
V$THRESHOLD_TYPES
V$TIMER
V$TIMEZONE_FILE
V$TIMEZONE_NAMES
V$TOPLEVELCALL
V$TRANSACTION
V$TRANSACTION_ENQUEUE
V$TRANSPORTABLE_PLATFORM
V$TSDP_SUPPORTED_FEATURE
V$TSM_SESSIONS
V$TYPE_SIZE
V$UNDOSTAT
V$UNIFIED_AUDIT_RECORD_FORMAT
V$UNIFIED_AUDIT_TRAIL
V$UNUSABLE_BACKUPFILE_DETAILS
V$VERSION
V$VPD_POLICY
V$WAITCLASSMETRIC
V$WAITCLASSMETRIC_HISTORY
V$WAITSTAT
V$WAIT_CHAINS
V$WALLET
V$WLM_DB_MODE
V$WLM_PCMETRIC
V$WLM_PCMETRIC_HISTORY
V$WLM_PC_STATS
V$WORKLOAD_REPLAY_THREAD
V$XML_AUDIT_TRAIL
V$XSTREAM_APPLY_COORDINATOR
V$XSTREAM_APPLY_READER
V$XSTREAM_APPLY_RECEIVER
V$XSTREAM_APPLY_SERVER
V$XSTREAM_CAPTURE
V$XSTREAM_MESSAGE_TRACKING
V$XSTREAM_OUTBOUND_SERVER
V$XSTREAM_TABLE_STATS
V$XSTREAM_TRANSACTION
V$XS_SESSIONS
V$XS_SESSION_NS_ATTRIBUTE
V$XS_SESSION_ROLE
V$ZONEMAP_USAGE_STATS
V$_LOCK
V$_LOCK1
V$_SEQUENCES

746 rows selected.
```

Oracle 12*c* Scripts for the X$ Tables Used to Create the V$ Views

Because of the number of views in 12*c*, it's no longer possible to list all queries in this book. To give you a sampling of what's available, this section list scripts for a few dozen views that pertain to performance tuning so you can see the results. You can run your own query to see a specific one. The most common new columns that you'll see in the 12*c* of the views are CON_ID (Container ID), with the advent of pluggable databases, and Adaptive Query Optimization columns. Here is the Oracle 12*c*R2 query to get a listing of *all* X$ queries for the V$ views (it will return 1457 rows in 12*c*R2; V$ and GV$ are returned):

```
select 'View Name: '||view_name,
 substr(substr(view_definition,1,3900),1,(instr(view_definition,'from')-1)) def1,
 substr(substr(view_definition,1,3900),(instr(view_definition,'from')))||';'def2
from   v$fixed_view_definition
order  by view_name;
```

View Name: GV$BH (New in 12*c* Bolded)

```
select bh.inst_id, file#, dbablk, class, decode(state,0,'free',1,'xcur',2,
       'scur',3,'cr', 4,'read',5,'mrec',6,'irec',7,'write',8,'pi',
       9,'memory',10,'mwrite',11,'donated', 12,'protected',13,'securefile',
       14,'siop',15,'recckpt', 16, 'flashfree',  17, 'flashcur', 18, 'flashna'),
       0, 0, 0, bh.le_addr, le_id1, le_id2, decode(bitand(flag,1), 0, 'N', 'Y'),
       decode(bitand(flag,16),0,'N','Y'), decode(bitand(flag,1536),0, 'N','Y'),
       decode(bitand(flag,16384), 0, 'N', 'Y'),
       decode(bitand(flag,65536), 0, 'N', 'Y'), 'N',
       obj, ts#, lobid,  bitand(OBJ_FLAG, 240)/16,
       decode(bitand(OBJ_FLAG, 48)/16, 1, 'KEEP', 2, 'NONE', 'DEFAULT'),
       decode(bitand(OBJ_FLAG,192)/64,1,'KEEP',2,'NONE','DEFAULT'),bh.con_id
from   x$bh bh, x$le le
where  bh.le_addr = le.le_addr (+);
```

View Name: V$BH (New in 12*c* Bolded)

```
select file#, block#, class#, status, xnc, forced_reads, forced_writes,
       lock_element_addr,lock_element_name, lock_element_class, dirty,
       temp, ping, stale, direct, new, objd,
       ts#, lobid, cachehint, flash_cache, cell_flash_cache, con_id
from   gv$bh
where  inst_id = USERENV('Instance');
```

View Name: GV$CELL

```
select inst_id, cellpath_cellrow, cellhashval_cellrow,
       con_id, celltype_cellrow
from   x$cell_name;
```

View Name: V$CELL

```
select cell_path, cell_hashval, con_id, cell_type
from   gv$cell
where  inst id = userenv('Instance');
```

View Name: GV$CELL_DISK

```
select c.cellpath_cellrow, cd.cell_hash, cd.incarnation_num, cd.metric_timestamp,
       cd.disk, cd.disk_id, cd.metric_id, md.metric_name, cd.metric_value,
       md.metric_type, cd.inst_id, cd.con_id
from   x$kxdcm disk cd, x$kxdcm metric desc md,x$cell name c
where  cd.metric_id - md.metric_id
and    cd.cell_hash = c.cellhashval_cellrow and cd.inst_id = md.inst_id
and    cd.con_id = md.con_id and cd.inst_id = c.inst_id
and    cd.con id - c.con id;
```

View Name: V$CELL_DISK

```
select cell name, cell hash, incarnation num, metric timestamp, disk name,
       disk_id, metric_id, metric_name, metric_value, metric_type, con_id
from   gv$cell_disk
where  inst id = userenv('Instance');
```

View Name: GV$CONTAINERS

```
select inst_id, con_id, dbid, con_uid, guid, name,
       decode(state, 0, 'MOUNTED', 1, 'READ WRITE', 2, 'READ ONLY',
       3, 'MIGRATE'), decode(restricted, 0, 'NO', 1, 'YES'), stime,
       create_scn, total_size, block_size, decode(recovery_status, 0,
       'ENABLED', 1, 'DISABLED'), snapshot_parent_con_id,decode(app_root,
       1, 'YES', 'NO'),decode(app_root_con_id, NULL,'NO','YES'),
       decode(app_seed, 1, 'YES', 'NO'), app_root_con_id, decode(app_root_clone,
       1, 'YES', 'NO'),decode(proxy pdb, 1, 'YES', 'NO')  from   x$con;
```

View Name: V$CONTAINERS

```
select con_id, dbid, con_uid, guid, name,  open_mode, restricted, open_time,
       create_scn, total_size,block_size,recovery_status,snapshot_parent_con_id,
       application_root,application_pdb,application_seed,application_root_con_id,
       application root clone, proxy pdb
from   gv$containers
where  inst id = userenv('Instance');
```

View Name: GV$INMEMORY_AREA

```
select inst id, pool, allocated len, used len, status, con id
from   x$ktsimau;
```

View Name: V$INMEMORY_AREA

```
select pool, alloc_bytes, used_bytes, populate_status, con_id
from   gv$inmemory_area
where  inst id= userenv('instance');
```

View Name: GV$LATCH

```
select lt.inst id,lt.kslltaddr,lt.kslltnum,lt.kslltlvl,lt.kslltnam, lt.kslltgsh,
       lt.kslltwgt,lt.kslltwff,lt.kslltwsl,lt.kslltngt,lt.kslltnfa,lt.kslltwkc,
       lt.kslltwth,lt.ksllthst0,lt.ksllthst1,lt.ksllthst2,lt.ksllthst3,
       lt.ksllthst4,lt.ksllthst5,lt.ksllthst6,lt.ksllthst7,t.ksllthst8,
       lt.ksllthst9, lt.ksllthst10, lt.ksllthst11, lt.kslltwtt, lt.con_id
from   x$kslltr lt;
```

View Name: V$LATCH

```
select addr,latch#,level#,name,hash,gets,misses,sleeps,immediate_gets,
       immediate misses,waiters woken,waits holding latch,spin
gets,sleep1,sleep2,
       sleep3,sleep4,sleep5,sleep6,sleep7,sleep8,sleep9,sleep10,sleep11,
       wait_time, con_id
from   gv$latch
where  inst id = USERENV('Instance');
```

View Name: GV$LATCHHOLDER

```
select inst_id,ksuprpid,ksuprsid,ksuprlat, ksuprlnm, ksulagts, con_id
from   x$ksuprlat;
```

View Name: V$LATCHHOLDER

```
select pid,sid,laddr,name,gets,con_id
from   gv$latchholder
where  inst_id = userenv('Instance');
```

View Name: GV$LATCHNAME

```
select inst_id, indx,kslldnam, kslldd sp, kslldhsh, con_id
from   x$kslld;
```

View Name: V$LATCHNAME

```
select latch#, name, display_name, hash, con_id
from   gv$latchname
where  inst_id = userenv('Instance');
```

View Name: GV$LATCH_CHILDREN

```
select t.inst_id,t.kslltaddr,t.kslltnum,t.kslltcnm,t.kslltlvl,t.kslltnam,
       t.ksllthsh,t.kslltwgt,t.kslltwff,t.kslltwsl,t.kslltngt,t.kslltnfa,
       t.kslltwkc,t.kslltwth,t.ksllthst0,t.ksllthst1,t.ksllthst2,t.ksllthst3,
       t.ksllthst4,t.ksllthst5,t.ksllthst6,t.ksllthst7,t.ksllthst8,t.ksllthst9,
       t.ksllthst10, t.ksllthst11,t.kslltwtt,t.con_id
from   x$kslltr_children t;
```

View Name: V$LATCH_CHILDREN

```
select addr,latch#,child#,level#,name,hash,gets,misses,sleeps,immediate_gets,
       immediate_misses,waiters_woken,waits_holding_latch,spin_gets,sleep1,sleep2,
       sleep3,sleep4,sleep5,sleep6,sleep7,sleep8,sleep9,sleep10,sleep11,
       wait_time,con_id
from   gv$latch_children
where  inst_id = USERENV('Instance');
```

View Name: GV$LATCH_MISSES

```
select t1.inst_id,t1.ksllasnam,t2.ksllwnam,t1.kslnowtf,t1.kslsleep,t1.kslwscwsl,
       t1.kslwsclthg,t2.ksllwnam,t1.con_id
from   x$ksllw t2,x$kslwsc t1
where  t2.indx = t1.kslwscwhere;
```

View Name: V$LATCH_MISSES

```
select parent_name,location,nwfail_count,sleep_count,wtr_slp_count,longhold_count,
       location, con_id
from   gv$latch_misses
where  inst_id = USERENV('Instance');
```

View Name: GV$LIBRARYCACHE

```
select inst_id, kglstdsc, kglstget, kglstght,
       decode(kglstget,0,1,kglstght/kglstget),kglstpin,kglstpht,
       decode(kglstpin,0,1,kglstpht/kglstpin),kglstrld,kglstinv,
       kglstlrq, kglstprq, kglstprq, kglstmiv, kglstmiv, con_id
from   x$kglst
where  kglsttyp = 'NAMESPACE'
and    kglstget != 0
and    LENGTH(kglstdsc) <= 15 ;
```

View Name: V$LIBRARYCACHE

```
select namespace,gets,gethits,gethitratio,pins,pinhits,pinhitratio,reloads,
       invalidations,dlm_lock_requests,dlm_pin_requests,dlm_pin_releases,
       dlm_invalidation_requests,dlm_invalidations, con_id
from   gv$librarycache
where  inst id = USERENV('Instance');
```

View Name: GV$MUTEX_SLEEP

```
select inst_id, mutex_type, location, sleeps, wait_time, con_id
from   x$mutex sleep;
```

View Name: V$MUTEX_SLEEP

```
select mutex type, location, sleeps, wait time, con id
from   gv$mutex_sleep
where  inst id = USERENV('Instance');
```

View Name: GV$PDBS

```
select inst_id, con_id, dbid, con_uid, guid, name, decode(state, 0,
       'MOUNTED', 1, 'READ WRITE', 2, 'READ ONLY', 3, 'MIGRATE', 4,
       'DISMOUNTED'), decode(restricted, 0, 'NO', 1, 'YES'), stime, create_scn,
       total size, block size, decode(recovery status, 0, 'ENABLED', 1,
       'DISABLED'),snapshot_parent_con_id, decode(app_root, 1, 'YES', 'NO'),
       decode(app_root_con_id, NULL, 'NO', 'YES'), decode(app_seed, 1,'YES','NO'),
       app_root_con_id, decode(app_root_clone, 1, 'YES', 'NO'),
       decode(proxy_pdb, 1, 'YES', 'NO')
from   x$con where con id > 1;
```

View Name: V$PDBS

```
select con_id, dbid, con_uid, guid, name,  open_mode, restricted, open_time,
       create_scn, total_size,block_size,recovery_status,snapshot_parent_con_id,
       application_root,application_pdb,application_seed,application_root_con_id,
       application root con id, application root clone, proxy pdb
from   gv$pdbs
where  inst id = USERENV('Instance');
```

View Name: GV$SESSION_LONGOPS

```
select  inst_id,ksulosno,ksulosrn,ksulopna,ksulotna,ksulotde,ksulosfr,ksulotot,
        ksulouni,to_date(ksulostm,'MM/DD/RR HH24:MI:SS','NLS_CALENDAR=Gregorian'),
        to_date(ksulolut,'MM/DD/RR HH24:MI:SS','NLS_CALENDAR=Gregorian'),
        to_date(ksuloinft, 'MM/DD/RR HH24:MI:SS','NLS_CALENDAR=Gregorian'),
        decode(ksulopna, 'Advisor', ksuloif2,
        decode(sign(ksulotot-ksulosfr),-1,to_number(NULL),
        decode(ksulosfr,0,to_number(NULL),
        round(ksuloetm*((ksulotot-ksulosfr)/ksulosfr))))),
        ksuloetm,ksuloctx,ksulomsg,
        ksulounm,ksulosql,ksulosqh,ksulosqi, ksulosqph, ksulosqesta,
        decode(ksulosqeid, 0, to_number(NULL), ksulosqeid),
        decode(ksulosqplid, 0, to_number(NULL), ksulosqplid),
        ksulosqplop,ksulosqplnm,ksuloqid, con_id
from    x$ksulop;
```

View Name: V$SESSION_LONGOPS

```
select  sid,serial#,opname,target,target_desc,sofar,totalwork,units,start_time,
        last_update_time,timestamp,
        time_remaining,elapsed_seconds,context,message,username,
        sql_address,sql_hash_value,sql_id, sql_plan_hash_value,
        sql_exec_start, sql_exec_id, sql_plan_line_id,

        sql_plan_operation, sql_plan_options, qcsid, con_id
from    gv$session_longops
where   inst_id = USERENV('Instance');
```

View Name: GV$SQL (New in 12*c* Bolded)

```
select inst_id,kglnaobj,kglfnobj,kglobt03, kglobhs0+kglobhs1+kglobhs2+
       kglobhs3+kglobhs4+kglobhs5+kglobhs6+kglobt16, kglobt08+kglobt11,
       kglobt10, kglobt01, decode(kglobhs6,0,0,1), decode(kglhdlmd,0,0,1),
       kglhdlkc, kglobt04, kglobt05, kglobt48, kglobt35, kglobpc6, kglhdldc,
       substr(to_char(kglnatim,'YYYY-MM-DD/HH24:MI:SS'),1,19), kglhdivc,
       kglobt12, kglobt13, kglobwdw, kglobt14, kglobwap, kglobwcc,
       kglobwcl, kglobwui, kglobt42, kglobt43, kglobt15, kglobt02,
       decode(kglobt32,0,'NONE',1,'ALL_ROWS',2,'FIRST_ROWS',3,'RULE',
       4,'CHOOSE','UNKNOWN'), kglobtn0, kglobcce, kglobcceh, kglobt17,
       kglobt18, kglobts4, kglhdkmk, kglhdpar, kglobtp0, kglnahsh, kglobt46,
       kglobt30, kglobt09, kglobts5, kglobt48, kglobts0, kglobt19, kglobts1,
       kglobt20, kglobt21, kglobts2, kglobt06, kglobt07,
       decode(kglobt28, 0, to_number(NULL), kglobt28), kglhdadr, kglobt29,
       decode(bitand(kglobt00,64),64, 'Y', 'N'), decode(kglobsta,
       1,'VALID',2,'VALID_AUTH_ERROR',3,'VALID_COMPILE_ERROR',
       4,'VALID_UNAUTH',5,'INVALID_UNAUTH',6,'INVALID'), kglobt31,
       substr(to_char(kglobtt0,'YYYY-MM-DD/HH24:MI:SS'),1,19),
       decode(kglobt33, 1, 'Y', 'N'),decode(bitand(kglobacs, 1), 1, 'Y', 'N'),
       decode(bitand(kglobacs, 2), 2, 'Y', 'N'),
       decode(bitand(kglobacs, 4), 4, 'Y', 'N'),  kglhdclt,
       kglobts3, kglobts7, kglobts6, kglobt44, kglobt45,  kglobt47, kglobt49,
       kglobcla,  kglobcbca, kglobt22, kglobt52, kglobt53, kglobt54, kglobt55,
       kglobt56, kglobt57, kglobt58, kglobt23, kglobt24, kglobt59,
       kglobt53 - ((kglobt55+kglobt57) - kglobt52), con_id,
       decode(bitand(kglobaqp,1), 1, decode(bitand(kglobaqp,2), 2, 'R', 'Y'),
       'N'), decode(bitand(kglobaqp,4),4,decode(bitand(kglobaqp,8), 8, 'Y', 'N'),
       ''),  kglimscans, kglimbytesuncomp, kglimbytesinmem,
       decode(bitand(kglobfl2, 2097152), 0, 'N', decode(bitand(kglhdfl2, 8),
       8, 'X' , 'Y')),  decode(bitand(kglobfl2, 4194304), 0, 'N',
       decode(bitand(kglhdfl2, 16), 16, 'X', 'Y')),
       decode(bitand(kglobfl2, 8388608+16777216), 0, 'N',
       decode(bitand(kglhdfl2, 32), 32, 'X', 'Y'))
from   x$kglcursor_child;
```

View Name: V$SQL (New in 12*c* Bolded)

```
select SQL_TEXT,SQL_FULLTEXT,
       SQL_ID,SHARABLE_MEM,PERSISTENT_MEM,RUNTIME_MEM,SORTS,
       LOADED_VERSIONS,OPEN_VERSIONS,USERS_OPENING,FETCHES,EXECUTIONS,
       PX_SERVERS_EXECUTIONS,END_OF_FETCH_COUNT,USERS_EXECUTING,LOADS,
       FIRST_LOAD_TIME,INVALIDATIONS,PARSE_CALLS,DISK_READS,DIRECT_WRITES,
       BUFFER_GETS,APPLICATION_WAIT_TIME,CONCURRENCY_WAIT_TIME,
       CLUSTER_WAIT_TIME, USER_IO_WAIT_TIME, PLSQL_EXEC_TIME,
       JAVA_EXEC_TIME, ROWS_PROCESSED , COMMAND_TYPE , OPTIMIZER_MODE,
       OPTIMIZER_COST,OPTIMIZER_ENV, OPTIMIZER_ENV_HASH_VALUE, PARSING_USER_ID,
       PARSING_SCHEMA_ID,PARSING_SCHEMA_NAME, KEPT_VERSIONS , ADDRESS ,
          TYPE_CHK_HEAP , HASH_VALUE, OLD_HASH_VALUE, PLAN_HASH_VALUE,
          CHILD_NUMBER, SERVICE, SERVICE_HASH, MODULE, MODULE_HASH , ACTION ,
          ACTION_HASH, SERIALIZABLE_ABORTS , OUTLINE_CATEGORY, CPU_TIME,
          ELAPSED_TIME, OUTLINE_SID, CHILD_ADDRESS, SQLTYPE, REMOTE,
          OBJECT_STATUS, LITERAL_HASH_VALUE, LAST_LOAD_TIME, IS_OBSOLETE,
          IS_BIND_SENSITIVE, IS_BIND_AWARE, IS_SHAREABLE, CHILD_LATCH,
          SQL_PROFILE, SQL_PATCH, SQL_PLAN_BASELINE, PROGRAM_ID,PROGRAM_LINE#,
          EXACT_MATCHING_SIGNATURE,FORCE_MATCHING_SIGNATURE, LAST_ACTIVE_TIME,
          BIND_DATA TYPECHECK_MEM, IO_CELL_OFFLOAD_ELIGIBLE_BYTES,
          IO_INTERCONNECT_BYTES,PHYSICAL_READ_REQUESTS, PHYSICAL_READ_BYTES,
          PHYSICAL_WRITE_REQUESTS, PHYSICAL_WRITE_BYTES,
          OPTIMIZED_PHY_READ_REQUESTS, LOCKED_TOTAL, PINNED_TOTAL,
          IO_CELL_UNCOMPRESSED_BYTES, IO_CELL_OFFLOAD_RETURNED_BYTES, CON_ID,
          IS_REOPTIMIZABLE, IS_RESOLVED_ADAPTIVE_PLAN, IM_SCANS,
          IM_SCAN_BYTES_UNCOMPRESSED, IM_SCAN_BYTES_INMEMORY, DDL_NO_INVALIDATE,
          IS_ROLLING_INVALID, IS_ROLLING_REFRESH_INVALID
from      GV$SQL
where     inst_id = USERENV('Instance');
```

View Name: GV$SQLAREA (New in 12*c* Bolded)

```
select inst_id, kglnaobj, kglfnobj, kglobt03, kglobhs0+kglobhs1+
       kglobhs2+kglobhs3+kglobhs4+kglobhs5+kglobhs6, kglobt08+kglobt11,
       kglobt10, kglobt01, kglobccc, kglobclc, kglhdlmd, kglhdlkc, kglobt04,
       kglobt05, kglobt48, kglobt35, kglobpc6, kglhdldc,
       substr(to_char(kglnatim,'YYYY-MM-DD/HH24:MI:SS'),1,19), kglhdivc,
       kglobt12, kglobt13, kglobwdw, kglobt14, kglobwap, kglobwcc, kglobwcl,
       kglobwui, kglobt42, kglobt43, kglobt15, kglobt02, decode(kglobt32, 0,
       'NONE',1,'ALL_ROWS',2,'FIRST_ROWS',3,'RULE',4, 'CHOOSE', 'UNKNOWN'),
       kglobtn0, kglobcce, kglobcceh, kglobt17, kglobt18, kglobts4, kglhdkmk,
       kglhdpar, kglnahsh, kglobt46, kglobt30, kglobts0, kglobt19, kglobts1,
       kglobt20, kglobt21, kglobts2, kglobt06, kglobt07,
       decode(kglobt28, 0, NULL, kglobt28), kglhdadr,
       decode(bitand(kglobt00,64),64, 'Y', 'N'),
       decode(kglobsta,1,'VALID',2,'VALID_AUTH_ERROR',3, 'VALID_COMPILE_ERROR',
       4,'VALID_UNAUTH',5,'INVALID_UNAUTH',6,'INVALID'), kglobt31, kglobtt0,
       decode(kglobt33, 1, 'Y', 'N'),  decode(bitand(kglobacs, 1), 1, 'Y', 'N'),
       decode(bitand(kglobacs, 2), 2, 'Y', 'N'),kglhdclt,kglobts3,
       kglobts7, kglobts6,kglobt44,kglobt45,kglobt47,kglobt49,kglobcla,
       kglobcbca,kglobt22,kglobt52,kglobt53,kglobt54,kglobt55,kglobt56,kglobt57,
       kglobt58, kgloblct,kglobpct,kglobt59,kglobt53 -
       ((kglobt55+kglobt57) - kglobt52), con_id, decode(bitand(kglobaqp,1), 1,
        decode(bitand(kglobaqp,2), 2,'R','Y'), 'N'), decode(bitand(kglobaqp,4), 4,
        decode(bitand(kglobaqp,8), 8, 'Y', 'N'), '')
from   x$kglcursor_child_sqlid
where  kglobt02 != 0;
```

View Name: V$SQLAREA (New in 12*c* Bolded)

```
select sql_text, sql_fulltext, sql_id,sharable_mem, persistent_mem,
       runtime_mem,sorts,version_count,loaded_versions,open_versions,
       users_opening,fetches,executions, px_servers_executions,
       end_of_fetch_count, users_executing,loads,first_load_time,

       invalidations,parse_calls,disk_reads,direct_writes, buffer_gets,
       application_wait_time,concurrency_wait_time,cluster_wait_time,
       user_io_wait_time, plsql_exec_time, java_exec_time, rows_processed,
       command_type,optimizer_mode, optimizer_cost, optimizer_env,
       optimizer_env_hash_value, parsing_user_id,parsing_schema_id,
       parsing_schema_name, kept_versions,address,hash_value,old_hash_value,
       plan_hash_value, module,module_hash,action,action_hash,serializable_aborts,
       outline_category, cpu_time,elapsed_time, outline_sid,
       last_active_child_address, remote, object_status,
       literal_hash_value, last_load_time, is_obsolete, is_bind_sensitive,
       is_bind_aware, child_latch, sql_profile,sql_patch,
       sql_plan_baseline, program_id, program_line#, exact_matching_signature,
       force_matching_signature, last_active_time, bind_data, typecheck_mem,
       io_cell_offload_eligible_bytes,io_interconnect_bytes,
       physical_read_requests,
       physical_read_bytes, physical_write_requests, physical_write_bytes,
       optimized_phy_read_requests, locked_total, pinned_total,
       io_cell_uncompressed_bytes, io_cell_offload_returned_bytes
       con_id, is_reoptimizable, is_resolved_adaptive_plan
from   GV$SQLAREA
where  inst_id = USERENV('Instance');
```

View Name: GV$SQLTEXT

```
select inst_id,kglhdadr,kglnahsh, kglnasqlid, kgloboct,piece,name
from   x$kglna
where  kgloboct != 0;
```

View Name: V$SQLTEXT

```
select address,hash_value,sql_id,command_type,piece,sql_text,con_id
from   gv$sqltext
where  inst_id = USERENV('Instance');
```

View Name: GV$SQL_CURSOR

```
select inst_id,kxscccur,kxscccfl,decode(kxsccsta,0,'CURNULL',1,'CURSYNTAX',2
       'CURPARSE',3,'CURBOUND',4,'CURFETCH',5,'CURROW','ERROR'),kxsccphd,
       kxsccplk, kxsccclk, kxscccpn,kxscctbm,kxscctwm,kxscctbv,kxscctdv,
       kxsccbdf,kxsccflg,kxsccfl2,kxsccchd,con_id
from   x$kxscc;
```

View Name: V$SQL_CURSOR

```
select curno,flag,status,parent_handle,parent_lock,child_lock,child_pin,
       pers_heap_mem,work_heap_mem,bind_vars,define_vars,bind_mem_loc,
       inst_flag,inst_flag2,child_handle,con_id
from   gv$sql_cursor
where  inst_id = USERENV('Instance');
```

View Name: GV$SYSSTAT

```
select inst_id,indx,ksusdnam,ksusdcls,ksusgstv,ksusdhsh, con_id
from   x$ksusgsta;
```

View Name: V$SYSSTAT

```
select statistic#,name,class,value,stat_id, con_id
from   gv$sysstat
where  inst_id = USERENV('Instance');
```

APPENDIX C

The X$ Tables (DBA)

The X$ tables are usually not mentioned or talked about in many Oracle books or even in the Oracle user community. For this reason, I am including them in this book as one of the few references available (Chapter 13 contains *many* X$ queries). There are 1312 X$ tables in 12*c*R2. There were 945 X$ tables in 11*g*R2 (11.2.0.1.0), 613 X$ tables in 10*g*R2 (10.2.0.1), and only 394 in Oracle9*i* Release 2 (9.2.0.1.0). The X$ tables vary in structure and number, depending on the database version and release used. Run the queries on your version of the database to get the number of views and structure for your specific version. Areas covered in this appendix include

- A list of all Oracle 12*c*R2 (12.2.0.0.2) X$ tables (1312 total)
- Query to list the Oracle 12*c*R2 (12.2.0.0.2) X$ indexed columns (1312 total)
- Some of the Oracle 12*c*R2 (12.2.0.0.2) V$ views cross-referenced to the X$ tables

Oracle 12*c*R2 X$ Tables Ordered by Name

Here is the Oracle 12*c*R2 query to get the following listing:

```
select      name
from        v$fixed_table
where       name like 'X%'
order by    name;
```

Here are the entire 1312 X$ tables in Oracle 12cR2, ordered by name:

```
NAME
------------------------------    ------------------------------    ------------------------------
X$ABSTRACT_LOB                     X$CONTEXT                          X$DBKH_CHECK_PARAM
X$ACTIVECKPT                       X$CON_KEWMDRMV                     X$DBKINCMETCFG
X$AQ_MESSAGE_CACHE_ADVICE          X$CON_KEWMSMDV                     X$DBKINCMETINFO
X$AQ_OPT_CACHED_SUBSHARD           X$CON_KEWSSYSV                     X$DBKINCMETSUMMARY
X$AQ_OPT_INACTIVE_SUBSHARD         X$CON_KSLEI                        X$DBKINFO
X$AQ_OPT_STATS                     X$CON_KSLSCS                       X$DBKRECO
X$AQ_OPT_UNCACHED_SUBSHARD         X$CON_KSUSGSTA                     X$DBKRUN
X$AQ_REMOTE_DEQAFF                 X$DBGALERTEXT                      X$DBREPLAY_PATCH_INFO
X$AQ_SUBSCRIBER_LOAD               X$DBGATFLIST                       X$DGLPARAM
X$AQ_SUBTRANS                      X$DBGDIREXT                        X$DGLXDAT
X$ASH                              X$DBGLOGEXT                        X$DIAG_ADR_CONTROL
X$AUD_DPAPI_ACTIONS                X$DBGRICX                          X$DIAG_ADR_CONTROL_AUX
X$AUD_DP_ACTIONS                   X$DBGRIFX                          X$DIAG_ADR_INVALIDATION
X$AUD_DV_OBJ_EVENTS                X$DBGRIKX                          X$DIAG_ALERT_EXT
X$AUD_OBJ_ACTIONS                  X$DBGRIPX                          X$DIAG_AMS_XACTION
X$AUD_OLS_ACTIONS                  X$DBGTFLIST                        X$DIAG_DDE_USER_ACTION
X$AUD_XS_ACTIONS                   X$DBGTFOPTT                        X$DIAG_DDE_USER_ACTION_DEF
X$BH                               X$DBGTFSOPTT                       X$DIAG_DDE_USR_ACT_PARAM
X$BMAPNONDURSUB                    X$DBGTFSQLT                        X$DIAG_DDE_USR_ACT_PARAM_DEF
X$BUFFER                           X$DBGTFSSQLT                       X$DIAG_DDE_USR_INC_ACT_MAP
X$BUFFER2                          X$DBGTFVIEW                        X$DIAG_DDE_USR_INC_TYPE
X$BUFFERED_PUBLISHERS              X$DBKECE                           X$DIAG_DFW_CONFIG_CAPTURE
X$BUFFERED_QUEUES                  X$DBKEFAFC                         X$DIAG_DFW_CONFIG_ITEM
X$BUFFERED_SUBSCRIBERS             X$DBKEFDEAFC                       X$DIAG_DFW_PATCH_CAPTURE
X$CDBVW$                           X$DBKEFEFC                         X$DIAG_DFW_PATCH_ITEM
X$CELL_NAME                        X$DBKEFIEFC                        X$DIAG_DFW_PURGE
X$CKPTBUF                          X$DBKFDG                           X$DIAG_DFW_PURGE_ITEM
X$COMVW$                           X$DBKFSET                          X$DIAG_DIAGV_INCIDENT
X$CON                              X$DBKH_CHECK                       X$DIAG_DIR_EXT
```

X$DIAG_EM_DIAG_JOB
X$DIAG_EM_TARGET_INFO
X$DIAG_EM_USER_ACTIVITY
X$DIAG_HM_FDG_SET
X$DIAG_HM_FINDING
X$DIAG_HM_INFO
X$DIAG_HM_MESSAGE
X$DIAG_HM_RECOMMENDATION
X$DIAG_HM_RUN
X$DIAG_INCCKEY
X$DIAG_INCIDENT
X$DIAG_INCIDENT_FILE
X$DIAG_INC_METER_CONFIG
X$DIAG_INC_METER_IMPT_DEF
X$DIAG_INC_METER_INFO
X$DIAG_INC_METER_PK_IMPTS
X$DIAG_INC_METER_SUMMARY
X$DIAG_INFO
X$DIAG_IPS_CONFIGURATION
X$DIAG_IPS_FILE_COPY_LOG
X$DIAG_IPS_FILE_METADATA
X$DIAG_IPS_PACKAGE
X$DIAG_IPS_PACKAGE_FILE
X$DIAG_IPS_PACKAGE_HISTORY
X$DIAG_IPS_PACKAGE_INCIDENT
X$DIAG_IPS_PKG_UNPACK_HIST
X$DIAG_IPS_PROGRESS_LOG
X$DIAG_IPS_REMOTE_PACKAGE
X$DIAG_LOG_EXT
X$DIAG_PICKLEERR
X$DIAG_PROBLEM
X$DIAG_RELMD_EXT
X$DIAG_SWEEPERR
X$DIAG_VEM_USER_ACTLOG
X$DIAG_VEM_USER_ACTLOG1
X$DIAG_VHM_RUN
X$DIAG_VIEW
X$DIAG_VIEWCOL
X$DIAG_VINCIDENT
X$DIAG_VINCIDENT_FILE
X$DIAG_VINC_METER_INFO
X$DIAG_VIPS_FILE_COPY_LOG
X$DIAG_VIPS_FILE_METADATA
X$DIAG_VIPS_PACKAGE_FILE
X$DIAG_VIPS_PACKAGE_HISTORY
X$DIAG_VIPS_PACKAGE_MAIN_INT
X$DIAG_VIPS_PACKAGE_SIZE
X$DIAG_VIPS_PKG_FILE
X$DIAG_VIPS_PKG_INC_CAND
X$DIAG_VIPS_PKG_INC_DTL
X$DIAG_VIPS_PKG_INC_DTL1
X$DIAG_VIPS_PKG_MAIN_PROBLEM
X$DIAG_VNOT_EXIST_INCIDENT
X$DIAG_VPROBLEM
X$DIAG_VPROBLEM1
X$DIAG_VPROBLEM2
X$DIAG_VPROBLEM_BUCKET
X$DIAG_VPROBLEM_BUCKET1
X$DIAG_VPROBLEM_BUCKET_COUNT
X$DIAG_VPROBLEM_INT
X$DIAG_VPROBLEM_LASTINC
X$DIAG_VSHOWCATVIEW
X$DIAG_VSHOWINCB
X$DIAG_VSHOWINCB_I
X$DIAG_VTEST_EXISTS
X$DIAG_V_ACTINC
X$DIAG_V_ACTPROB
X$DIAG_V_INCCOUNT
X$DIAG_V_INCFCOUNT
X$DIAG_V_INC_METER_INFO_PROB
X$DIAG_V_IPSPRBCNT
X$DIAG_V_IPSPRBCNT1
X$DIAG_V_NFCINC
X$DIAG_V_SWPERRCOUNT
X$DIR
X$DNFS_CHANNELS
X$DNFS_FILES
X$DNFS_HIST
X$DNFS_META
X$DNFS_SERVERS
X$DNFS_STATS
X$DRA_FAILURE
X$DRA_FAILURE_CHECK
X$DRA_FAILURE_CHECK_MAP
X$DRA_FAILURE_PARAM
X$DRA_FAILURE_PARENT_MAP
X$DRA_FAILURE_REPAIR
X$DRA_FAILURE_REPAIR_MAP
X$DRA_REPAIR
X$DRA_REPAIR_PARAM
X$DRC
X$DRM_HISTORY
X$DRM_HISTORY_STATS
X$DRM_WAIT_STATS
X$DUAL
X$DURABLE_SHARDED_SUBS
X$ESTIMATED_MTTR
X$GCRACTIONS
X$GCRLOG
X$GCRMETRICS
X$GCRSTATUS
X$GIMSA
X$GLOBALCONTEXT
X$GSMREGIONS
X$HEATMAPSEGMENT
X$HEATMAPSEGMENT1
X$HOFP
X$HS_SESSION
X$IEE
X$IEE_CONDITION
X$IEE_ORPIECE
X$IMCSEGEXTMAP
X$IMCSEGMENTS
X$IMCTBSEXTMAP
X$INSTANCE_CACHE_TRANSFER
X$IPCOR_TOPO_DOMAIN
X$IPCOR_TOPO_NDEV
X$IR_MANUAL_OPTION
X$IR_REPAIR_OPTION
X$IR_REPAIR_STEP
X$IR_RS_PARAM
X$IR_WF_PARAM
X$IR_WORKING_FAILURE_SET
X$IR_WORKING_REPAIR_SET
X$IR_WR_PARAM
X$JOXDRC
X$JOXDRR
X$JOXFC
X$JOXFD
X$JOXFM
X$JOXFR
X$JOXFS
X$JOXFT
X$JOXMAG
X$JOXMEX
X$JOXMFD
X$JOXMIC
X$JOXMIF
X$JOXMMD
X$JOXMOB
X$JOXOBJ
X$JOXREF
X$JOXRSV
X$JOXSCD
X$JSKJOBQ
X$JSKMIMMD
X$JSKMIMRT
X$JSKSLV
X$K2GTE
X$K2GTE2
X$KAUVRSTAT
X$KBRPSTAT
X$KCBBES
X$KCBBF
X$KCBBHS
X$KCBDBK
X$KCBDWOBJ
X$KCBDWS
X$KCBFCIO
X$KCBFWAIT
X$KCBINSTVIEW
X$KCBKPFS
X$KCBKWRL
X$KCBLDRHIST
X$KCBLSC
X$KCBMKID
X$KCBMMAV
X$KCBOBH
X$KCBOQH
X$KCBPDBRM
X$KCBPINTIME
X$KCBPRFH
X$KCBSC
X$KCBSDS
X$KCBSH
X$KCBSW
X$KCBTEK

X$KCBUWHY
X$KCBVBL
X$KCBWAIT
X$KCBWBPD
X$KCBWDS
X$KCBWH
X$KCCACM
X$KCCADFC
X$KCCAGF
X$KCCAL
X$KCCBF
X$KCCBI
X$KCCBL
X$KCCBLKCOR
X$KCCBP
X$KCCBS
X$KCCCC
X$KCCCF
X$KCCCP
X$KCCDC
X$KCCDFHIST
X$KCCDI
X$KCCDI2
X$KCCDL
X$KCCFC
X$KCCFE
X$KCCFLE
X$KCCFN
X$KCCIC
X$KCCIRT
X$KCCLE
X$KCCLH
X$KCCNRS
X$KCCOR
X$KCCPA
X$KCCPD
X$KCCPDB
X$KCCPIC
X$KCCRDI
X$KCCRL
X$KCCRM
X$KCCRS
X$KCCRSP
X$KCCRSR
X$KCCRT
X$KCCSL
X$KCCTF
X$KCCTIR
X$KCCTKH
X$KCCTS
X$KCFIO
X$KCFIOFCHIST
X$KCFIOHIST
X$KCFISCAP
X$KCFISOSS
X$KCFISOSSAWR
X$KCFISOSSC
X$KCFISOSSL
X$KCFISOSSN
X$KCFISOSST
X$KCFISTCAP
X$KCFISTSA
X$KCFTIO
X$KCLCRST
X$KCLCURST
X$KCLFX
X$KCLLS
X$KCLPINGPIN
X$KCLPINGNEV
X$KCLRCVST
X$KCMSCN
X$KCPDBINC
X$KCPXPL
X$KCRFDEBUG
X$KCRFSTRAND
X$KCRFWS
X$KCRFX
X$KCRMF
X$KCRMT
X$KCRMX
X$KCRRARCH
X$KCRRASTATS
X$KCRRDSTAT
X$KCRRLNS
X$KCRRNHG
X$KCTICW
X$KCTLAX
X$KCVDF
X$KCVFH
X$KCVFHALL
X$KCVFHMRR
X$KCVFHONL
X$KCVFHTMP
X$KDLT
X$KDLU_STAT
X$KDMADOELEMENTS
X$KDMADOTASKDETAILS
X$KDMADOTASKS
X$KDMIMCCOL
X$KDMIMCHEAD
X$KDMIMEUCOL
X$KDMIMEUHEAD
X$KDMUSEGDICT
X$KDMUSEGDICTPMAP
X$KDMUSEGDICTSC
X$KDMUSEGDICTVER
X$KDNSSF
X$KDXHS
X$KDXST
X$KDZCOLCL
X$KD_COLUMN_STATISTICS
X$KEACMDN
X$KEAFDGN
X$KEAOBJT
X$KECPDENTRY
X$KECPRT
X$KECPFU
X$KEC_COMPONENT_TIMING
X$KEHECLMAP
X$KEHETSX
X$KEHEVTMAP
X$KEHF
X$KEHOSMAP
X$KEHPRMMAP
X$KEHR
X$KEHRP
X$KEHR_CHILD
X$KEHSQT
X$KEHSYSMAP
X$KEHTIMMAP
X$KEIUT
X$KEIUT_INFO
X$KELRSGA
X$KELRTD
X$KELRXMR
X$KELTGSD
X$KELTOSD
X$KELTSD
X$KEOMN_DROP_LIST
X$KEOMNMON_SESSTAT
X$KERPIREPREQ
X$KERPISTATS
X$KESPLAN
X$KESSPAMET
X$KESWXMON
X$KESWXMON_PLAN
X$KESWXMON_STATNAME
X$KETCL
X$KETOP
X$KETTG
X$KEUMLINKTB
X$KEUMREGTB
X$KEUMSVCTB
X$KEUMTB
X$KEUMTOPTB
X$KEWAM
X$KEWASH
X$KEWCATPDBINSNAP
X$KEWECLS
X$KEWEFXT
X$KEWEPCS
X$KEWESMAS
X$KEWESMS
X$KEWMAFMV
X$KEWMCHKMV
X$KEWMDRMV
X$KEWMDSM
X$KEWMEVMV
X$KEWMFLMV
X$KEWMGSM
X$KEWMIOFMV
X$KEWMRMGMV
X$KEWMRMPDBMV
X$KEWMRSM
X$KEWMRWMV
X$KEWMSEMV
X$KEWMSMDV

X$KEWMSRGMV
X$KEWMSVCMV
X$KEWMWCRMV
X$KEWMWPCMV
X$KEWPDBINSNAP
X$KEWPDBIX
X$KEWRATTRNEW
X$KEWRATTRSTALE
X$KEWRCONIDLOOKUP
X$KEWRIMSEGSTAT
X$KEWRIPSL
X$KEWRSQLCRIT
X$KEWRSQLIDTAB
X$KEWRSQLSUM
X$KEWRSTGTB
X$KEWRTB
X$KEWRTB_ALL
X$KEWRTOPTENV
X$KEWRTSEGSTAT
X$KEWRTSQLPLAN
X$KEWRTSQLTEXT
X$KEWSSESV
X$KEWSSMAP
X$KEWSSVCV
X$KEWSSYSV
X$KEWXOCF
X$KEWX_LOBS
X$KEWX_SEGMENTS
X$KEXSVFU
X$KEXSVUS
X$KFALS
X$KFBF
X$KFBH
X$KFCBH
X$KFCCE
X$KFCLLE
X$KFCSGA
X$KFCSTAT
X$KFDAP
X$KFDAT
X$KFDDD
X$KFDFS
X$KFDPARTNER
X$KFDSD
X$KFDSK
X$KFDSK_SPARSE
X$KFDSK_SPARSE_STAT
X$KFDSK_STAT
X$KFDSR
X$KFDXEXT
X$KFENV
X$KFFG
X$KFFGP
X$KFFGPT
X$KFFIL
X$KFFIL_SPARSE
X$KFFOF
X$KFFSCRUB
X$KFFXP

X$KFGBRB
X$KFGBRC
X$KFGBRS
X$KFGBRW
X$KFGMG
X$KFGRP
X$KFGRP_SPARSE
X$KFGRP_STAT
X$KFGXP
X$KFIAS_CLNT
X$KFIAS_FILE
X$KFIAS_PROC
X$KFIPCOMPAT
X$KFKID
X$KFKLIB
X$KFKLSOD
X$KFMDGRP
X$KFNCL
X$KFNDIOSPRS
X$KFNRCL
X$KFNSDSKIOST
X$KFQG
X$KFRC
X$KFTMTA
X$KFVACFS
X$KFVACFSADMIN
X$KFVACFSCMDRULE
X$KFVACFSENCR
X$KFVACFSREALM
X$KFVACFSREALMFILTER
X$KFVACFSREALMGROUP
X$KFVACFSREALMS
X$KFVACFSREALMUSER
X$KFVACFSREPL
X$KFVACFSREPLTAG
X$KFVACFSRULE
X$KFVACFSRULESET
X$KFVACFSRULESETRULE
X$KFVACFSS
X$KFVACFSTAG
X$KFVACFSV
X$KFVOL
X$KFVOLSTAT
X$KFZGDR
X$KFZPBLK
X$KFZUAGR
X$KFZUDR
X$KGHLU
X$KGICS
X$KGLAU
X$KGLBODY
X$KGLCLUSTER
X$KGLCURSOR
X$KGLCURSOR_CHILD
X$KGLCURSOR_CHILD_SQLID
X$KGLCURSOR_CHILD_SQLIDPH
X$KGLCURSOR_PARENT
X$KGLDP
X$KGLINDEX

X$KGLJMEM
X$KGLJSIM
X$KGLLK
X$KGLMEM
X$KGLNA
X$KGLNA1
X$KGLOB
X$KGLOBXML
X$KGLPN
X$KGLRD
X$KGLSIM
X$KGLSN
X$KGLSQLTXL
X$KGLST
X$KGLTABLE
X$KGLTR
X$KGLTRIGGER
X$KGLXS
X$KGSCC
X$KGSKASP
X$KGSKCFT
X$KGSKCP
X$KGSKDOPP
X$KGSKMEMINFO
X$KGSKNCFT
X$KGSKPDBFT
X$KGSKPDBHISTFT
X$KGSKPFT
X$KGSKPP
X$KGSKQUEP
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X$KGSKTE
X$KGSKTO
X$KGSKVFT
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X$KJAC_ID
X$KJAC_MY_ID
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X$KJBL
X$KJBLFX
X$KJBR
X$KJBRFX
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X$KJCISPT
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X$KJCTFRI
X$KJCTFS
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X$KJDDDEADLOCKSES
X$KJDRHV
X$KJDRMAFNSTATS
X$KJDRMHVSTATS
X$KJDRMREADMOSTLYSTATS
X$KJDRMRQ
X$KJDRPCMHV
X$KJDRPCMPF
X$KJFMHBACL
X$KJICVT
X$KJIDT

X$KJILFT
X$KJILKFT
X$KJIRFT
X$KJISFT
X$KJITRFT
X$KJKMKGA
X$KJKMLOCK
X$KJKMSREQ
X$KJLEQFP
X$KJMDDP
X$KJMSDP
X$KJPMPRC
X$KJPNDX
X$KJREQFP
X$KJRTBCFP
X$KJR_CHUNK_STATS
X$KJR_FREEABLE_CHUNKS
X$KJSCAPKAT
X$KJSCASVCAT
X$KJXGNA_STATS
X$KJXM
X$KJZNCBHANGS
X$KJZNHANGS
X$KJZNHANGSES
X$KJZNHHMLST
X$KJZNHNGMGRSTS
X$KJZNHNGSTATS
X$KJZNRSLNRC
X$KJZNWLMPCRANK
X$KJZSIWTEVT
X$KKAEST
X$KKCNEREG
X$KKCNEREGSTAT
X$KKCNRSTAT
X$KKKICR
X$KKOAR_HINT
X$KKOCS_HISTOGRAM
X$KKOCS_SELECTIVITY
X$KKOCS_STATISTICS
X$KKSAI
X$KKSBV
X$KKSCS
X$KKSPCIB
X$KKSSQLSTAT
X$KKSSQLSTAT_PLAN_HASH
X$KKSSRD
X$KKSXSQLSTAT
X$KLCIE
X$KLPT
X$KMCQS
X$KMCVC
X$KMGSBSADV
X$KMGSBSMEMADV
X$KMGSCT
X$KMGSOP
X$KMGSTFR
X$KMMDI
X$KMMDP
X$KMMHST
X$KMMNV
X$KMMRD
X$KMMSAS
X$KMMSG
X$KMMSI
X$KMPCMON
X$KMPCP
X$KMPCSO
X$KMPDH
X$KMPSRV
X$KNGFL
X$KNGFLE
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X$KNLASG
X$KNSTACR
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X$KNSTCAPCACHE
X$KNSTCAPS
X$KNSTMT
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X$KNSTORD
X$KNSTPSTS
X$KNSTRPP
X$KNSTRQU
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X$KNSTTXN
X$KNSTXSTS
X$KOCST
X$KPONDCONSTAT
X$KPONDESTAT
X$KPONESTAT
X$KPONJSTAT
X$KPOQSTA
X$KPPLCC_INFO
X$KPPLCC_STATS
X$KPPLCONN_INFO
X$KPPLCP_STATS
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X$KQFCO
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X$KQFTA
X$KQFTVRTTST0
X$KQFVI
X$KQFVT
X$KQLFBC
X$KQLFSQCE
X$KQLFXPL
X$KQLSET
X$KQPXINV
X$KQRFP
X$KQRFS
X$KQRPD
X$KQRSD
X$KQRST
X$KRASGA
X$KRBABRSTAT
X$KRBAFF
X$KRBMCA
X$KRBMROT
X$KRBMRST
X$KRBMSFT
X$KRBPDATA
X$KRBPDIR
X$KRBPHEAD
X$KRBPPBCTX
X$KRBPPBTBL
X$KRBZA
X$KRCBIT
X$KRCCDE
X$KRCCDR
X$KRCCDS
X$KRCEXT
X$KRCFBH
X$KRCFDE
X$KRCFH
X$KRCGFE
X$KRCSTAT
X$KRDEVTHIST
X$KRDMMIRA
X$KRDRSBROV
X$KRFBLOG
X$KRFGSTAT
X$KRFSTHRD
X$KRSOPROC
X$KRSSMS
X$KRSSRTT
X$KRSTALG
X$KRSTAPPSTATS
X$KRSTDEST
X$KRSTDGC
X$KRSTPVRS
X$KRVSLV
X$KRVSLVPG
X$KRVSLVS
X$KRVSLVST
X$KRVSLVTHRD
X$KRVXDKA
X$KRVXDTA
X$KRVXISPCHK
X$KRVXISPLCR
X$KRVXOP
X$KRVXSV
X$KRVXTHRD
X$KRVXTX
X$KRVXWARNV
X$KSACLTAB
X$KSAST
X$KSBDD
X$KSBDP

X$KSBDPNEEDED
X$KSBFT
X$KSBSRVDT
X$KSBTABACT
X$KSDAF
X$KSDAFT
X$KSDHNG_CACHE_HISTORY
X$KSDHNG_CHAINS
X$KSDHNG_SESSION_BLOCKERS
X$KSFDFTYP
X$KSFDKLL
X$KSFDSSCLONEINFO
X$KSFDSTBLK
X$KSFDSTCG
X$KSFDSTCMP
X$KSFDSTFILE
X$KSFDSTHIST
X$KSFDSTLL
X$KSFDSTTHIST
X$KSFMCOMPL
X$KSFMELEM
X$KSFMEXTELEM
X$KSFMFILE
X$KSFMFILEEXT
X$KSFMIOST
X$KSFMLIB
X$KSFMSUBELEM
X$KSFQDVNT
X$KSFQP
X$KSFVQST
X$KSFVSL
X$KSFVSTA
X$KSIMAT
X$KSIMAV
X$KSIMSI
X$KSIMTSR
X$KSIPCIP
X$KSIPCIP_CI
X$KSIPCIP_KGGPNP
X$KSIPCIP_OSD
X$KSIPC_INFO
X$KSIPC_PROC_STATS
X$KSIPC_SKGSNDOMAIN
X$KSIRESTYP
X$KSIRGD
X$KSIRPINFO
X$KSI_REUSE_STATS
X$KSKCGMETRIC
X$KSKPDBMETRIC
X$KSKPLW
X$KSKQDPT
X$KSKQVFT
X$KSLCS
X$KSLECLASS
X$KSLED
X$KSLEI
X$KSLEMAP
X$KSLEPX
X$KSLES
X$KSLHOT
X$KSLLCLASS
X$KSLLD
X$KSLLTR
X$KSLLTR_CHILDREN
X$KSLLTR_PARENT
X$KSLLW
X$KSLPO
X$KSLSCS
X$KSLSESHIST
X$KSLSESHIST_MICRO
X$KSLSESOUT
X$KSLWH
X$KSLWSC
X$KSLWT
X$KSMDD
X$KSMDUT1
X$KSMFS
X$KSMFSV
X$KSMGE
X$KSMHP
X$KSMJCH
X$KSMJS
X$KSMLRU
X$KSMLS
X$KSMMEM
X$KSMNIM
X$KSMNS
X$KSMPGDP
X$KSMPGDST
X$KSMPGDSTA
X$KSMPGST
X$KSMPP
X$KSMSD
X$KSMSGMEM
X$KSMSP
X$KSMSPR
X$KSMSP_DSNEW
X$KSMSP_NWEX
X$KSMSS
X$KSMSSINFO
X$KSMSST
X$KSMSTRS
X$KSMUP
X$KSOLSFTS
X$KSOLSSTAT
X$KSOLTD
X$KSO_PRESPAWN_POOL
X$KSO_SCHED_DELAY_HISTORY
X$KSPPCV
X$KSPPCV2
X$KSPPI
X$KSPPO
X$KSPPSCV
X$KSPPSV
X$KSPPSV2
X$KSPRSTV
X$KSPRSTV2
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X$KSPSPFILE
X$KSPTCH
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X$KSQST
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X$KSRMPCTX
X$KSRMSGDES
X$KSRMSGO
X$KSRPCIOS
X$KSSSQUAR
X$KSTEX
X$KSUCF
X$KSUCLNDPCC
X$KSUCLNPROC
X$KSUCPUSTAT
X$KSUINSTSTAT
X$KSULL
X$KSULOP
X$KSULV
X$KSUMYSTA
X$KSUNETSTAT
X$KSUPDBSES
X$KSUPGP
X$KSUPGS
X$KSUPL
X$KSUPR
X$KSUPRLAT
X$KSURLMT
X$KSURU
X$KSUSD
X$KSUSE
X$KSUSECON
X$KSUSECST
X$KSUSESTA
X$KSUSEX
X$KSUSGIF
X$KSUSGSTA
X$KSUSIO
X$KSUSM
X$KSUTM
X$KSUVMSTAT
X$KSUXSINST
X$KSWSAFTAB
X$KSWSASTAB
X$KSWSCLSTAB
X$KSWSCRSSVCTAB
X$KSWSCRSTAB
X$KSWSEVTAB
X$KSWSINTTAB
X$KSWSJPTAB

X$KSXAFA
X$KSXMME
X$KSXM_DFT
X$KSXM_EXP_STATS
X$KSXM_ZUT
X$KSXPCLIENT
X$KSXPIA
X$KSXPIF
X$KSXPPING
X$KSXPTESTTBL
X$KSXP_STATS
X$KSXRCH
X$KSXRCONQ
X$KSXRMSG
X$KSXRREPQ
X$KSXRSG
X$KTADM
X$KTATL
X$KTATRFIL
X$KTATRFSL
X$KTCNCLAUSES
X$KTCNINBAND
X$KTCNQROW
X$KTCNQUERY
X$KTCNREG
X$KTCNREGQUERY
X$KTCSP
X$KTCXB
X$KTFBFE
X$KTFBHC
X$KTFBNSTAT
X$KTFBUE
X$KTFSAN
X$KTFSBI
X$KTFSIMSTAT
X$KTFSRI
X$KTFSTAT
X$KTFTBTXNGRAPH
X$KTFTBTXNMODS
X$KTFTHC
X$KTFTME
X$KTIFB
X$KTIFF
X$KTIFP
X$KTIFV
X$KTMTXNCHUNK
X$KTMTXNCRCLONE
X$KTMTXNHEAD
X$KTPRHIST
X$KTPRXRS
X$KTPRXRT
X$KTRSO
X$KTSIMAPOOL
X$KTSIMAU
X$KTSIMXMEMAREA
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X$KTSJTASK
X$KTSJTASKCLASS
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X$KTSLCHUNK
X$KTSPGS_STAT
X$KTSPSTAT
X$KTSP_REPAIR_LIST
X$KTSSO
X$KTSSPU
X$KTSTFC
X$KTSTSSD
X$KTSTUSC
X$KTSTUSG
X$KTSTUSS
X$KTTEFINFO
X$KTTETS
X$KTTVS
X$KTUCUS
X$KTUGD
X$KTUMASCN
X$KTUQQRY
X$KTURD
X$KTURHIST
X$KTUSMST
X$KTUSMST2
X$KTUSUS
X$KTUTST
X$KTUXCHE
X$KTUXE
X$KUPVA
X$KUPVJ
X$KVII
X$KVIS
X$KVIT
X$KWDDEF
X$KWQBPMT
X$KWQDLSTAT
X$KWQITCX
X$KWQMNC
X$KWQMNJIT
X$KWQMNSCTX
X$KWQMNTASK
X$KWQMNTASKSTAT
X$KWQPD
X$KWQPS
X$KWQSI
X$KWRSNV
X$KWSBGAQPCSTAT
X$KWSBGQMNSTAT
X$KWSBJCSQJIT
X$KWSBSMSLVSTAT
X$KWSCPJOBSTAT
X$KWSSUBSTATS
X$KXDBIO_STATS
X$KXDCM_DB
X$KXDCM_DB_HISTORY
X$KXDCM_DISK
X$KXDCM_DISK_HISTORY
X$KXDCM_GLOBAL
X$KXDCM_GLOBAL_HISTORY
X$KXDCM_IOREASON
X$KXDCM_IOREASON_NAME
X$KXDCM_METRIC_DESC
X$KXDCM_OPEN_ALERTS
X$KXDRS
X$KXDSPPHYSMP
X$KXFBBOX
X$KXFPBS
X$KXFPCDS
X$KXFPCMS
X$KXFPCST
X$KXFPDP
X$KXFPIG
X$KXFPNS
X$KXFPPFT
X$KXFPPIG
X$KXFPREMINSTLOAD
X$KXFPSDS
X$KXFPSMS
X$KXFPSST
X$KXFPYS
X$KXFQSROW
X$KXFRSVCHASH
X$KXFSOURCE
X$KXFTASK
X$KXSBD
X$KXSCC
X$KXSREPLAY
X$KXSREPLAYDATE
X$KXSREPLAYGUID
X$KXSREPLAYLOB
X$KXSREPLAYSEQ
X$KXSREPLAYTIME
X$KXTTSTECS
X$KXTTSTEHS
X$KXTTSTEIS
X$KXTTSTETS
X$KYWMCLTAB
X$KYWMNF
X$KYWMPCMN
X$KYWMPCTAB
X$KYWMWRCTAB
X$KZAHIST
X$KZAJOBS
X$KZAPARAMS
X$KZATS
X$KZCKMCS
X$KZCKMEK
X$KZDOS
X$KZDPSUPSF
X$KZEKMENCWAL
X$KZEKMFVW
X$KZPOPR
X$KZRTPD
X$KZSPR
X$KZSRO
X$KZSRPWFILE
X$KZSRT

```
X$KZVDVCLAUSE                      X$MUTEX_SLEEP                      X$QKSMMWDS
X$LE                               X$MUTEX_SLEEP_HISTORY              X$QKSXA_REASON
X$LOBSEGSTAT                       X$NFSCLIENTS                       X$QOSADVACTIONDEF
X$LOBSTAT                          X$NFSLOCKS                         X$QOSADVFINDINGDEF
X$LOBSTATHIST                      X$NFSOPENS                         X$QOSADVRATIONALEDEF
X$LOGBUF_READHIST                  X$NLS_PARAMETERS                   X$QOSADVRECDEF
X$LOGMNR_ATTRCOL$                  X$NONDURSUB                        X$QOSADVRULEDEF
X$LOGMNR_ATTRIBUTE$                X$NONDURSUB_LWM                    X$QUIESCE
X$LOGMNR_CALLBACK                  X$NSV                              X$RFAFO
X$LOGMNR_CDEF$                     X$OBJECT_POLICY_STATISTICS         X$RFAHIST
X$LOGMNR_CLU$                      X$OBLNK$                           X$RFMP
X$LOGMNR_COL$                      X$OCT                              X$RFMTE
X$LOGMNR_COLTYPE$                  X$OFSMOUNT                         X$RFOB
X$LOGMNR_CONTENTS                  X$OFS_LATENCY_STATS                X$RMA_LATCH
X$LOGMNR_DICTIONARY                X$OFS_STATS                        X$RO_USER_ACCOUNT
X$LOGMNR_DICTIONARY_LOAD           X$OPARG                            X$RULE
X$LOGMNR_ENC$                      X$OPDESC                           X$RULE_SET
X$LOGMNR_ENCRYPTED_OBJ$            X$OPERATORS                        X$RXS_SESSION_ROLES
X$LOGMNR_ENCRYPTION_PROFILE$       X$OPTIM_CALIB_STATS                X$SHADOW_DATAFILE
X$LOGMNR_FILES                     X$OPTION                           X$SKGXPIA
X$LOGMNR_IND$                      X$OPVERSION                        X$SKGXP_CONNECTION
X$LOGMNR_INDCOMPART$               X$ORAFN                            X$SKGXP_MISC
X$LOGMNR_INDPART$                  X$PERSISTENT_PUBLISHERS            X$SKGXP_PORT
X$LOGMNR_INDSUBPART$               X$PERSISTENT_QUEUES                X$TARGETRBA
X$LOGMNR_KOPM$                     X$PERSISTENT_SUBSCRIBERS           X$TEMPORARY_LOB_REFCNT
X$LOGMNR_KTFBUE                    X$POLICY_HISTORY                   X$TIMEZONE_FILE
X$LOGMNR_LATCH                     X$POSCANRATE                       X$TIMEZONE_NAMES
X$LOGMNR_LOB$                      X$PRMSLTYX                         X$TRACE
X$LOGMNR_LOBFRAG$                  X$PROPS                            X$TRACE_EVENTS
X$LOGMNR_LOG                       X$QERFXTST                         X$UGANCO
X$LOGMNR_LOGFILE                   X$QESBLSTAT                        X$UNFLUSHED_DEQUEUES
X$LOGMNR_LOGS                      X$QESMMAHIST                       X$UNIFIED_AUDIT_RECORD_FORMAT
X$LOGMNR_NTAB$                     X$QESMMAPADV                       X$UNIFIED_AUDIT_TRAIL
X$LOGMNR_OBJ$                      X$QESMMIWH                         X$VERSION
X$LOGMNR_OPQTYPE$                  X$QESMMIWT                         X$VINST
X$LOGMNR_PARAMETERS                X$QESMMSGA                         X$XML_AUDIT_TRAIL
X$LOGMNR_PARTOBJ$                  X$QESRCDEP                         X$XPLTON
X$LOGMNR_PROCESS                   X$QESRCDR                          X$XPLTOO
X$LOGMNR_PROPS$                    X$QESRCMEM                         X$XSAGGR
X$LOGMNR_REFCON$                   X$QESRCMSG                         X$XSAGOP
X$LOGMNR_REGION                    X$QESRCOBJ                         X$XSAWSO
X$LOGMNR_ROOT$                     X$QESRCRD                          X$XSLONGOPS
X$LOGMNR_SEG$                      X$QESRCRR                          X$XSOBJECT
X$LOGMNR_SESSION                   X$QESRCSTA                         X$XSOQMEHI
X$LOGMNR_SUBCOLTYPE$               X$QESRSTAT                         X$XSOQOJHI
X$LOGMNR_TAB$                      X$QESRSTATALL                      X$XSOQOPHI
X$LOGMNR_TABCOMPART$               X$QESXL                            X$XSOQOPLU
X$LOGMNR_TABPART$                  X$QKSBGSES                         X$XSOQSEHI
X$LOGMNR_TABSUBPART$               X$QKSBGSYS                         X$XSSINFO
X$LOGMNR_TS$                       X$QKSCESES                         X$XS_SESSIONS
X$LOGMNR_TYPE$                     X$QKSCESYS                         X$XS_SESSION_NS_ATTRIBUTES
X$LOGMNR_UET$                      X$QKSCR                            X$XS_SESSION_ROLES
X$LOGMNR_UNDO$                     X$QKSCR_RSN                        X$ZASAXTAB
X$LOGMNR_USER$                     X$QKSFGI_CURSOR                    X$ZASAXTD1
X$MESSAGES                         X$QKSFM                            X$ZASAXTD2
X$MESSAGE_CACHE                    X$QKSFMDEP                         X$ZASAXTD3
X$MODACT_LENGTH                    X$QKSFMPRT
X$MSGBM                            X$QKSHT                            1312 rows selected.
```

Oracle 12*c*R2 X$ Indexes

To get the 799 X$ indexed columns in Oracle 12*c*R2, run the following query:

```
select    table_name, column_name, index_number
from      v$indexed_fixed_column
order by  table_name, index_number;
…799 rows selected.
```

Oracle 12*c*R2 V$ Views Cross-Referenced to the X$ Tables

This section presents some of the X$ tables mapped back to the V$ views. Because of the large number of views in 12*c*R2, it's no longer possible to list all cross-references here. I have, however, listed several that pertain primarily to performance tuning. You can run your own query to see a specific query associated with the GV$ or V$ views, as shown in Appendix B. You must go through the GV$ view to make this inference. Here are some of the referenced X$ tables, ordered by the selected V$ view names:

Fixed View	**Underlying Base X$ Tables and/or Fixed Views**
V$BH	xbh, xle
V$BUFFER_POOL	x$kcbwbpd
V$BUFFER_POOL_STATISTICS	x$kcbwds, kcbwds, x$kcbwbpd, kcbwbpd
V$DATABASE	x$kccdi, x$kccdi2
V$DATAFILE	x$kccfe, x$kccfn, x$kccfn, x$kcvfh
V$DB_CACHE_ADVICE	x$kcbsc, x$kcbwbpd
V$DB_OBJECT_CACHE	x$kglob
V$DLM_ALL_LOCKS	V$GES_ENQUEUE
V$DLM_LATCH	V$LATCH
V$DLM_LOCKS	V$GES_BLOCKING_ENQUEUE
V$ENQUEUE_LOCK	x$ksqeq, x$ksuse, x$ksqrs
V$ENQUEUE_STAT	x$ksqst
V$EVENT_NAME	x$ksled
V$EXECUTION	x$kstex
V$FILESTAT	x$kcfio, x$kccfe
V$FILE_CACHE_TRANSFER	x$kcfio, x$kccfe
V$FIXED_TABLE	x$kqfta, x$kqfvi, x$kqfdt
V$FIXED_VIEW_DEFINITION	x$kqfvi, x$kqfvt
V$GES_BLOCKING_ENQUEUE	V$GES_BLOCKING_ENQUEUE
V$GES_ENQUEUE	x$kjilkft, x$kjbl

V$GLOBAL_BLOCKED_LOCKS	v$lock, v$dlm_locks
V$GLOBAL_TRANSACTION	x$k2gte2
V$INDEXED_FIXED_COLUMN	x$kqfco, x$kqfta
V$INSTANCE	x$ksuxsinst, x$kvit, x$quiesce
V$LATCH	x$ksllt r
V$LATCHHOLDER	x$ksuprlat
V$LATCHNAME	x$kslld
V$LATCH_CHILDREN	x$ksllt r_children
V$LATCH_MISSES	x$ksllw, x$kslwsc
V$LATCH_PARENT	x$ksllt r_parent
V$LIBRARYCACHE	x$kglst
V$LIBRARY_CACHE_MEMORY	x$kglmem
V$LOCK	v$_lock, x$ksuse, x$ksqrs
V$LOCKED_OBJECT	x$ktcxb, x$ktadm, x$ksuse
V$LOCKS_WITH_COLLISIONS	v$bh
V$LOCK_ACTIVITY	Dual
V$LOCK_ELEMENT	x$le
V$MTTR_TARGET_ADVICE	x$kcbmmav
V$MUTEX_SLEEP	x$mutex_sleep
V$MUTEX_SLEEP_HISTORY	x$mutex_sleep_history
V$MVREFRESH	x$knstmvr, v$session
V$MYSTAT	x$ksumysta, x$ksusgif
V$OBSOLETE_PARAMETER	x$ksppo
V$OPEN_CURSOR	x$kgllk
V$OPTION	x$option
V$PARAMETER	x$ksppi, x$ksppcv
V$PARAMETER2	x$ksppi, x$ksppcv2
V$PGASTAT	x$qesmmsga
V$PGA_TARGET_ADVICE	x$qesmmapadv
V$PGA_TARGET_ADVICE_HISTOGRAM	x$qesmmahist
V$PROCESS	x$ksupr
V$QUEUE	x$kmcqs
V$ROLLSTAT	x$kturd
V$ROWCACHE	x$kqrst
V$ROWCACHE_PARENT	x$kqrfp

V$ROWCACHE_SUBORDINATE	x$kqrfs
V$SEGMENT_STATISTICS	obj$, user$, x$ksolsfts, ts$, ind$
V$SEGSTAT	x$ksolsfts
V$SEGSTAT_NAME	x$ksolsstat
V$SESSION	x$ksuse, x$ksled
V$SESSION_CONNECT_INFO	x$ksusecon
V$SESSION_CURSOR_CACHE	x$kgscc
V$SESSION_EVENT	x$ksles, x$ksled
V$SESSION_LONGOPS	x$ksulop
V$SESSION_OBJECT_CACHE	x$kocst
V$SESSION_WAIT	x$kslwt, x$ksled
V$SESSION_WAIT_CLASS	x$kslcs
V$SESSION_WAIT_HISTORY	x$kslwh
V$SESSMETRIC	x$kewmsemv
V$SESSTAT	x$ksusesta, x$ksusgif
V$SESS_IO	x$ksusio
V$SGA	x$ksmsd
V$SGASTAT	x$ksmfs, x$ksmss, x$ksmls, x$ksmjs, x$ksmns, x$ksmstrs
V$SHARED_POOL_ADVICE	x$kglsim
V$SHARED_POOL_RESERVED	x$ksmspr, x$kghlu
V$SORT_SEGMENT	x$ktstssd
V$SORT_USAGE	x$ktsso, v$session
V$SPPARAMETER	x$kspspfile
V$SQL	x$kglcursor_child
V$SQLAREA	x$kglcursor_child_sqlid
V$SQLAREA_PLAN_HASH	x$kglcursor_child_sqlidph
V$SQLSTATS	x$kkssqlstat
V$SQLTEXT	x$kglna
V$SQLTEXT_WITH_NEWLINES	x$kglna1
V$SQL_BIND_CAPTURE	x$kqlfbc
V$SQL_BIND_DATA	x$kxsbd
V$SQL_BIND_METADATA	x$kksbv
V$SQL_CURSOR	x$kxscc
V$SQL_JOIN_FILTER	x$qesblstat

V$SQL_OPTIMIZER_ENV	x$kqlfsqce
V$SQL_PLAN	x$kqlfxpl
V$SQL_PLAN_STATISTICS	x$qesrstat
V$SQL_PLAN_STATISTICS_ALL	x$qesrstatall
V$SQL_REDIRECTION	x$kglcursor_child, x$kkssrd
V$SQL_SHARED_CURSOR	x$kkscs
V$SQL_SHARED_MEMORY	x$kglcursor, x$ksmhp
V$SQL_WORKAREA	x$qksmmwds
V$SQL_WORKAREA_ACTIVE	x$qesmmiwt
V$STATISTICS_LEVEL	x$prmsltyx
V$SUBCACHE	x$kqlset
V$SYSSTAT	x$ksusgsta
V$SYSTEM_CURSOR_CACHE	x$kgics
V$SYSTEM_EVENT	x$kslei, x$ksled
V$SYSTEM_PARAMETER	x$ksppi, x$ksppsv
V$SYSTEM_PARAMETER2	x$ksppi, x$ksppsv2
V$TABLESPACE	x$kccts
V$TEMPFILE	x$kcctf, x$kccfn, x$kcvfhtmp
V$TEMPSTAT	x$kcftio, x$kcctf
V$TEMP_CACHE_TRANSFER	x$kcftio, x$kcctf
V$TEMP_EXTENT_MAP	ts$, x$ktftme
V$TEMP_EXTENT_POOL	ts$, x$ktstfc
V$TEMP_PING	x$kcftio, x$kcctf
V$TEMP_SPACE_HEADER	ts$, x$ktfthc
V$THREAD	x$kccrt, x$kcctir, x$kcccp
V$TRANSACTION	x$ktcxb
V$TRANSACTION_ENQUEUE	x$ktcxb, x$ksuse, x$ksqrs
V$UNDOSTAT	x$ktusmst
V$VERSION	x$version
V$WAITSTAT	x$kcbwait
V$_LOCK	v$_lock1, x$ktadm, x$ktatrfil, x$ktatrfsl, x$ktatl, x$ktstusc, x$ktstuss, x$ktstusg, x$ktcxb
V$_LOCK1	x$kdnssf, x$ksqeq
O$SQL_BIND_CAPTURE	x$kqlfbc

Thanks to Jacob Niemiec for testing the queries and providing the new listings.

Index

Please note that index links point to page beginnings from the print edition. Locations are approximate in e-readers, and you may need to page down one or more times after clicking a link to get to the indexed material.

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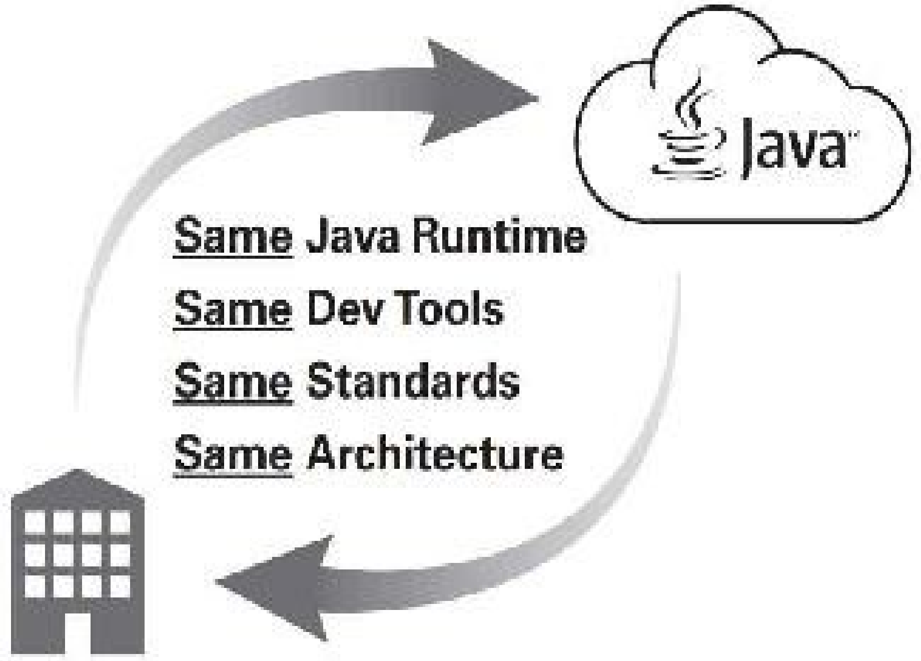

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