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- **Identify storage features that boost performance and efficiency**
- **Cut storage costs, even while databases are growing**

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Database Storage

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Contents at a Glance

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Introduction

As digital data continues to grow exponentially, traditional IT and database storage infrastructures are struggling to keep up with the demand for more capacity and higher performance. Too often, new business-critical applications are deployed with separate database instances installed on isolated "islands" of storage, as a temporary fix. Even when these storage systems have native file systems that optimize storage access, much more is needed to deliver the level of performance required by today's demanding applications and users. And as enterprises attempt to cobble these systems together, the complexity, risk, cost, and management burden rise significantly.

Today's enterprise database workloads demand storage solutions that embed a rich variety of features so that the optimal level of performance, manageability, and operational efficiency can be achieved. One solution is to fully integrate storage devices into an engineered stack that includes all of the components — software, servers, networking, and storage — required to build a high-performance database system.

Database Storage For Dummies, Oracle Special Edition, explores data storage and infrastructure challenges. It shows how Oracle's hardware and software engineered-together strategy, embodied in Application Engineered Storage, yields unique Oracle Database on Oracle storage capabilities that customers can leverage to achieve significant performance, efficiency, and cost benefits. This book also introduces several database

storage architectures, optimization features, and use-case scenarios to help you retake control of your database storage environments.

About This Book

This book consists of five short chapters chock-full of just the information you need. The topics include data growth trends and the challenges they create for your database storage, an overview of Oracle storage systems, a few of Oracle's optimization features for database storage, and some use cases, as well as information about Oracle key capabilities and benefits you don't want to miss.

Icons Used in This Book

Throughout this book, you'll see icons that call attention to important information. Here's what to expect.

This icon points out information that may well be worth committing to your noggin!

If you're an insufferable insomniac, take note. This icon explains the jargon beneath the jargon.

This icon points out helpful suggestions and useful nuggets of information.

Chapter 1

Understanding Why Database Storage Matters

In This Chapter

- Tracking the growth of digital data
- Identifying key drivers and impacts
- Addressing database storage challenges

In this chapter, you discover how today's explosive data growth trends affect your database infrastructure's performance, efficiency, complexity, and total cost of ownership. You also see how Oracle's database storage systems help businesses address these challenges.

Exponential Data Growth

Digital data — both structured and unstructured — continues to grow at a stunning rate. The 2014 IDC Digital Universe Study estimates that by 2020 the "digital universe" — all the digital data that is created, replicated, and consumed — will grow to 44,000 exabytes (see Figure 1-1), almost doubling in size every two years. This data growth was seen as the number one concern keeping database administrators awake at night in a

recent Independent Oracle Users Group (IOUG) Database Storage survey.

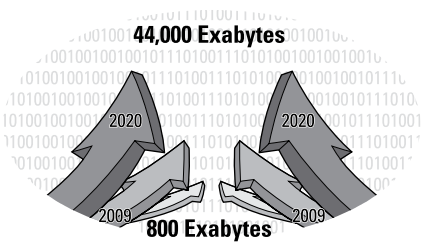

Figure 1-1: Digital data is growing at an unprecedented rate.

Just to put that in context, it would take almost 2.1 quadrillion (yes, *quad*rillion) trees to print 44,000 exabytes of data! That's more than 5,000 times the number of trees on the entire planet (which NASA estimates at approximately 400 billion)!

A terabyte is equal to 1024 gigabytes, a petabyte is equal to 1024 terabytes, and an exabyte is equal to 1024 petabytes.

Although some 70 percent of the data stored in organizations today is unstructured (for example, text documents, presentations, PDF files, images, and videos), structured data still comprises much of the critical data collected in day-to-day operations. Large databases containing structured data are associated with many core enterprise applications, such as online transaction processing (OLTP), product lifecycle management (PLM), enterprise resource planning (ERP), and customer relationship management (CRM).

Understanding the Drivers and Impacts of Data Growth

The ability to efficiently manage large databases containing structured and unstructured data is critical to IT operations. As data storage requirements grow, increases in IT infrastructure become inevitable and application performance is potentially impacted.

Several key drivers (see Figure 1-2) are contributing to this unprecedented growth in data and data storage requirements. These drivers are increasing database storage requirements between 40 and 45 percent annually, thereby doubling database sizes roughly every two years.

- **Data sources.** The increasing number and types of automated data sources, referred to as "The Internet of Things" — from RFID (Radio Frequency Identification) tags to health monitors to solar panel, car, and aircraft engine sensors — are generating continuous streams of real-time data that can be used and analyzed in numerous ways.
- **Consumers.** Largely driven by the mobile computing trend, the number of data consumers of all types has increased dramatically, with consumers generating digital content (pictures, videos) and accessing images, video streams, and data from practically anywhere, at any time, and on any device.
- **Data reuse.** Data is increasingly being used and reused in new and innovative ways, for example, "mashups" of structured and unstructured data

from different sources and big data analytics. Increasing the number of times and ways that data is accessed and analyzed increases the need for high-performance databases with increasingly complex back-end storage infrastructures.

- **Virtualization.** Server virtualization supports data center consolidation and cloud initiatives, making it possible to deploy a growing number of applications that, in turn, generate increasing volumes of data.
- **Retention.** Regulatory compliance is driving increasingly longer data retention requirements, creating new data-storage and management challenges for organizations.

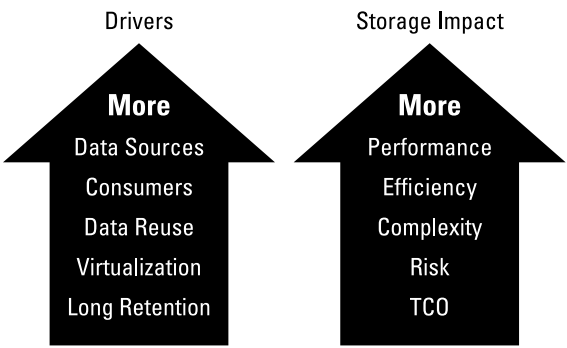

Figure 1-2: Database storage growth drivers and impacts.

These growth drivers impact organizations of all sizes, creating a diverse set of challenges for database storage. They include

- **Performance.** As storage capacity grows, system performance typically suffers. Reports that query large databases can take hours to run, and simply retrieving data can be a frustrating experience for users. In fact, the 2014 IOUG Database Storage survey showed that about one out of ten database administrators finds that database or application performance is limited by shortcomings in storage a significant amount of the time (over 25 percent of the time or more).
- **Efficiency.** As databases grow, their associated data is often stored inefficiently, scattered across multiple disparate systems or islands of storage. Even within single storage systems, data is often stored inefficiently to meet performance requirements, thus only taking advantage of a third to half of the actual hard disk drive capacity.
- **Complexity.** Keeping multiple storage systems of different types running optimally and integrating them with multiple database servers adds complexity to the storage infrastructure. Integrating solutions and managing the resulting complexity in storage infrastructure often requires additional IT staff and specialized database and storage administration skills.
- **Risk.** Organizational risk increases as data grows due to a multitude of factors, including human error (both users and administrators), lack of compliance with regulatory retention and security

requirements, electronic discovery issues, data integrity, and system outages and failures.

- **Total cost of ownership (TCO).** All of the preceding factors, which include capital and operational expenses, contribute to an ever-increasing TCO for an organization's database storage systems.

Optimizing Database Storage

Too often, organizations attempt to address their growing data storage challenges with ad hoc solutions. For example, a data center may have multiple applications each of which runs its own Oracle Database instance on its own dedicated NAS (Network-Attached Storage) or SAN (Storage Area Network) storage silos. These organizations also may have separate and disparate solutions for data protection, disaster recovery, and archiving of these same databases.

But as the volume of data grows, what is really needed are complete, integrated storage solutions that meet the performance and data handling requirements of the most-demanding applications, maximize storage efficiency, reduce complexity and risk, ease management and administration, automate manual processes, and reduce the overall TCO. Oracle's approach to meeting these needs is to co-develop Oracle Database and Oracle storage resulting in engineered systems and Application Engineered Storage with deep integration up and down the stack — delivering unique capabilities and significant benefits and business value to customers — which you learn about in the chapters that follow!

Chapter 2

Architecting the Best Database Storage Solution

In This Chapter

- Discovering Oracle Engineered Systems
- Exploring networked storage options
- Looking at tape and library solutions

In this chapter, you learn about several Oracle storage solutions and which ones are best for meeting your database storage needs, including Oracle Engineered Systems and Oracle's Application Engineered Storage: Network-Attached Storage, Storage Area Networks, and tape solutions.

Oracle Engineered Systems

An Oracle Engineered System is a set of hardware and software that is designed, engineered, and tested to work together to take full advantage of what each knows about the other, with the combination offering the best reliability and performance possible. Decisions about how to process work can be optimized because the database, storage management, and clustering software can take advantage of certain features or facilities that don't exist with a build-your-own

assembly of hardware and software components. For example, because Oracle has unique knowledge of the system and is aware of the operating environment, down to the patch level of the operating system (OS) and database, Oracle can

- Make installation, configuration, and tuning decisions, and automate the setup.
- Enable customer support to quickly diagnose and resolve issues.
- Issue "system" patches that combine OS, database, clusterware, and storage management updates.
- Deploy updates and patches for any element immediately when available; no cross-certification of different vendor's technologies, some of which can take more than a year to test and certify, is required.

Oracle Engineered Systems include Oracle Exadata Database Machine, Oracle Database Appliance (ODA), Oracle Exalogic, Elastic Cloud, Oracle SuperCluster, Virtual Compute Appliance (VCA), and more, several of which we highlight in the following sections.

Oracle Exadata Database Machine

The Oracle Exadata Database Machine is an easy-to-deploy system that includes all the hardware — database servers, storage servers, and network components — preconfigured, pretuned, and pretested by Oracle to run Oracle Database in critical environments that require extreme performance. Exadata combines industry-standard database servers, storage servers, massive memory, a high-speed InfiniBand internal fabric, and unique software advantages to run all types

of database workloads on a high-performance, high-availability platform.

Exadata uses an intelligent scale-out architecture for both database and storage servers. *Intelligent* means that much of the low-level database functionality has been offloaded to multiple Exadata Storage Servers to increase parallelism, reduce latency, and dramatically accelerate database throughput. *Scale-out* means that as an Exadata Database Machine grows, more database CPUs, storage, and networking components are added in a balanced fashion, ensuring scalability without bottlenecks.

Exadata leverages next-generation technologies to deliver significant performance improvements, including up to 40 percent faster response times, up to 30 percent reduction in power and cooling, and the ability to store and manage hundreds of terabytes of data entirely in Flash. Exadata Storage Servers are also used in Oracle SuperCluster systems.

Use Oracle ZFS Storage ZS3-BA for high-performance backup/restore and application development/testing, while taking advantage of the storage capacity savings of Oracle Database Hybrid Columnar Compression. For the best economics and as the last line of defense, consider Oracle's StorageTek tape storage for long-term data retention and archive data.

Oracle Database Appliance (ODA)

Many mid-size and growing enterprises need the power of proven, enterprise-quality database environments but lack the time and expertise to implement them from scratch. ODA is an engineered system consisting

of servers, storage, networking, and software that simplifies deployment, maintenance, and support of high-availability database solutions. ODA makes deploying the database easy — at a cost that makes it practical. ODA offers the flexibility to double the system's storage capacity. With the optional storage expansion shelf, the raw storage capacity of the appliance increases to a total of 36TB. Use Oracle ZFS Storage Appliance to expand storage outside of the appliance for online backups, application development and testing, data staging, or additional database files.

Oracle Exalogic Elastic Cloud

Oracle Exalogic is an integrated platform for running business applications. Exalogic is an engineered system that provides extreme performance, reliability, and scalability. To accelerate production deployments and reduce ongoing maintenance and administration costs, the Exalogic system includes a suite of exclusive system-level diagnostic and configuration tools. These tools ensure that Exalogic consistently delivers maximum performance and reliability while requiring less time to install, administer, and maintain than other platforms.

Oracle SuperCluster

Oracle SuperCluster engineered systems speed production deployments and reduce total cost of ownership (TCO) up to 5 times, increase application consolidation up to 10 times, provide 10 times faster provisioning of multi-tenant cloud services, and 32 times faster deployment of Oracle Database instances. Just like Exadata, Oracle SuperCluster includes Exadata Storage Servers to support Oracle Database 11g R2 and later versions. In

addition, it can also run previous versions of Oracle Database, Oracle middleware, and Oracle applications as well as non-Oracle software. Oracle SuperCluster systems enable you to dramatically simplify your complete data center with new levels of performance, system consolidation, and streamlined management. Use Oracle ZFS Storage Appliance to expand NAS storage outside of Oracle SuperCluster for online backups, storing shared directories, and application development/testing, while taking advantage of the storage capacity savings of Oracle Database Hybrid Columnar Compression. For SAN-based environments, Oracle FS1 Flash Storage System provides expanded storage that optimizes data placement based on performance, cost, and business priority, and streamlines management with application profiles that enable one-click quick provisioning of a wide variety of Oracle and third-party applications.

Oracle's Application Engineered Storage

Application Engineered Storage is one result of Oracle's hardware and software engineered-together strategy for delivering unmatched customer value. Oracle offers databases and applications that are storage-aware and storage systems that are database and application-aware. Unique points of co-engineering, including Hybrid Columnar Compression (see Chapter 4) and Oracle Intelligent Storage Protocol (discussed in Chapter 5), provide customers with significant efficiency and performance gains, while Application Profiles (see Chapter 5) streamline management with one-click provisioning. Customers can now spend time focusing on strategic business initiatives instead of spending endless hours fine-tuning and managing their storage systems.

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Oracle ZFS Storage Appliance

Oracle ZFS Storage Appliance is a Network-Attached Storage (NAS) appliance with unified storage capability, an in-memory architecture, and a rich set of data services for enterprise environments. The ZFS Storage Appliance is built on a rock-solid software foundation, Solaris, a multi-threaded, symmetric multi-processing (SMP) operating system that takes full advantage of multi-core CPUs and, as a result, easily handles heavily virtualized environments. The ZFS Storage Appliance features a cache-centric Hybrid Storage Pools architecture (see Chapter 5) with massive DRAM and flash media to accelerate performance and optimize efficiency. In fact, compressed Oracle Databases can run in memory.

Using sophisticated algorithms, the ZFS Storage Appliance recognizes I/O patterns and automatically places data on the best of several tiers of storage media. For example, the ZFS Storage Appliance logs all write requests to low-latency solid-state drive (SSD) media so that writes can be acknowledged quickly, allowing the application to continue processing. The ZFS Storage Appliance then automatically gathers together multiple logical writes into a smaller number of physical writes and sends them to hard disk drives (HDDs) as a background task. In addition, terabytes of DRAM memory plus additional terabytes of SSDs act as a multi-level read cache to reduce read latency. Oracle's Hybrid Storage Pool technology transparently manages the process of copying frequently accessed data into this cache to seamlessly satisfy read requests from the client so that up to 70–90 percent of read requests are served from DRAM, the fastest media.

This combination of SMP operating system and Hybrid Storage Pools technology enabled the latest ZFS Storage Appliances, the ZS3 Series, to establish world-record benchmark performance, while beating major competitors in price/performance. In addition, the Oracle ZFS Storage ZS3-2 easily handled unpredictable virtual machine (VM) workloads by booting 16,000 VMs in under 7 minutes.

Other performance-enhancing features of the ZFS Storage Appliance include Oracle Database Hybrid Columnar Compression (HCC) and Oracle Database Direct NFS (both discussed in Chapter 4) and Oracle Intelligent Storage Protocol (OISP) (discussed in Chapter 5).

HCC enhances both database storage efficiency and performance by reducing the physical size of the data on storage devices and in memory, and therefore how long it takes to process it.

ZFS Storage Appliances offer advanced management and monitoring tools through DTrace Analytics. With DTrace, system and storage administrators can quickly and intuitively identify and diagnose system performance issues, gain granular visibility into critical business workloads, and leverage key performance indicators that contribute to longer-term capacity planning and operational efficiencies. You learn more about DTrace in Chapter 3.

The ZS3 Series is available in three configurations, ZS3-2, ZS3-4, and ZS3-BA ensuring flexibility to meet customer requirements and with cluster capabilities for high availability. ZFS Storage Appliances can scale as needed with additional disk shelves to increase capacity and performance.

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Oracle FS1 Flash Storage System

Oracle FS1 Flash Storage System is the best application-engineered SAN storage solution for Oracle Database and Applications. The FS1 delivers enterprise-grade storage capabilities that are architected to exploit the power of flash for greater performance predictability and better economics through automated tiering of flash and disk.

Oracle FS1 is designed from the ground up to exploit the unique characteristics of flash storage to provide predictable high performance with low latency, high I/O operations per second (IOPS) and throughput without compromising expandability. It scales to 912TB of flash and up to 2.9 petabytes combined flash and disk, to meet the most demanding performance requirements.

Using the patented Quality of Service Plus (QoS Plus) feature, Oracle FS1 combines with fine-grained auto-tiering (up to 1600 times more granular than competitive systems) to place data across four tiers of flash and disk storage to optimize performance, efficiency, and cost, based on usage profiles and business priorities. The FS1 also enhances storage efficiency for Oracle Database environments by combining support for Hybrid Columnar Compression (HCC, discussed in Chapter 4) with QoS Plus. This means that multiple production databases, along with development and test environments, can run on a single FS1and benefit from HCC efficiencies.

The FS1 takes application-engineered storage to a new level by providing out-of-the-box tuned one-click storage provisioning profiles for Oracle Database and key applications, including Microsoft SharePoint and

Exchange. Storage Domains software enables multiple virtual storage systems within a single FS1. Each storage domain is a data container that isolates data from other storage domains, providing independence in multitenancy environments for private or public cloud deployments, regulatory compliance requirements, or chargeback models. With storage domains, you can custom-tailor QoS settings for each domain enabling you to consolidate storage while achieving predictable performance for multiple diverse workloads in enterprise computing or multitenant environments.

The FS1 is designed with enterprise-grade hardware and software features to provide maximum uptime, data availability, and application access. These features deliver rapid controller failover, warm start technology for upgrades and error end-to-end data integrity checking protects against silent data corruption from the application to the storage devices, and no single point of failure.

Oracle's StorageTek Tape and Library Solutions

Oracle's StorageTek family of scalable tape libraries, enterprise and mid-range tape drives, and management software provides long-term archiving and data protection for Oracle Database. StorageTek products work with Oracle Engineered Systems, ZFS Storage Appliances, and FS-1 flash storage systems to create complete multi-tier archiving solutions. StorageTek tape libraries are available in three models, ranging from entry-level to multi-exabyte systems. StorageTek tape drive offerings include the T10000D that currently has a raw capacity of

8.5TB and performance of 252MBps. With the T10000D, customers can store more data in a smaller footprint, yielding savings in capacity, footprint, and management resources. Oracle also added StorageTek Linear Tape File System, Library Edition, to its tape software portfolio, extending the drag-and-drop capabilities of LTFS to the library level.

Archive solutions that use tape storage for long-term data retention and disk storage for data staging provide the highest levels of efficiency by optimizing for access, performance, and cost. A recent study by The Clipper Group revealed that implementing a disk storage infrastructure for long-term data retention can be 26 times more expensive than deploying a tape storage infrastructure. Oracle's StorageTek Storage Archive Manager 5.4 extends storage tiering by enabling object data to be archived to and retrieved from low-cost private clouds using standard OpenStack Swift-based web access protocols. See the discussion of archiving (Chapter 4) and Storage Archive Manager software (Chapter 5) for more information.

Chapter 3

Recognizing the Oracle Storage Advantage

In This Chapter

- Uncovering and solving storage inefficiencies
- Maximizing throughput
- Simplifying database storage management

As part of Oracle's hardware and software engineered-together strategy, a number of key capabilities for Oracle Database are integrated with Oracle Engineered Systems, ZFS Storage Appliances, and FS1 Flash Storage Systems (see Chapter 2). This chapter explores the three major areas of optimization in which these capabilities can be broadly classified: storage efficiency, throughput, and management. Some capabilities contribute to more than one of these areas of optimization.

Storage Efficiency Optimization

The goal of storage efficiency is to reduce the amount of storage space needed for your organization's data. Several technologies and strategies commonly used in

various storage-centric solutions include thin provisioning, snapshots and cloning, and data compression and deduplication. Oracle Database offers key storage efficiency options like Oracle Partitioning, Oracle Advanced Compression Option with new Heat Map and Automatic Data Optimization features, and Hybrid Columnar Compression (HCC), which is only available on Oracle Exadata, ZFS Storage Appliance, and FS1 Flash Storage Systems. With HCC, you can reduce your data warehouse storage footprint by 75 percent.

Figure 3-1 shows active (or "hot") data, which typically comprises approximately 5 percent of data stored on primary disk. Less active (or "warm") data, which typically comprises 15 percent of data, can typically be compressed by a factor of 2 to 4 using Oracle Advanced Compression Option. And finally, historical data comprises approximately 80 percent of all data, which can typically be compressed by an average of 12x using HCC (with some customers even seeing up to 50x compression). Combine Oracle Advanced Compression Option and HCC for end-to-end cost and performance benefits across your CPU, DRAM, Flash, Disk, and network.

Oracle Database 12*c* supports new features like Heat Map, an in-memory option, and Automatic Data Optimization (ADO) in Oracle Advanced Compression. ADO, only available with Oracle storage, enables you to set policies about your data to automate compression and storage tiering for smarter data lifecycle management.

Oracle Database Partitioning

Oracle Database Partitioning enhances the manageability, efficiency, performance, and availability of a wide variety of applications and enables a simple, yet very powerful, approach to Information Lifecycle Management (ILM).

Partitioning for manageability

Partitioning allows tables, indexes, and index-organized tables to be subdivided into smaller, more manageable units, enabling these database objects to be managed and accessed at a finer level of granularity.

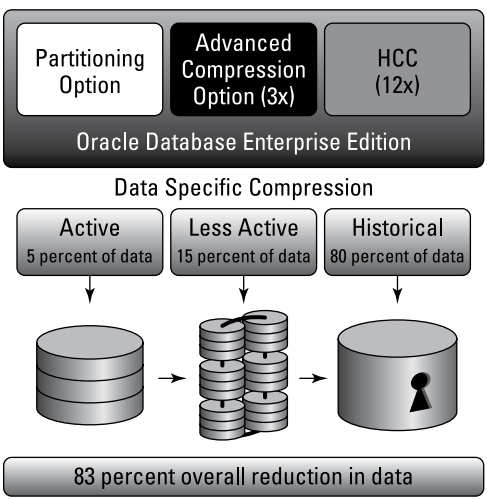

Figure 3-1: Example results of Oracle Database Partitioning and Compression on Oracle Storage.

With partitioning, maintenance operations can be focused on particular portions of tables. For example, a database administrator could back up a single partition of a table rather than backing up the entire table. For maintenance operations across an entire database object, these operations can be performed on a per-partition basis, thus dividing the maintenance process into more manageable chunks.

Partitioning for efficiency and ILM

Through partitioning, tables containing less active and historical data can be separated from active data and from each other. Each table can be stored on different storage tiers, with different access rates, compression ratios, and vastly different costs — enabling enormous reductions in total cost of ownership (TCO) that are much greater than that provided by compression alone.

Partitioning for performance

When data volumes increase, a common concern is that system performance will degrade because all of the data has to be examined during a query. Partitioning eliminates this problem by limiting the amount of data to be examined or operated on for a single query, thus significantly improving performance beyond what is possible with a table that has not been partitioned.

Partitioning provides a number of performance-enhancing features, including

- **Partitioning pruning:** Eliminates unneeded partitions, enabling the database to perform operations only on those that are relevant.

- **Partition-wise joins:** Reduces query response time by minimizing the amount of data exchanged when joins execute in parallel.

Partitioning for availability

Partitioned database objects provide partition independence, which is an important part of a high-availability strategy. For example, if one partition in a table is unavailable, all of the other partitions of the table remain online and available. The application can continue to execute queries and transactions against this partitioned table, and these database operations will run successfully if they do not need to access the unavailable partition.

Oracle Database Advanced Compression Option

The Oracle Database Advanced Compression Option (ACO) provides a comprehensive set of compression capabilities to help reduce overall database storage footprints by enabling compression for structured and unstructured data, as well as backups. ACO automates what many DBAs do manually on a regular basis, freeing up time for more strategic projects. Storage efficiency benefits of the Advanced Compression Option include

- Two to four times reduction in storage across all environments, such as production, standby, development, test, backup, and disaster recovery
- Faster query performance due to improved disk scan rates and a reduction in the number of I/Os
- Minimal or no performance impact on DML (Data Manipulation Language) operations due to performance optimized compression technology, which means it can be used on OLTP (online

transaction processing) and Data Warehousing applications without change

- Heat Map and Automated Data Optimization with Oracle Database 12*c* looks at actual database usage and migrates data between partitions based on frequency and type of usage
- Shorter delivery time for applications that track changes to data

Hybrid Columnar Compression

Oracle Database 11g Release 2 and later use Hybrid Columnar Compression (HCC) technology, a combination of both row and columnar methods for storing and compressing data in a logical construct called a *compression unit* (see Figure 3-2), is only available on Oracle Exadata, ZFS Storage Appliance, and FS1 Flash Storage Systems. Storing column data with the same data type and similar characteristics together dramatically improves storage efficiencies achieved with compression. This approach also minimizes I/O requests, providing the benefits of columnar compression for data warehouses, historical data in OLTP database partitions, and other mixed use environments while avoiding the performance shortfalls of a pure columnar format.

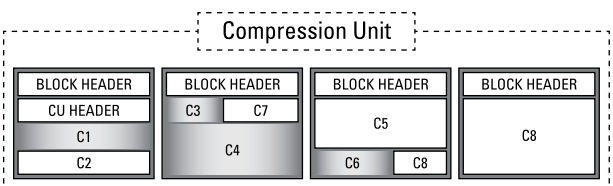

Figure 3-2: A compression unit stores a set of HCC rows.

HCC is only available on Oracle Exadata Storage Servers, ZFS Storage Appliances, Oracle SuperCluster Storage, and FS1 Flash Storage Systems. HCC is not available with any third-party storage systems.

Oracle Database HCC provides a robust set of features that dramatically reduce infrastructure costs, enable the highest levels of data compression, and provide users with significant performance improvements when querying historical data.

Depending on data classification, HCC can provide both compression and performance benefits with typical compression ratios of 12 times being achieved, so that entire rows of a database can be accessed in a single I/O operation. See Figure 3-3 for an example of the compression and performance benefits of HCC in a retail data warehouse.

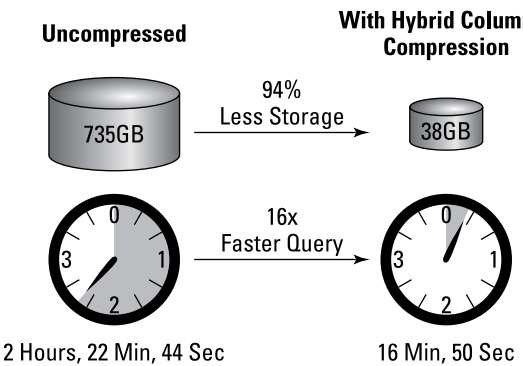

Figure 3-3: Retail data warehouse example using HCC.

Using HCC in your data center can help you to:

- Compress historical data by 90 to 98 percent
- Increase application performance when querying historical data
- Dramatically reduce the cost of storing and managing data

Throughput Optimization

Throughput optimization includes improving disk I/O performance and the efficiency of communications between storage systems and their associated databases and applications. This is typically accomplished with high throughput storage controllers and large, fast caches.

Several key Oracle technologies for throughput optimization include Oracle Database Smart Flash Cache, InfiniBand, Oracle Database Direct NFS (Network File System) and RDMA (Remote Direct Memory Access). OISP for ZFS Storage Appliances and QoS Plus for FS1 Flash Storage Systems are discussed in Chapter 5.

Oracle Database and Exadata Smart Flash Cache

Oracle Database Smart Flash Cache and Exadata Smart Flash Cache enable you to increase the effective size of an Oracle Database buffer cache without adding main memory to the system. For transaction-based workloads, Oracle Database blocks are normally loaded into a dedicated shared memory area in main memory called the System Global Area (SGA). Oracle Database

Smart Flash Cache allows the database buffer cache to be expanded beyond the SGA in main memory to a second level cache in flash memory, which is integrated in Oracle Exadata Storage Servers found in Oracle Exadata Database Machines and Oracle SuperCluster.

InfiniBand

InfiniBand is a high-bandwidth, low-latency 40 Gigabit per second network protocol that delivers application-to-application latencies as low as one microsecond. InfiniBand is the backbone network fabric between Oracle Database servers and their associated Oracle storage systems, such as Exadata Storage Servers and ZFS Storage Appliances (refer to Chapter 2).

InfiniBand is also the underlying technology behind Oracle Virtual Networking, which can be used to combine Fibre Channel, Gigabit Ethernet, 10Gigabit Ethernet, iSCSI, and other networking protocols onto a single physical wire — significantly simplifying your data center network.

Oracle Database Direct NFS

NAS (Network-Attached Storage) appliances and their client systems typically communicate via the Network File System (NFS) protocol. NFS allows client systems to access files over the network as easily as if the underlying storage were directly attached to the client. However, performance degradation and complex configuration requirements previously limited the benefits of using NFS and NAS for database storage.

Oracle Database Direct NFS overcomes many of the challenges associated with using NFS with the Oracle Database. Direct NFS Client outperforms traditional NFS clients, is simple to configure, and provides a standard NFS client implementation across all hardware and operating system platforms.

Direct NFS Client includes two fundamental I/O optimizations to increase throughput and overall performance. First, it eliminates copying of data between the database SGA and the operating system, and it bypasses operating system caches and write-ordering locks to decrease memory consumption and CPU overhead. Second, the Direct NFS Client uses asynchronous I/O, so processing can continue while the I/O request is being processed.

Oracle Remote Direct Memory Access

Remote Direct Memory Access (RDMA) enables the network adapter, such as an InfiniBand card, to transfer data directly from application memory to the network. This eliminates CPU processing required to copy data buffers between application memory locations, increases CPU efficiency for transmitting data, and reduces latency to data to deliver higher storage throughput and lower storage response time. RDMA is a great way to transfer large amounts of data quickly. Typical uses for RDMA technology include backup and recovery, data warehouse loads, and ETL (Extraction, Transformation, and Loading) activities.

Management Optimization

Oracle management optimization includes Enterprise Manager, Oracle VM integration, and DTrace Analytics.

Many Oracle management optimizations also improve performance and efficiency in Oracle Database and storage systems.

Enterprise Manager

Oracle Enterprise Manager provides a unified view of hardware and software, including hardware components such as compute nodes, Exadata Storage Servers, ZFS Storage Appliances, FS1 Flash Storage Systems, and InfiniBand switches. You can also see the placement of software running on systems, along with their resource utilization. Enterprise Manager integration enables centralized management across the entire Oracle stack so that you can easily correlate application problems with storage issues and fix them quickly.

Plug-ins for Enterprise Manager 12c are available for both ZFS Storage Appliance and FS1 to provide a single-pane enterprise-wide view of all storage systems.

ZFS Storage Appliance Analytics

DTrace Analytics provides a comprehensive and intuitive easy-to-use interface for Oracle storage. It uses built-in instrumentation to provide real-time granular visibility throughout the data path, from the application to the storage, even down to the virtual machine level. This capability empowers administrators to act quickly to identify performance issues, using in-depth analysis of key storage systems components and I/O traffic patterns with related client systems. Graphical displays of performance and utilization statistics can be used to locate and quickly remedy bottlenecks and optimize storage performance and capacity usage — all while systems continue running in production.

See Chapter 5 for information about Oracle VM integration and Hybrid Storage Pools.

FS1 storage systems

Oracle FS1's MaxMan feature enables the management of multiple FS1 and/or Pillar Axiom systems from a single console. FS1 also provides management plug-ins for Oracle Enterprise Manager and the Oracle VM Storage Connect feature for single pane of glass monitoring and management.

Chapter 4

Exploring Use Cases

In This Chapter

- Realizing performance gains in primary storage
- Backing up mission-critical databases
- Replicating to remote sites for disaster recovery
- Building a development and test environment
- Complying with retention requirements

Oracle's broad IT organizations handle hundreds of petabytes of data across a vast spectrum of workloads. Oracle's internal-facing IT business units must meet the needs of the application developers and well over 120,000 employees worldwide. At the same time, Oracle IT also manages Oracle's customer-facing cloud businesses (with more than 25 million users) and various mission-critical databases.

Thus, from a database storage perspective, Oracle is a great place to look for real-world database storage use cases. In this chapter, you learn not only about Oracle real-world use cases but about some Oracle customers as well!

Primary Database Storage

Oracle Managed Cloud Services (formerly Oracle On Demand) is responsible for the operation, administration, and management of Oracle's customer-facing IT resources. Oracle IT uses more than 1,000 ZFS Storage Appliances with more than 225 petabytes of storage capacity that is continuously increasing. These systems are used extensively for mission-critical storage for the full suite of Oracle's many cloud application offerings including

- Oracle E-Business Suite
- Oracle Express
- Oracle E-mail Center
- Oracle iLearning
- Oracle's Agile PLM solution
- Oracle Beehive
- Oracle's PeopleSoft product portfolio
- Oracle's Siebel products
- Oracle Hyperion products
- Oracle's JD Edwards EnterpriseOne

The Oracle Managed Cloud Services infrastructure consists of approximately 17,000 virtual machines (VMs) running on more than 4,000 physical servers with over 5,300 customer instances.

The typical customer environment involves a complete software stack, from the operating system (OS) level (Oracle Linux or Oracle Solaris) with Oracle Database (including Oracle RAC, in some cases), Oracle Fusion

Middleware, and Oracle Fusion Applications running on top.

Prior to migrating to ZFS Storage Appliances, the Oracle Managed Cloud Services business relied primarily on a leading third-party manufacturer's NAS (Network-Attached Storage) filers.

By leveraging the superior performance and management efficiency benefits of the ZFS Storage Appliance, Oracle Managed Cloud Services has achieved a 3:1 consolidation of storage, 3 times faster performance with twice as many clones and snapshots, 12 times faster overall performance on compute farm workloads, simplified management with less tuning and troubleshooting required, and 5 times faster database test suite executions (see Figure 4-1).

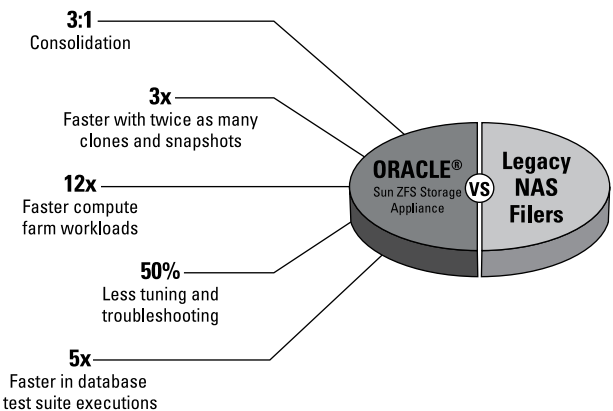

Figure 4-1: Oracle Managed Cloud Services on Oracle storage versus competitive storage solutions.

Furthermore, Oracle leveraged the benefits of the ZFS Storage Appliance Shadow Migration feature, which provides automated migration of referenced data from application storage "islands" (or silos) to the ZFS Storage Appliance. An Oracle On Demand IT manager described the experience as "migrating a client as fast as the [data] share can be created," which demonstrates the performance and ease of use of the Shadow Migration tool.

Oracle Cloud Services has also deployed Pillar Axiom systems for dedicated customer environments that require the highest level of SAN (Storage Area Network) performance and data isolation. These systems use the Axiom's Quality-of-Service (QoS) capabilities to maximize throughput for multiple applications on a single storage platform.

Backup Database Storage

The Oracle Patches and Updates and Oracle Software Cloud Delivery system database is a mission-critical OLTP (Online Transaction Processing) workload. This system handles a variety of important tasks, including patch deployment to more than 3 million registered Oracle software users. Each week, this database handles more than 6 million requests and 400,000 patch downloads.

The primary and backup storage for both the database and patch file repository associated with this system is Oracle ZFS Storage Appliance. The entire database resides on two storage pools (see Figure 4-2).

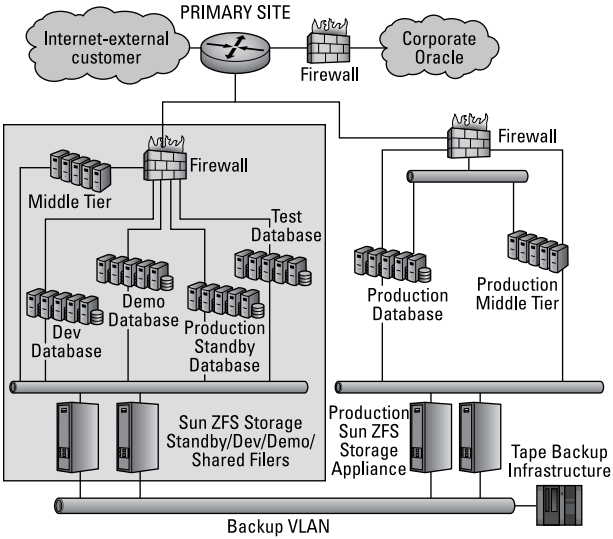

Figure 4-2: Oracle's Patches and Updates and Software Cloud Delivery primary and backup database.

Prior to migrating to the ZFS Storage Appliance, this database resided on a major third-party manufacturer's NAS filers. Once replaced with the ZFS Storage Appliance, the time required for all SQL transactions dropped significantly. Overall reduction in elapsed time per execution ranged from 23 percent to 66 percent, depending on the specific SQL transaction.

In addition to the performance improvements, significant efficiency gains have been realized with a 3:1 consolidation ratio, 50 percent less troubleshooting, and storage space reduced by approximately 50 percent due to compression.

Remote Replication

SunGard Availability Services provides IT operations support to keep businesses' mission-critical information and applications up and running. SunGard provides responsive and integrated disaster recovery, cloud services, managed services, IT consulting, and business continuity management software solutions that help keep people and information connected in the financial services, manufacturing, retail, healthcare, business services, transportation, telecommunications, utilities, and government industries.

A strategic Oracle partner for the last 15 years, SunGard selected Oracle Exadata Database Machine and Oracle ZFS Storage Appliance to meet growing data needs and to help consolidate its existing data warehouse. Since these solutions work in conjunction with its existing Oracle infrastructure, which includes Oracle's SPARC T4 servers running Oracle Solaris, Oracle Business Intelligence, and Oracle WebCenter, SunGard uses Oracle Exadata to support both its legacy database and Oracle E-Business Suite implementation. It is leveraging ZFS Storage Appliances for backup and data replication to an off-site disaster recovery location.

In addition, SunGard wanted to take advantage of Oracle Database Hybrid Columnar Compression, enabled by ZFS Storage Appliance, to improve its customer offering, compress its data, and enable replication of its production backups to an off-site data center several times a day. Further, with ZFS Storage Appliance's direct InfiniBand connection to Oracle Exadata, SunGard expects to write 5 to 8 terabytes per hour to the device, supporting full data recovery in less than an hour. SunGard has also achieved a 70 percent performance increase after testing Oracle Exadata running Oracle E-Business Suite, a performance increase that is expected to have a direct impact on the company's bottom line by enhancing its responsiveness to customers. Read the complete SunGard case study at `www.oracle.com/customers`.

Development and Testing

R.L. Polk & Co. (Polk) is a leader in automotive information and marketing solutions. The company collects and interprets data and provides extensive automotive business expertise to help its customers understand their market position, identify trends, build brand loyalty, win new business, and gain a competitive advantage.

Looking to continually expand services and develop new applications for its automotive industry clients, Polk wanted to improve performance in its development and testing centers to better replicate production conditions and accelerate time to deployment. With Polk's production databases processing up to 10 million

records per day, the company needed to ensure that new applications can handle massive loads.

Polk selected Oracle ZFS Storage Appliance for its application development and testing center. With the appliance, Polk can back up and restore an entire database — closely replicating what the application will experience when it goes into production — enabling the development team to test against full-scale data and identify bugs and causes better and faster.

In its production environment, Polk uses Oracle Exadata Database Machine to power its automotive information applications and its business systems. The Exadata enables the company to efficiently manage 12 terabytes of data and quickly provide in-depth business and market intelligence to its executives, field staff, and customers.

Polk uses Oracle Database Hybrid Columnar Compression (HCC) in both its Oracle Exadata and ZFS Storage environments. Having HCC available in both environments is critical to Polk's ability to replicate the complete database in the ZFS Storage Appliance to the development and test environment. At Polk, HCC improved compression on an average of 5 to 10 times, and now every one of its customer-facing data warehouses can fit onto one Oracle Exadata Database Machine. For example, Polk's auto parts database, which was 1.5 terabytes, now fits into 300 gigabytes of storage, thanks to HCC. Read the complete Polk & Co. case study at `www.oracle.com/customers`.

Database Archive Storage

The flexible, cost-effective, and reliable long-term retention of data is critical for historical intelligence, risk reduction, and compliance. Data needs to be available over ever-longer periods of time for government retention requirements and legal discovery requests. As such, organizations look to tape storage systems to achieve long-term data retention.

The Michigan Department of Human Services (DHS), the state's public assistance, child, and family welfare agency, directs the operations of public assistance and service programs through a network of more than 100 offices throughout the state.

Michigan implemented the nation's largest legacy welfare system replacement project with the design and implementation of Bridges, an integrated eligibility and payment solution that enables DHS employees to manage eligibility determination, benefits issuance, and reporting processes from a single system. With Bridges, Michigan DHS can manage an increased volume of cases more efficiently and accurately with existing staff. Currently, approximately 3,000 caseworkers use the system to serve 2.2 million clients. In addition, to determine eligibility for assistance programs, Bridges, built on Oracle SPARC Enterprise M9000 servers running Oracle Solaris 10 and Oracle Database 11g Release 2, also integrates with the Michigan Department of Community Health (DCH) to share Medicaid eligibility information.

To ensure long-term storage of critical data from its Bridges system as well as other core applications, Michigan DHS relies on Oracle's StorageTek tape systems, including the highly scalable and flexible StorageTek SL8500 and StorageTek SL3000 modular library systems, configured with StorageTek T10000A and StorageTek T10000B tape drives. Michigan DHS data is backed up in a consolidated tape environment, serving all of the state's agencies. Read the complete Michigan DHS case study at `www.oracle.com/customers`.

Chapter 5

Ten (Okay, Eight) Important Oracle Storage Capabilities and Database Benefits

In This Chapter

- Understanding Oracle capabilities and benefits

This chapter talks about several (eight, to be exact) important Oracle storage and database capabilities and features that will help you optimize and manage your mission-critical database storage systems. When looking at storage systems for your Oracle Database, these factors will be critical in making a decision.

Oracle Intelligent Storage Protocol (OISP)

OISP is a unique communications protocol that enables Oracle Database 12*c* to communicate dynamically with the ZFS Storage Appliance to automatically tune critical factors, including logbias and record size, for optimal database performance. With OISP, storage administrators reduce manual tuning tasks by 65 percent,

enabling them to spend more time on revenue-generating projects. OISP is only available for ZFS Storage Appliances.

Oracle Database Hybrid Columnar Compression (HCC) for Oracle Exadata and Oracle Storage Systems

Oracle Database HCC, available only with Oracle Exadata and Oracle storage systems, enables customers to compress data 12 to 50 times, depending on usage, resulting in a 3 to 5 times reduction in storage capacity requirements. HCC combines with new features in Oracle Database 12c to provide Heat Map and Automatic Data Optimization (ADO) in Oracle Advanced Compression. ADO enables you to set policies about your data to automate compression and storage tiering for smarter data lifecycle management (see Chapter 3 for details).

Quality of Service (QoS) Plus for FS1

QoS Plus is a policy-based virtualization feature, incorporating business priority I/O (input/output) queue management fused with sub-LUN (logical unit number) automatic tiering into one simple management framework. Built on Oracle's patented storage QoS technology, QoS Plus collects detailed information on your storage usage profile, evaluates data granules for movement to different storage tiers, and then

automatically migrates data to the most cost-effective media (flash or disk) from a cost per IOP (I/O Operations) and cost per GB standpoint based on the usage profile and the importance of that data to the business. QoS Plus performs data collection, evaluation, and movement based on the most efficient data granularity in the storage industry — up to 1600 times more granular than other systems.

Application Profiles for FS1

Oracle FS1 Flash Storage System comes with predefined application profiles that provide tuned and tested out-of-the-box storage optimization for Oracle Database and key enterprise applications, including non-Oracle applications such as Microsoft Exchange. With one-click provisioning, you can optimize flash performance and manage Oracle applications with minimal administration. FS1 database storage profiles can disaggregate database components (such as index files, database tables, archive logs, redo logs, control files, and temp files) so that provisioning automatically optimizes Oracle Database performance without requiring detailed knowledge of the database components. New application profiles can be added to the FS1, existing ones can be modified, and all profiles can be exported to other FS1systems to standardize storage provisioning across global datacenters.

Hybrid Storage Pools

Oracle ZFS Storage Appliances leverage Hybrid Storage Pools intelligent data caching algorithm and architecture to ensure that up to 70–90 percent of "hot" I/O is processed in DRAM (in memory) — up to

2TB per system, frequently accessed data is cached in flash, and less-frequently accessed data is read from disk when needed. This ensures continuous and optimal storage performance and efficiency, with no end-user involvement required (refer to Chapter 2 for a full description).

Snap Management Utility

The Oracle Snap Management Utility for Oracle Database is a standalone management tool specifically engineered to work with the ZFS Storage Appliance. It provides

- A simple, fast, efficient, and automatic way to back up, restore, clone, and provision Oracle Databases that are stored on the ZFS Storage Appliance — all performed directly by the database administrator with a graphical user interface
- One-step provisioning of database copies to accelerate development and test environments
- Support for Oracle Solaris, Linux, and Windows clients and database hosts, for databases configured for NAS or SAN storage types
- Support for Oracle Real Application Clusters (Oracle RAC)

The Oracle Snap Management Utility for Oracle Database combines the underlying snapshot, clone, and rollback capabilities of the ZFS Storage Appliance with standard host-side processing so that all operations are always in a consistent state. With Snap Management Utility, database administrators gain full control of the application development and test

environment, thereby speeding up time-to-market for new product offerings.

Oracle Enterprise Manager (EM) and Oracle VM Integration

Oracle EM is Oracle's cross-system, global management, and monitoring tool. With Oracle EM plug-ins for engineered systems, Oracle FS1, and Oracle ZFS Storage, users can monitor and manage their entire Oracle environment from application to storage from a single pane of glass. EM plug-ins enable DBAs to monitor and manage storage resources with storage administration involvement.

Oracle VM is server virtualization software that supports both Oracle and non-Oracle applications on x86 and SPARC server platforms. Oracle VM Storage Connect integration enables server administrators to provision storage directly from the Oracle VM browser user interface, without requiring a storage administrator.

Download a free copy of *Server Virtualization For Dummies,* Oracle Special Edition, at `www.oracle.com` to learn more about Oracle VM.

Oracle Storage Archive Manager and Long-term Archiving

Oracle StorageTek Storage Archive Manager (SAM) enables policy-based archiving and classification and provides ready access to data throughout its life cycle. Managed files appear to exist in the topmost directory of the storage hierarchy, no matter where they actually

reside on physical storage. In the background, SAM abstracts the actual location of the file data, automatically placing it on up to four tiers of local or remote disk or tape storage to ensure that it is readily accessible, efficiently compressed and stored, and preserved with the utmost care. Oracle's StorageTek Storage Archive Manager 5.4 extends storage tiering by enabling object data to be archived to and retrieved from low-cost private clouds using standard OpenStack Swift-based web access protocols. SAM dramatically simplifies archiving by enabling archive managers to make business-level decisions about what data to keep, for how long, and on what cost structure, while SAM implements those policies and stores and retrieves the archived data for them.

To learn more about SAM and long-term archiving, download a free copy of *Archiving For Dummies,* Oracle Special Edition, at `www.oracle.com`.

Optimize database storage for maximum performance and efficiency

Digital data — including structured data in large, mission-critical databases — is growing at an unprecedented rate and creating new challenges for organizations of all sizes. In this book, you learn about these challenges and how to address them!

- ***Navigate storage choices — leveraging the benefits of NAS, SAN, tape, or even a fully integrated database system***
- ***Implement cost-saving features — including compression technologies, multi-tier architectures, and more***
- ***Better protect your data — using essential features for database backup and recovery***

Open the book and find:

- **Why data growth increases organizational risk**
- **Which database storage solutions are best for your data center**
- **How innovations like InfiniBand and Direct NFS improve throughput performance**
- **How co-engineered software and hardware solutions maximize value and reduce TCO**

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