ORACLE
OPTIMIZED SOLUTIONS

Deploy a Fast and Secure Database Architecture: Oracle Optimized Solution for Secure Oracle Database

ORACLE WHITE PAPER | MARCH 2016

ORACLE

Table of Contents

Introduction

Increasingly companies are turning to their database investments to analyze complex business problems and inform strategic business decisions. Initiatives such as cloud delivery and big data are fueling efforts to consolidate and leverage existing database assets. Analytics are becoming progressively entwined with Oracle Database applications that require traditional transaction processing, blurring the lines between online transaction processing (OLTP) systems and data warehousing solutions.

At the same time, organizations face ongoing threats—malicious attacks and malware that make infrastructure security a paramount concern. Oracle is exceptionally positioned to help customers deliver superior database and decision-support solutions, because it merges engineering efforts for its flagship Oracle Database software with the development of state-of-the-art products and technologies at each tier of the solution stack, with an intense focus on how each layer protects data assets and applications. Oracle Optimized Solution for Secure Oracle Database unites the first converged infrastructure in silicon, the fastest microprocessor, and advanced security innovations with proven best practices for deployment. Configurations extend integration across the solution stack in a design that protects Oracle Database applications and data—including data in motion, in process, and at rest—while optimizing performance, security, and availability for both OLTP and analytical workloads.

In addition to optimizing deployment architectures, Oracle Optimized Solutions are designed to shorten time-to-deployment as well as save money and reduce integration risk. Each solution acts as a blueprint to implement a secure and effective infrastructure solution, applying validated configurations and proven best practices to address critical business challenges. Oracle Optimized Solution for Secure Oracle Database can host multiple Oracle Database releases and many instances within a single system using less hardware, fewer licenses, and a smaller footprint. It is designed to lower cost and complexity, decreasing the total cost of ownership for Oracle Database while protecting applications, systems, and data.

The solution creates a secure and flexible infrastructure to support rapid data analysis, high transaction throughput, and strategic decision-making. It takes advantage of Oracle investments in microprocessors, systems, software, and solution engineering to accelerate and secure Oracle Database analytical queries and transactional workloads. Recent Oracle-only innovations—such as Software in Silicon technology—bring significant benefits to database performance and security, helping businesses achieve faster intelligence and optimal compliance.

This paper describes the underlying solution architecture, technology components, optimizations, and security features, highlighting capabilities in the end-to-end Oracle converged infrastructure that add value to the overall solution.

Oracle Optimized Solution for Secure Oracle Database

Oracle Optimized Solutions follow an "Oracle-on-Oracle" approach that takes advantage of Oracle technologies and engineering expertise and supplies a single touch point for service and support. Oracle Optimized Solution for Secure Oracle Database is not a factory-built configuration. Instead, it is an architectural blueprint that combines Oracle technologies in proven, secure, and thoroughly tested configurations that simplify and speed deployment, allowing organizations to provision optimized database applications more rapidly.

As shown in Figure 1, the solution leverages Oracle products and technologies at each tier of the Oracle technology stack—storage, networking, and compute system components; built-in virtualization technologies; the Oracle Solaris 11 operating system; and the Oracle Database software itself. In addition, database software options such as Oracle Real Application Clusters (Oracle RAC) and Oracle Database In-Memory are available. The Oracle Enterprise Manager 12*c* product family enables comprehensive management of the environment through an intuitive interface. Oracle Enterprise Manager Ops Center 12*c*, provided with all Oracle servers, supports management and monitoring for Oracle server hardware, firmware, operating systems, and virtual servers. It supplies a console that simplifies the process of applying updates, helping administrators patch and maintain systems. Applying security errata quickly, of course, helps to eliminate possible avenues of attack and reduce incidents of unplanned downtime.

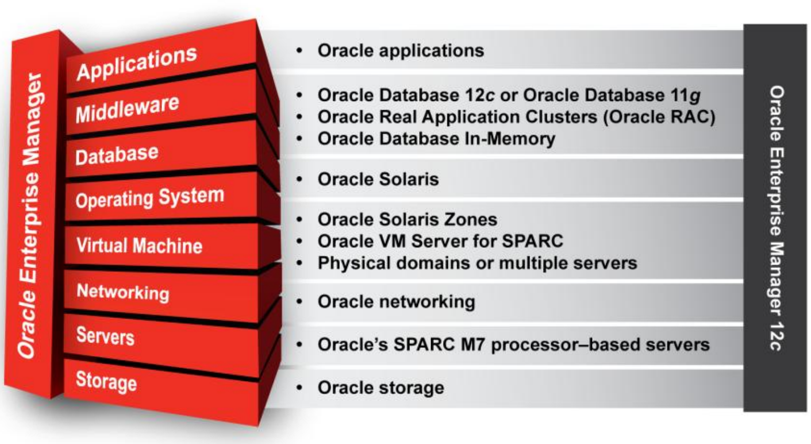

Figure 1. Oracle Optimized Solution for Secure Oracle Database integrates Oracle products and technologies at every tier.

Oracle Optimized Solution for Secure Oracle Database supports Oracle Database 12*c* and Oracle Database 11*g*, making this solution ideal for sites to modernize and consolidate databases using cost-effective virtualized and multitenant database architectures. Oracle Database 12*c* supports a multitenant architecture that makes it easy to consolidate quickly and manage databases as cloud services, simplifying many traditional DBA pain points including provisioning, patching, and consolidation. The Oracle Multitenant option to Oracle Database 12*c* constructs a container database (CDB) that allows multiple pluggable databases (PDBs) to take advantage of shared database functionality, including a shared system global area (SGA), as well as Oracle RAC and Oracle Active Data Guard. Oracle Database 12*c* also offers an option for in-memory data processing—Oracle Database In-Memory—that can deliver breakthrough analytical performance on the newest generation of Oracle's SPARC systems, the SPARC T7 and M7 servers.

Because innovations in hardware and software bring advances in performance, security, and availability, deploying databases based on Oracle Database 12*c* in this Oracle Optimized Solution is strongly recommended. If legacy applications exist that require earlier Oracle Database versions, Oracle consultants can help to migrate or modernize applications; see Migration, Upgrade, and Optimization Services for Oracle Database.

Oracle Optimized Solution for Secure Oracle Database offers tremendous flexibility through configuration choices and its ability to adapt to existing environments. Customers that already have a significant investment in enterprise SAN storage, for example, can configure the solution to complement and leverage those resources. However, using Oracle storage can yield additional performance and management advantages, because Oracle Database is specifically optimized for Oracle storage (a later section explains how these optimizations boost performance and ease data management operations).

Oracle Infrastructure Choices for Oracle Database

In addition to Oracle Optimized Solution for Secure Oracle Database, Oracle has a full complement of database infrastructure offerings. Oracle engineered systems are fully factory-integrated systems, in contrast to the configuration flexibility offered by Oracle Optimized Solution for Secure Oracle Database. The following engineered systems are targeted at database deployments:

» **Oracle Database Appliance.** Oracle Database Appliance is an entry-level engineered system that integrates Oracle software, servers, storage, and networking to deliver highly available database services for a range of OLTP, decision-support (DSS), and data warehousing (DW) applications. It is a 4U rack-mountable appliance that combines Oracle servers and storage to create an off-the-shelf solution for small database requirements.

» **Oracle Exadata Database Machine.** Oracle Exadata Database Machine (also called Oracle Exadata) is an Oracle engineered system that factory-integrates Oracle hardware and software and supplies integral optimizations for Oracle Database workloads. Oracle Exadata is designed for one task and one task alone: to accelerate Oracle Database 11*g* and 12*c* services for data warehousing and OLTP applications. It is a fully preassembled and purpose-built system that serves this single targeted function.

» **Oracle SuperCluster.** Oracle SuperCluster engineered systems are Oracle's fastest and most scalable engineered systems, and are ideal for consolidating databases and applications, private cloud deployments, and Oracle software applications. They deliver extreme performance, and the highest consolidation, availability, and efficiency, and they eliminate the risks of build-it-yourself architectures. With the world's fastest processors and Oracle Exadata Storage Servers optimized for Oracle Database, Oracle SuperCluster delivers unprecedented price/performance for mission-critical databases and applications.

Oracle designs these engineered systems to reduce the cost and complexity of IT infrastructures while increasing security, performance, and customer value. Like Oracle Optimized Solutions, these systems demonstrate how Oracle has made significant investments in engineering and optimizations at every layer of the stack, innovating to improve performance, simplify data center operations, reduce risk, and drive down costs.

While the factory-integrated engineered systems have tremendous value for many customers, they might not be the optimal solution for all sites and business needs. Engineered systems are purchased and shipped as specific configurations, so they aren't the best fit for organizations that might not benefit from built-in Oracle Exadata Storage Servers. With Oracle Optimized Solutions, organizations can continue to invest in SAN or legacy storage technologies, or they can take advantage of low-cost NAS storage from Oracle. In such cases, Oracle Optimized Solution for Secure Oracle Database is often a better fit while offering many of the same benefits of an Oracle engineered system.

Benefits of Deploying Oracle Optimized Solution for Secure Oracle Database

IT organizations often spend multiple weeks to plan, architect, troubleshoot, and deploy a secure infrastructure for Oracle Database applications. Deployment teams must assemble and integrate a range of hardware and software components from different vendors (for example, servers, storage, network components, virtualization software, and operating systems). The process is not only time-consuming but also prone to errors, making it hard to adhere to best practices, meet deployment schedules, and realize a profitable return on investment (ROI). Complex integration tasks can expose even the most carefully planned deployments to unanticipated risks that can result in delays, downtime, costly upgrades, inefficient performance, poor utilization, or data compromise. Risks are more prevalent in systems and architectures that are not engineered and implemented with a precise focus on security at every tier of the stack.

Pretested Solutions for Faster Deployment, Greater Security, Less Risk

Oracle Optimized Solution for Secure Oracle Database reduces the effort required to plan, architect, build, and test a database infrastructure, shortening time to deployment, enhancing security, and lowering risk. It allows enterprises to leverage a flexible architecture and operating model that Oracle has developed and tested, rather than piecing together an infrastructure from scratch. And because the components are all from Oracle, the solution includes the advantage of a single point of accountability, from purchasing to deployment, maintenance, patch integration and availability, and ongoing support.

Running Oracle Database software on a complete Oracle stack brings the simplicity and reliability of having a single vendor to call. In multivendor solutions, production teams can spend hours debugging or tracing an issue before they can determine whether the source of the problem is the application, the virtual machine, the operating system, the storage, or the physical server. When running an Oracle Optimized Solution, Oracle Support can be engaged right away, resolving problems more quickly to avoid vulnerabilities and downtime.

Virtualized Architecture for Efficient and Secure Database Consolidation

Virtualization capabilities are critical to achieve secure workload isolation, efficient consolidation, and high levels of availability. General best practices as well as certain security standards (such as the Payment Card Industry Data Security Standard [PCI DSS] and other standards) mandate the practice of workload segmentation, requiring applications that process sensitive data to be separated from other application workloads. Virtualization technologies are also valuable when combining many workloads on a single physical server, providing isolation, effective resource management, and consolidation as well as potentially lowering software costs.

But many commercially available virtualization technologies are inefficient and add overhead to demanding and CPU-intensive database workloads. Oracle provides extremely lightweight, no-charge server virtualization technologies—physical domains (in Oracle's SPARC M7-8 and M7-16 servers), Oracle VM Server for SPARC logical domains, and Oracle Solaris Zones—that provide virtualization benefits without impacting performance:

» **Fault partitioning using physical domains (PDoms) or physical servers.** PDoms (available in SPARC M7-8 and M7-16 servers) or multiple physical servers can be configured into failure groups. If a hardware fault occurs in in the group, another completely isolated PDom is available that can continue to execute the workload. Hardware fault partitioning via PDoms or separate physical machines is needed to support the continuous availability and failover of mission-critical Oracle RAC workloads.

» **Operating system and software partitioning using Oracle VM Server for SPARC.** Oracle VM Server for SPARC (formerly called Sun Logical Domains) leverages the built-in SPARC hypervisor to subdivide platform resources (CPUs, memory, network, and storage) into logical domains (LDoms), each running an independent instance of Oracle Solaris. From a software lifecycle perspective, administrators maintain each LDom separately, updating binaries and applying patch releases autonomously in each software environment. This enables best practices for Development, Test, Acceptance, and Production (DTAP) environments, making it easy to isolate development environments, for example, from production databases. LDoms create an independent entity for software management, allowing administrators to tightly control the installation and testing of patches and updates.

» **Fine-grained resource allocation and management.** Oracle Solaris Zones are an extremely lightweight virtualization mechanism that provides multiple isolated execution environments within a single instance of the Oracle Solaris operating system. When deployed within an LDom, zones provide fine-grained resource control via software, allowing resources allocated to the LDom to be further partitioned between software environments as needed. Oracle Solaris Zones also support the creation of software-defined virtual networks, including virtual switches and virtual network interfaces (VNICs) that isolate traffic, enabling network bandwidth control and configurations that are agile and secure.

As performance testing has shown, these technologies require almost no overhead, especially in comparison to other commercially available virtualization products. Layering these technologies is a common practice (Figure 2), adding benefits without adding any cost or any noticeable overhead.

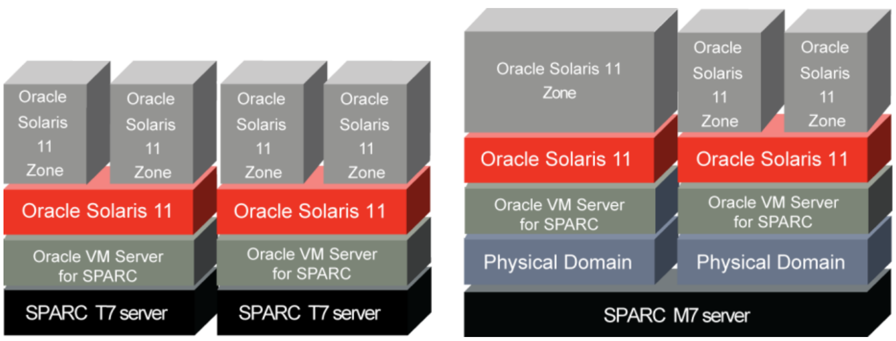

Figure 2. PDoms provide hardware fault isolation, while LDoms support independent OS instances that can host multiple isolated Oracle Solaris Zones.

An additional benefit of these no-charge server virtualization approaches is that they can also be configured to construct hard partitions that comply with Oracle Database and application licensing policies. When only a subset of cores on a large system is needed for a database instance, using these virtualization approaches to construct a hard partition can generate substantial savings for software licensing. Oracle's SPARC T7-2 server, for example, has two 32-core processors. Configuring virtual environments with a subset of processor cores can considerably reduce costs for Oracle Database and Oracle Database options. The white paper "Hard Partitioning With Oracle VM Server for SPARC" and the "Oracle Partitioning Policy" describe licensing implications with respect to partitioning and virtualization technologies. For database software version compatibility details, refer to Supported Virtualization and Partitioning Technologies for Oracle Database and RAC Product Releases.

Beyond server virtualization, Oracle Database 12*c* directly supports multitenant database virtualization. Oracle Database 12*c* can consolidate multiple PDBs that can plug and unplug into a CDB. Oracle Optimized Solution for Secure Oracle Database supports Oracle Database 12*c* along with native operations and cloning for Oracle Database single-instance deployments and Oracle RAC deployments.

Oracle's new SPARC M7 processor–based servers feature unprecedented thread scale and large memory footprints. The density of these servers enables efficient consolidation that reduces footprint, conserves energy, and simplifies administration. Administrators can assign system resources (such as virtual CPUs, memory, I/O, and network devices) to virtualized environments and reallocate them as needed, even on live production systems (in many cases without interruption). The same management tool—Oracle Enterprise Manager Ops Center—defines virtual servers, allocates resources to each virtual environment, adjusts resource allocations to meet business requirements, and monitors the health of both virtual and physical machines.

Validated and Flexible Configurations

Oracle Optimized Solution engineers extensively validate configurations and document typical implementations. They record recommended best practices and optimal deployment approaches for Oracle Database, Oracle RAC nodes, server platforms, virtualization, networking, and shared storage components.

Enterprise OLTP systems, such as those running Oracle's PeopleSoft, JD Edwards EnterpriseOne, and Siebel Customer Relationship Management (CRM) product lines, often support a workload mix that consists of both OLTP transactions and ad-hoc analytical queries. The Oracle Database In-Memory option for Oracle Database can significantly accelerate real-time analytics and reporting using these databases. To help customers understand the potential for real-time query and mixed workload performance on Oracle Optimized Solution for Secure Oracle Database, Oracle engineers have validated performance gains and compression ratios on a sample solution configuration and database (see "Optimizing for Performance and Throughput").

Figure 3 illustrates one of many possible deployment configurations for the solution. It depicts components at each tier of the stack and how both OLTP and DSS database workloads might be consolidated and virtualized while securing sensitive data, achieving high availability, and supporting high-speed database services. Mixed OLTP and DSS workloads execute on highly threaded SPARC M7 processor–based servers and the scalable Oracle Solaris operating system. As shown, Oracle RAC is used to support distributed database instances hosted on clustered SPARC servers with access to shared storage, a design that provides high availability. (Alternatively, PDoms in SPARC M7-8 or M7-16 servers could provide fault group isolation.) Defining Oracle RAC nodes across physical servers or PDoms supplies redundancy that eliminates a single point of failure while helping to scale performance. LDoms provide isolation at the operating system layer, while Oracle Grid Infrastructure and Oracle RAC provide high availability across multiple LDoms. The Logical Domains Manager software (included with Oracle Solaris 11) enables precise control and flexible reallocation of resources within LDoms.

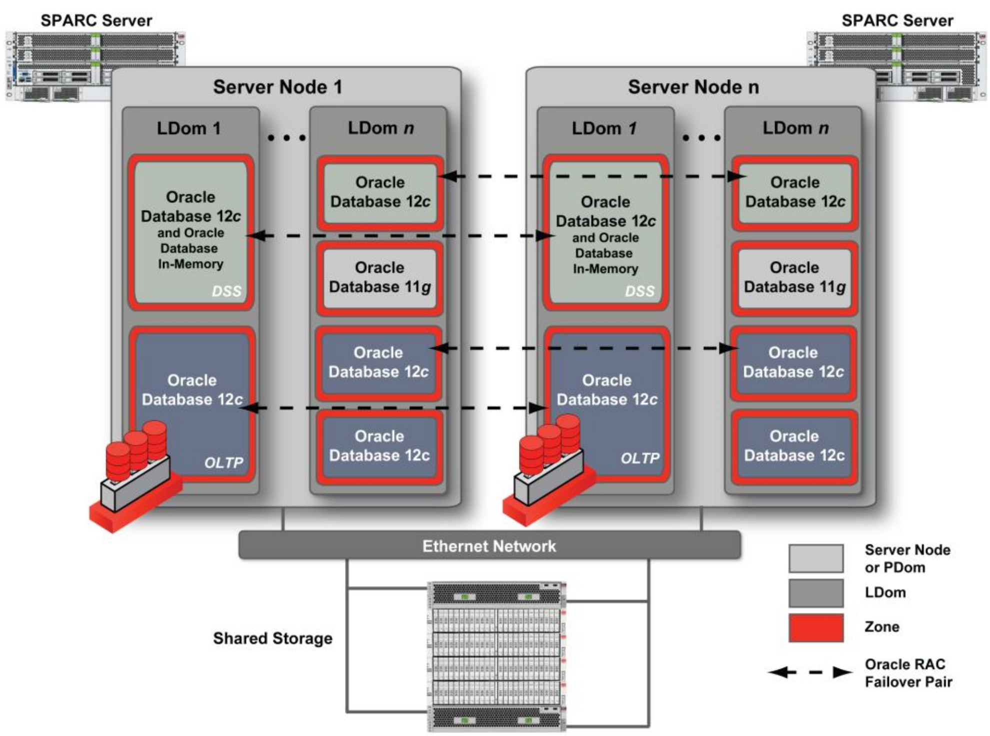

Figure 3. Hypothetical deployment configuration for Oracle Optimized Solution for Secure Oracle Database.

The Oracle RAC interconnect can be implemented using either redundant Ethernet switches (such as Oracle Switch ES1-24) or Oracle InfiniBand connections. Shared storage can be implemented via Ethernet to Oracle ZFS Storage Appliances or, optionally, using Fibre Channel to SAN storage (such as the Oracle FS1-2 flash storage system) with either a secure dedicated data link or using SR-IOV within a logical domain. Redundant components, multiple physical connections, and IP and storage multipathing can help IT departments meet demanding service level agreements (SLAs). Oracle Optimized Solution for Secure Oracle Database follows best practices for an availability architecture (see "Optimizing for Availability" for details).

Oracle-Only Optimizations: An Overview

While Oracle Database releases are available for a number of commercially available operating systems, virtualization technologies, and hardware platforms, there are distinct advantages to deploying Oracle Database applications on Oracle infrastructure. All components in Oracle Optimized Solution for Secure Oracle Database are engineered and tested to work together. Oracle has made considerable cross-product engineering investments that add value when deploying an end-to-end Oracle solution stack. These optimizations deliver advantages in areas such as security, performance, availability, and ease of data center operations. While this paper supplies details and references for learning more about Oracle technologies at each tier of the stack, Oracle innovations and optimizations that bring significant value to the solution are summarized briefly below.

Server Enhancements and Processor Optimizations

- **New servers with greater processor density and performance enhancements.** Oracle Optimized Solution for Secure Oracle Database configurations incorporate new servers, Oracle's SPARC T7 and SPARC M7 servers, that feature the new SPARC M7 processor—later sections provide more details about these servers (see pages 9 and 28). The SPARC M7 processor doubles the core count of the previous generation of SPARC processors, supporting 32 cores per processor. A new on-chip L2 and L3 cache design and an increased processor frequency also help to improve per-thread performance.
- **Oracle's Software in Silicon (SWiS) optimizations.** Coengineered by Oracle's software and microprocessor engineers, Software in Silicon technology implements optimizations directly into the SPARC M7 processor to accelerate database applications and make them less prone to compromise. Specifically, the SPARC M7 processor features in-chip Data Analytics Accelerators (DAX), In-Line Data Decompression capabilities, Silicon Secured Memory enhancements, and Crypto Instruction Accelerators. (See page 9 for more information about these features and how they safeguard applications against cyber-attacks while supporting Oracle Database workloads more efficiently.)
- **Enhanced system features.** In addition to processor innovations, Oracle's SPARC T7 and M7 servers incorporate faster DDR4 memories (versus DDR3) in larger capacity configurations. These servers also include support for x16 PCIe slots.

Storage Optimizations for Oracle Database Workloads

- **Oracle Database optimizations exclusive to Oracle storage.** Oracle Database instances detect the use of Oracle storage devices and apply specific Oracle-only optimizations. When Oracle Database 12*c* detects the use of Oracle storage, for example, it automatically applies the Oracle Intelligent Storage Protocol to optimize I/O operations with Oracle ZFS Storage Appliance. Oracle Database 11*g* and Oracle Database 12*c* both use Hybrid Columnar Compression (HCC) technology on Oracle storage devices to compress data, substantially reducing the storage footprint and required interconnect bandwidth, which improves performance (see page 33).
- **Direct NFS (dNFS).** Both Oracle Database 11*g* and Oracle Database 12*c* implement a Direct NFS (dNFS) client that optimizes NFS operations to Oracle ZFS Storage Appliances over Ethernet. This capability yields performance that makes Ethernet-connected NAS storage systems a cost-effective alternative to SAN storage systems for many application workloads (see page 34).
- **Fast cloning of production database systems.** The Database Configuration Assistant (DBCA) automates database cloning, especially when cloning pluggable databases in Oracle Database 12*c*. In addition, cloning

techniques that take advantage of the underlying storage, such as fast snapshots in Oracle ZFS Storage Appliance, can dramatically speed cloning over manual methods (see page 35 for details).

- **Storage encryption.** Oracle ZFS Storage Appliances encrypt at the file system level, providing greater granularity and security controls. For example, encryption can occur at the project, share, or LUN levels, allowing different security controls for different users, groups, or applications depending on the data's sensitivity, security policy, and business requirements. Hardware-assisted cryptography enables encryption/decryption at higher speeds, allowing organizations to use encryption more pervasively to protect data at rest.

Oracle Solaris and Virtualization Optimizations

- **Memory and kernel optimizations for Oracle Database and Oracle RAC.** Oracle Solaris features memory management functionality and an extensive number of enhancements that are targeted at accelerating Oracle Database performance. The operating system features memory placement optimizations for NUMA systems such as the SPARC T7 and M7 servers, and kernel acceleration for the Lock Management System (LMS) used by Oracle RAC.
- **A cloud-ready operating system.** Built-in support for secure workload isolation, software-defined networking, and OpenStack make it easier to consolidate and manage cloud-based database workloads (see page 35).
- **Secure live migration.** Migrating virtual environments provides a means of moving database workloads to other machines to support planned downtime or disaster recovery. Oracle VM Server for SPARC technology supports the migration of active domains while maintaining application services to users. In addition, in combination with the in-silicon cryptographic accelerators in SPARC servers, these migrations can be fully encrypted. Other virtualization solutions migrate VMs in the clear, which can leave sensitive data unprotected, compelling the use of dedicated networks or the addition of hardware-assisted encryption devices. Instead, Oracle Optimized Solution for Secure Oracle Database enables secure, wire-speed encryption capabilities for live LDom migrations, without any additional hardware or software investment required because of features built into the Oracle engineered hardware and software stack.

Management Optimizations

- **Management integration.** Oracle Enterprise Manager Ops Center 12*c*, which is included in Oracle Optimized Solutions and is part of the Oracle Enterprise Manager portfolio, provides an intuitive interface for managing solution components, including the hardware, firmware, operating system instances, virtual environments, administrative rights, patching, and updates.
- **Oracle Enterprise Manager for single-pane-of-glass management of the Oracle stack.** By adding other software products in the Oracle Enterprise Manager family, administrators can also control Oracle Database instances and Oracle applications across the enterprise. An integrated and consistent set of management tools can save considerable labor costs in comparison to working with a variety of different multivendor tools.

Oracle Optimized Solution Choices and Flexibility

Oracle Optimized Solution for Secure Oracle Database can be deployed using one of several recommended configurations (Table 1), making it easy to match expected workload and growth projections. Each configuration can be customized as needed to meet deployment objectives, including requirements for applications, high availability, or disaster recovery. All configurations share the same underlying architecture and are based on enterprise-class Oracle components, creating a solution that is secure, highly scalable, optimized for OLTP and DSS workloads, and engineered for high service levels. An Oracle sales team will work with site architects to fine-tune a configuration to meet infrastructure requirements and business goals.

TABLE 1. SAMPLE CONFIGURATIONS—ORACLE OPTIMIZED SOLUTION FOR SECURE ORACLE DATABASE

Component	Small	Medium	Large	X-large
Base server(s)	2x SPARC T7-1	2x SPARC T7-2	1x SPARC M7-8	1x SPARC M7-16
CPUs per system	2	4	Up to 8	Up to 16
Cores per system	64	128	256	512
Total RAM per system	1 TB	2 TB	4 TB	8 TB
Virtualization options	A layered approach using Oracle Solaris and Oracle VM Server for SPARC (LDoms). Additionally, Oracle Solaris Zones are available.		Factory-configured as two fixed PDoms; Oracle VM Server for SPARC (LDoms); Oracle Solaris. Additionally, Oracle Solaris Zones are available.	Two PDoms (8 CPUs each) recommended; Oracle VM Server for SPARC (LDoms); Oracle Solaris. Additionally, Oracle Solaris Zones are available.
NAS storage options	» Oracle ZFS Storage ZS3-2		» Oracle ZFS Storage ZS4-4	
SAN storage options	» Oracle FS1-2 flash storage system			
Software options	» Oracle Database 12*c,* Oracle Database 11*g*, Oracle RAC, and Oracle Database In-Memory options » Oracle Solaris 11 » Oracle Enterprise Management Ops Center 12*c* (included), plus optional Oracle Enterprise Manager 12*c* management packs			
Advanced services	» *Oracle Fixed Scope Services: Install and Configure, Production Support Readiness, Patch Review and Deployment* » *Annual Services: Advanced Support Assistance, Business Critical Assistance, Solution Support Center, Advanced Monitoring and Resolution*			

A New Generation of SPARC Processors and Servers

The new server family from Oracle (Figure 4) provides advanced levels of performance and throughput. Scaling from one to 16 SPARC M7 processors, these servers comprise a flexible and extensible product family with levels of integration to improve security, lower costs, and increase reliability while delivering superior performance for Oracle Database.

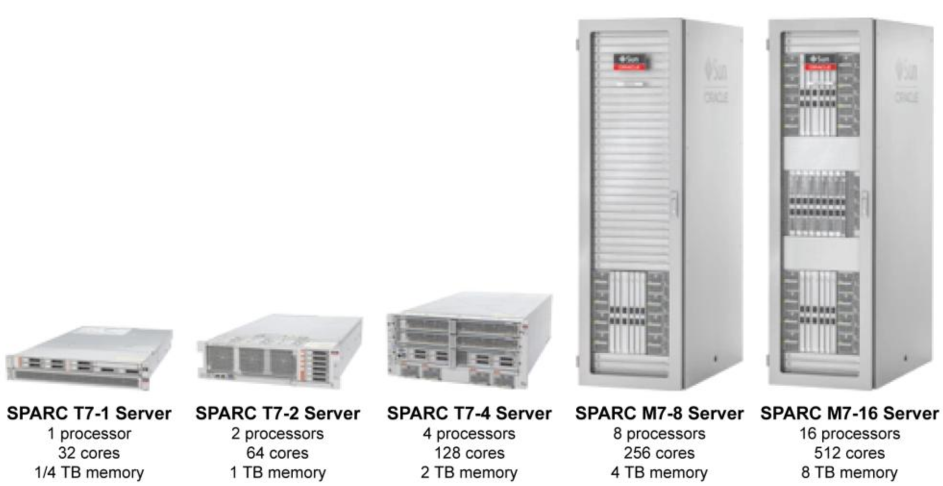

Figure 4. Oracle's SPARC M7 processor–based server product family.

SPARC M7 Processor Enhancements: Software in Silicon

Most processor chip development focuses on better and faster general-purpose processing. Several years ago Oracle initiated a groundbreaking project to move in-memory database functions directly onto the chip, with hard-wired protection for data in memory. By innovating at the processor, system, and application levels, Oracle is able to optimize security and application throughput. The Software in Silicon enhancements in SPARC M7 processors deliver impressive advantages and innovations:

- Eight on-chip Data Analytics Accelerator (DAX) coprocessors provide in-memory query processing that supplies **unprecedented performance results for mixed analytics and OLTP workloads**. Unlike competitive CPU technologies, the DAX coprocessors actually offload decompression and analytics processing from the SPARC M7 cores, freeing the cores to process other pipeline instructions. The DAX coprocessors speed in-memory query execution and place the results in the shared L3 cache for fast core access, improving performance as much as ten times for in-memory analytics. More importantly, while a DAX coprocessor executes an in-memory query, the active core is available to run other processing tasks (such as OLTP workloads).
- Silicon Secured Memory provides **real-time data integrity checking** to guard against pointer-related software errors and malware, replacing costly software instrumentation with fast and efficient in-silicon monitoring. This embedded functionality allows applications to identify erroneous or unauthorized memory accesses, diagnose the cause, and take appropriate recovery actions.
- In-line decompression features allow **up to three times more data to be stored in same memory footprint** without a performance penalty. This helps larger objects, including entire database tables, fit into available memory for in-memory processing with the Oracle Database In-Memory option.
- Accelerated cryptography helps eliminate performance and cost barriers typically associated with secure computing. Increasingly essential for business applications, **encryption and decryption operations can occur at hardware rates**.

Each DAX coprocessor included on the SPARC M7 die provides the following:

- A data/message pipe for very fast local data movement, offloading the CPU and providing secure remote cluster messaging
- A query pipe for in-memory columnar acceleration that scans data vectors and applies predicates

The DAX coprocessors provide very low-overhead interprocess communication and very fast atomic operations. DAX coprocessors on different processors can exchange messages and access remote memory locations, exchanging locks without CPU involvement. The DAX coprocessors efficiently offload processing from cores with almost no overhead, freeing cores for other computing tasks.

Optimizing Oracle Database Deployments

Businesses are aggressively implementing real-time decision-support queries that leverage data assets to improve decision-making. Delivering OLTP and DSS applications from a centralized and integrated cloud-ready infrastructure can increase administrative efficiency, enhance business agility, and lower costs. Oracle Optimized Solution for Secure Oracle Database can securely host a mix of Oracle Database workloads, and can be considered for any of these consolidation scenarios:

- **Consolidation of multiple application tiers** (such as database, application, and web tiers). Multiple tiers can securely reside on the same platform, using virtualized environments and resource allocations to provide predictable performance as well as workload isolation.
- **Consolidation of all phases of the database application lifecycle**—Development, Test, Acceptance, and Production (DTAP). These database environments can securely coexist on the same solution, with fast cloning capabilities that speed database provisioning.
- **Consolidation of mixed workloads.** As discussed, the SPARC M7 processor–based servers feature innovations that optimize performance for combined OLTP, DSS, and data warehousing workloads. In addition, this solution

can securely host applications using a variety of database versions and options, including Oracle Database 11*g*, Oracle Database 12*c*, Oracle RAC, and the Oracle Database In-Memory option.

In addition to speeding time to deployment and following best practices, Oracle Optimized Solution for Secure Oracle Database offers advanced data security, extreme efficiency, and industry-leading performance that make the solution the best infrastructure for Oracle Database. Oracle's new microprocessors deliver breakthrough value because of Software in Silicon (SWiS), which represents a key milestone in the Oracle strategy of deep integration between software and hardware. Oracle Optimized Solution for Secure Oracle Database is a pretested and proven architecture combining Oracle's new SPARC T7 and M7 Servers, Oracle Solaris, and Oracle's database-aware storage to construct a solution that realizes the full benefits of SWiS. The solution delivers three important core benefits—extreme performance, advanced security, and high availability—using the world's first converged infrastructure in silicon. The next few sections highlight how the solution provides benefits in these three areas.

Optimizing for Performance and Throughput

At the heart of this solution, Oracle's SPARC M7 processor is a key technology that accelerates database performance and throughput, while at the same time guarding against bad pointers and buffer overflows. In the past, performance gains were largely dictated by enhancements in processor clock speeds—faster clock speeds allowed new systems to experience performance gains over previous platform generations.

Several years ago, Oracle decided that hardware is the ultimate mechanism for optimizing software. In developing the next generation of SPARC processor technology that is now the SPARC M7 processor, the company pursued a Software in Silicon approach that offloads common database tasks to special-purpose hardware. The Data Analytics Accelerator (DAX) coprocessors and compression innovations in the SPARC M7 processor contribute to superior performance for processing mixed Oracle Database analytics and OLTP workloads.

In addition to advancements in silicon, the SPARC M7 processor doubles the number of cores (at a minimum) over the previous processor generation, providing 32 SPARC S4 cores organized into eight-core clusters. Processor cores support dynamic threading to achieve the highest possible per-thread performance.

A hierarchical cache design and large cache sizes—especially compared to previous SPARC processor generations—also help to optimize application performance. Each core has its own 16 KB L1 instruction and data cache. Two cores then share a 256 KB L2 data cache and four cores share a 256 KB L2 instruction cache. A 64 MB L3 cache is fully shared and partitioned, and any L3 partition can serve a request from any of the 32 cores. Hot cache lines are migrated to the closest L3 cache partition to increase performance. Along with the increased number of cores, the new processor cache capabilities help to improve both single and multithreaded performance.

As Oracle reported at the Hot Chips conference in August 2014, a variety of application benchmarks—including tests of OLTP and ERP workloads—show that the SPARC M7 processor can deliver up to three times the processing speed of Oracle's previous-generation SPARC T5 processor.[1] To see the most recent published benchmark results for SPARC M7 processor–based servers, visit oracle.com/benchmarks.

1 Hot Chips 26, August 12, 2014, Presentation: "M7: Next Generation SPARC"

Oracle Database In-Memory Option

Companies increasingly rely on real-time analytics to drive strategic business decisions. In the past, applications (such as business logistics, financials, customer management, and human resources) have been largely traditional OLTP workloads characterized by a need for high transactional throughput. To leverage existing data, improve competitive position, and discover new markets and business opportunities, companies are running analytics on these same operational database systems, performing ad-hoc queries for decision-support.

In such database environments, optimizing performance can be a difficult balancing act—OLTP workloads frequently perform operations on database rows (such as inserts or simple SQL fetches), but analytical queries execute more quickly on data in column format (Figure 5). In most cases traditional databases are designed to support row-oriented OLTP transactions, which means that decision-support queries that execute on these databases tend to result in suboptimal performance.

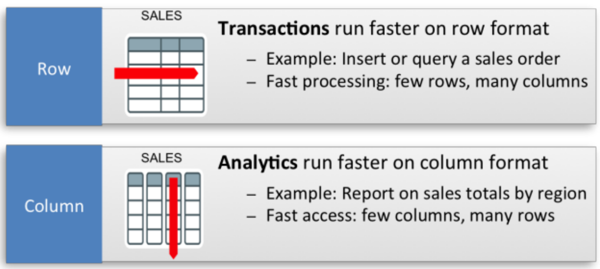

Figure 5. Tuning analytic queries on OLTP databases is difficult because of performance differences in row versus column access.

Oracle Database In-Memory is an option to Oracle Database 12*c* that allows a single database to support mixed workloads more efficiently, delivering superior performance for real-time analytic reporting as well as OLTP transactions. By constructing a unique dual-format architecture (Figure 6), the Oracle Database In-Memory option maintains data in the existing row format for OLTP but also configures a new in-memory (IM) column store optimized for analytical reporting. In mixed workload environments, Oracle Database In-Memory demonstrates significant speedups for real-time analytical queries ***without any application changes***. In addition, the dual-format architecture ***does not double requirements for memory capacity***.

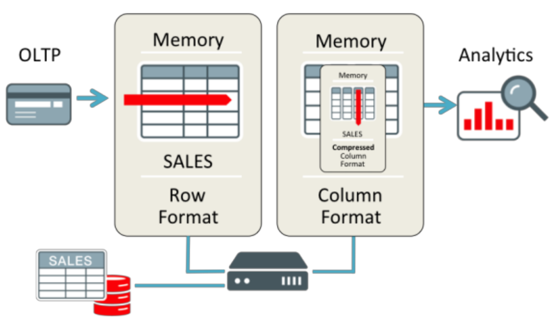

Figure 6. The Oracle Database In-Memory option supports a dual-format architecture that accelerates mixed workloads.

The IM column store is implemented as an optional static SGA pool. To conserve DRAM, it can be populated with performance-critical data (such as a specific tablespace, table, and so on) using the `INMEMORY` attribute, rather than populating it with an entire database. Because pluggable databases (PDBs) in Oracle Database 12*c* share the same SGA and background processes of a common CDB, multiple PDBs can share a single IM column store, conserving memory. For Oracle RAC nodes, it is recommended to define an IM column store of the same size on each node.

Data can be populated into the IM column store when the database is opened (so it's available immediately) or after other objects have been populated and memory space remains available. Data is compressed using a set of algorithms that save space and improve performance. Queries execute directly against the compressed data in the IM column store—data is decompressed only when it is required for the result set. DBAs have explicit control over compression algorithms, defining options that favor query performance, memory capacity, or a balance between the two. By default, compression is optimized for query performance using dictionary encoding, run length encoding, and bit-packing algorithms. For a more balanced approach that favors space savings, OZIP compression—an Oracle-only compression algorithm—offers fast decompression tuned specifically for Oracle Database.

There are four ways in which the IM column store enables faster analytic query processing:

» **Compressed columnar storage.** Storing data contiguously in compressed column units allows an analytic query to scan only data within the required columns. Columnar storage allows a query to perform highly efficient sequential memory references while compression optimizes the query's use of available system (processor to memory) bandwidth.

» **Vector processing.** Column format enables the use of vector processing. Oracle's SPARC M7 processor features highly parallel vector instructions known as Single Instruction Processing Multiple Data (SIMD). These instructions can process multiple values at once (for example, multiple values can be compared with a given value in a single instruction). Vector processing of compressed columnar data multiplies the scan speed of columnar storage, resulting in scan speeds that exceed tens of billions of rows per second per CPU core.

» **In-memory storage indexe**s. The IM column store for a given table is divided into units known as in-memory compression units (IMCUs) that typically represent a large number of rows (typically several hundred thousand). Each IMCU records the min/max values for the data within each column, as well as other summary information. This metadata serves as an in-memory storage index, allowing an entire IMCU to be skipped during a scan if it is known that no matching value will be found.

» **In-memory optimized joins and reporting.** As a result of massive increases in scan speeds, the optimizer commonly selects a bloom filter optimization (introduced in Oracle Database 10*g*). With a bloom filter optimization, the scan of the outer (dimension) table generates a compact bloom filter which can then be used to shrink the amount of data processed by the join from the scan of the inner (fact) table. Similarly, an optimization known as "vector group by" can be used to reduce a complex aggregation query on a typical star schema into a series of filtered scans against dimension and fact tables.

Oracle's SPARC M7 Processor: Superior Performance for Analytics

When running mixed workloads using the Oracle Database In-Memory option, Software in Silicon features in the SPARC M7 processor–based servers help to speed up real-time analytics performance. The eight on-chip Data Analytics Accelerator (DAX) coprocessors offload database query processing and perform real-time data decompression.

It's important to remember that **the DAX coprocessors offload analytical query processing from SPARC M7 processor cores**, allowing cores to execute other tasks and improving mixed workload performance (Figure 7).

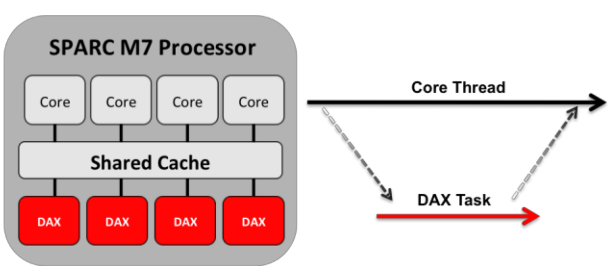

Figure 7. DAX coprocessors offload query processing from cores, freeing them for other processing.

When a core offloads columnar queries to the Data Analytics Accelerator (DAX) coprocessors, it's free to perform other operations, such as OLTP transactions—this capability is a distinct difference from how other modern system processors support in-memory analytics. Core processing of high-level SQL functions—while DAX coprocessors simultaneously perform column processing and compression—allows the SPARC M7 processor to support both OLTP and analytics on the same system with astounding performance results for mixed workloads.

The in-memory option is supported with Oracle Database 12*c* Release 1 (12.1.0.2) and requires Oracle Solaris 11.3 or later on SPARC M7 processor–based platforms. For more information about this option and its value for mixed workloads, see the white papers "Oracle Database In-Memory" and "When to Use Oracle Database In-Memory."

Accelerating Analytics in Mixed Workloads: An Example

In validating the Oracle Optimized Solution for Secure Oracle Database, Oracle engineers conducted testing of mixed workloads using the Oracle Database In-Memory option. Using the Sales database provided as part of the Swingbench benchmark, engineers simulated both OLTP and analytical workloads on the same SPARC T7 server (a single LDom with 32 cores was used for all tests). All performance tests were run using a secured configuration; Oracle Solaris was configured to adhere to security best practices using the `compliance` utility and in conjunction with best practices from the Oracle Solaris and SPARC Security Technical Implementation Guides (see page 21).

To investigate performance gains running the Oracle Database In-Memory option, engineers developed a sample analytical query that investigates product loyalty: how often does a customer buy the same product month-to-month based on sales patterns collected over a 13-year period. This SQL query (Figure 8) requires a number of full table scans and hash-join operations, which are characteristic of typical ad-hoc business queries.

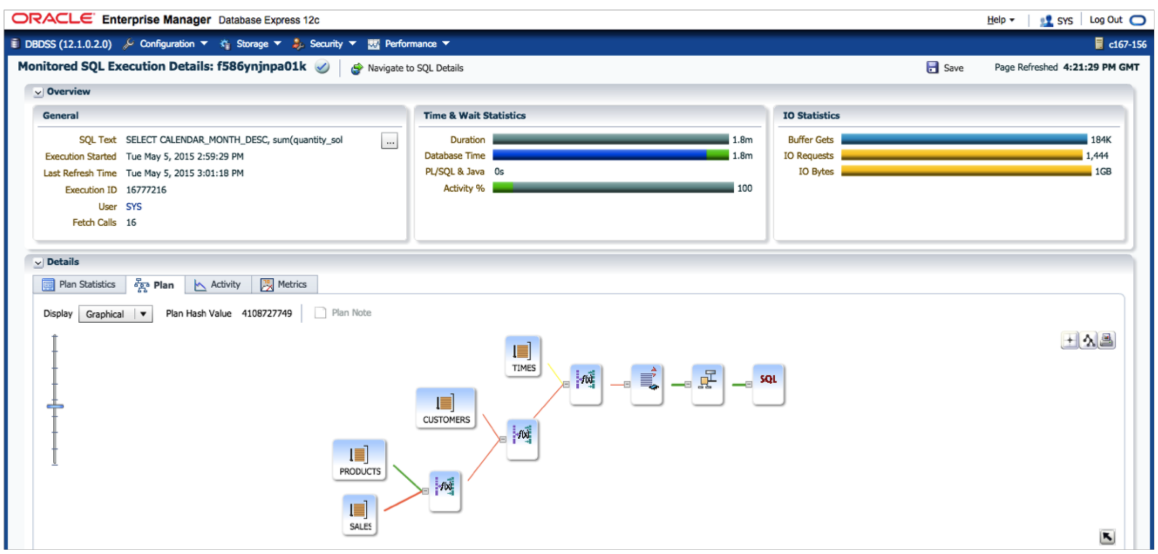

Figure 8. SQL plan for sample analytical query.

Figure 9 shows the monitored SQL execution details (from the Oracle Enterprise Manager Database Express feature of Oracle Database 12*c*) for the baseline analytical query ***without*** the Oracle Database In-Memory option—the query executed in 109 seconds and performed three hash-join operations that resulted in full table scans. As Figure 9 shows, because the query operated on a database in storage—not from memory using the Oracle Database In-Memory option—the query results in I/O operations add to the overall duration. (Note that the storage used in this test was low-latency Oracle SAN storage.) Without the Oracle Database In-Memory option, the query resulted in 1,444 I/O requests with a total I/O transfer of 1GB.

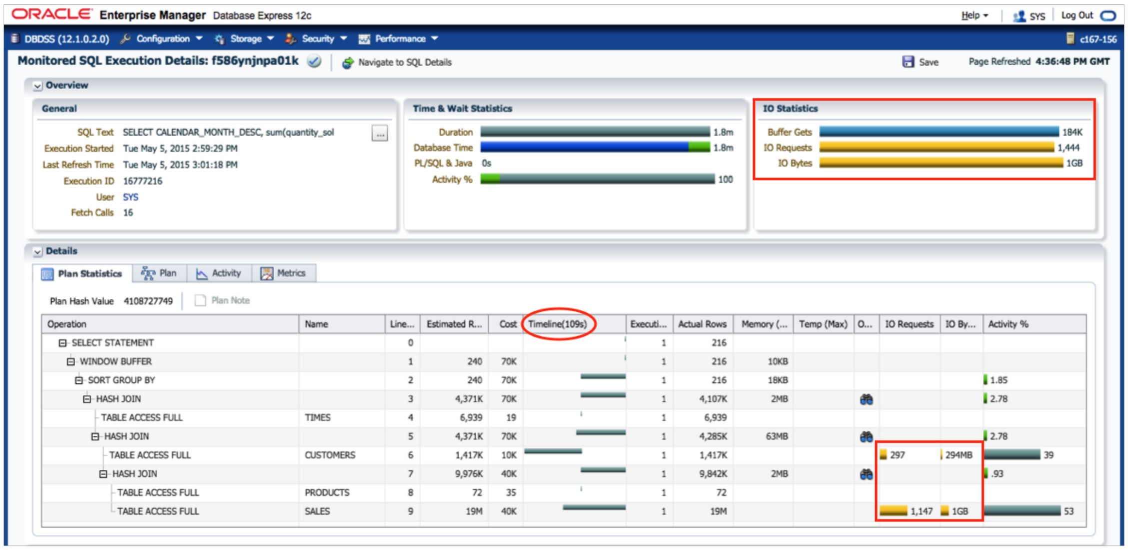

Figure 9. A sample analytical query took 109 seconds **without** the Oracle Database In-Memory option.

Next, the Oracle Database In-Memory option was activated and particular tables from the Sales database were loaded into the IM column store at database startup. (This allows queries to begin executing as soon as the database is available.) Figure 10 shows the monitored SQL execution for the sample query ***with*** the Oracle Database In-Memory option. For this particular query, execution time dropped from 109 seconds to 8 seconds—more than a ten times improvement!

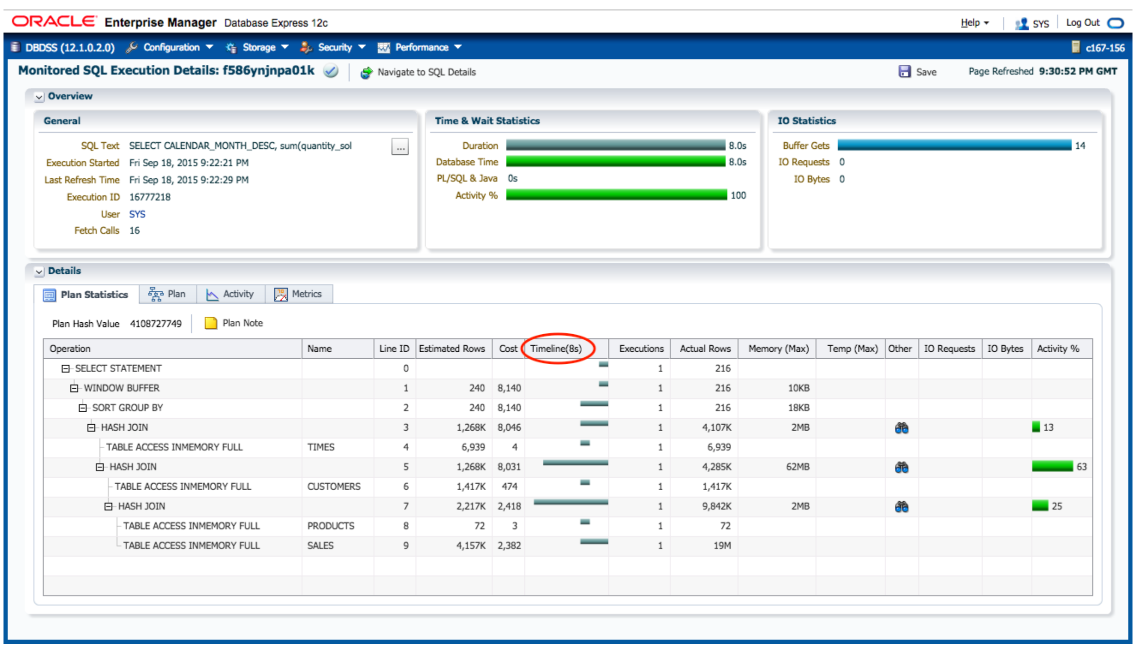

Figure 10. Running the IM query with DAX coprocessors in the SPARC M7 processor reduced execution time to eight seconds.

By default, Oracle Database 12*c* disables the automatic degree of parallelism (DOP) for statement queuing and in-memory parallel execution. Explicitly altering the initialization parameter `PARALLEL_DEGREE_POLICY` and setting it to `AUTO` (instead of `MANUAL`, the default) enables automatic DOP for the database session:

```
SQL> alter session set PARALLEL_DEGREE_POLICY=AUTO; &
```

Enabling automatic DOP allows an IM query to take advantage of any available cores allocated to the LDom, along with any available Data Analytics Accelerator (DAX) coprocessors. Figure 11 shows the execution plan for the parallelized IM query.

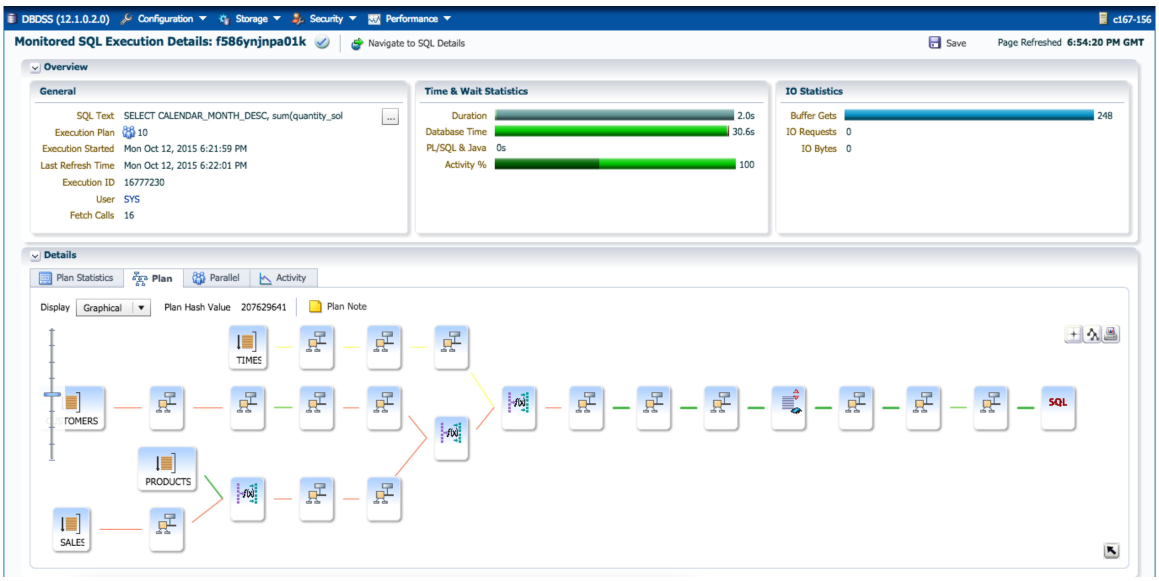

Figure 11. SQL plan for sample analytical query when the DOP policy for the session is set to `AUTO`.

The IM query (which previously took eight seconds) now takes only two seconds when parallelized (Figure 12).

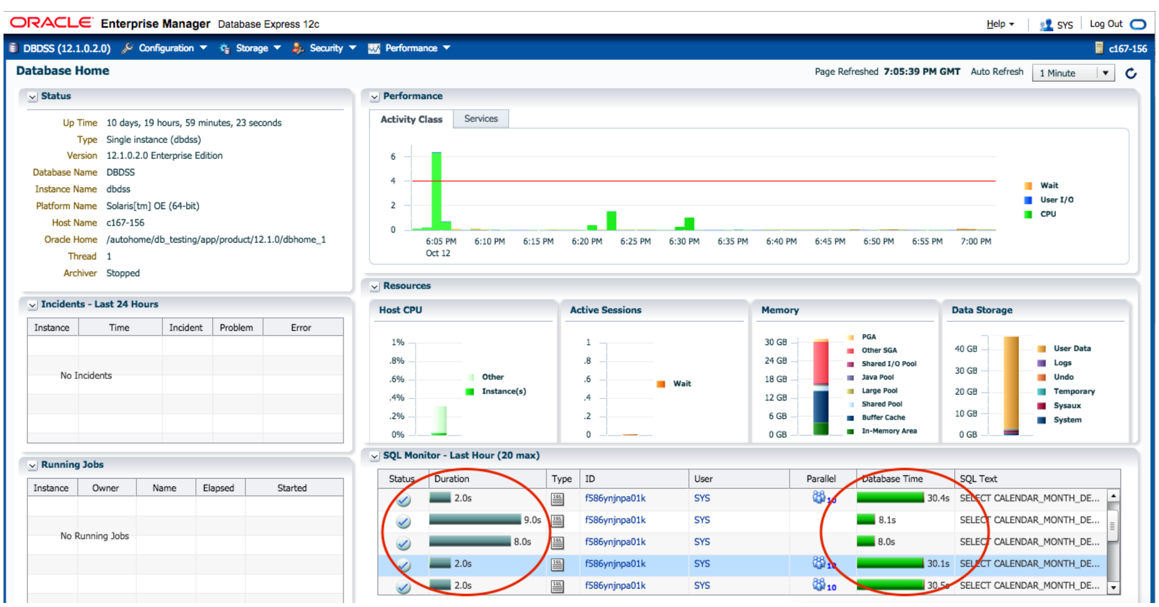

Figure 12. Setting automatic DOP for the database session reduces IM query duration to two seconds.

Figure 12 lists several test runs for the sample IM query. For the two runs, with `PARALLEL_DEGREE_POLICY` set to `MANUAL`, query duration values were 9.0 and 8.0 seconds; database time values (on the right side of Figure 12) were 8.1 and 8.0 seconds, respectively. When the session was initialized for automatic DOP and the query was parallelized across multiple cores and Data Analytics Accelerator (DAX) coprocessors, query duration was consistently two seconds and database time was approximately 30 seconds in each test case. Database times of 30 seconds represent the composite CPU utilization—in other words, it is the combined database execution time for all cores executing the query. Because query duration was only two seconds, the 30-second time clearly illustrates that multiple cores and DAX coprocessors were available and participated in query execution.

There are two ways in which engineers validated that DAX processing was indeed contributing to query acceleration. First, the following DTrace probe uses the `fbt:dax` provider to report DAX activity. Running this DTrace probe for the IM query without parallelization (`PARALLEL_DEGREE_POLICY=MANUAL`) gave these results:

```
# dtrace -n 'fbt:dax::entry { @num[probefunc] = count(); }'
dtrace: description 'fbt:dax::entry ' matched 69 probes
^C =
 dax_ctx_alloc                                                 1 =
 dax_devmap                                                    1 =
 dax_devmap_access                                             1 =
 dax_devmap_map                                                1
 dax_hma_enable                                                1 =
 dax_ioctl                                                     1 =
 dax_ioctl_ccb_thr_init                                        1 =
 dax_sfmmu_hash_add_state                                      1 =
 dax_sfmmu_hash_ent_add_state                                  1 =
 dax_sfmmu_hash_ent_create                                     1 =
 dax_state_add_sfmmu                                           1 =
 dax_state_add_thread                                          1 =
 dax_getinfo                                                   2 =
 dax_close                                                     3 =
 dax_minor_rele                                                3 =
 dax_sfmmu_hash_remove_state                                   3 =
 dax_state_destroy                                             3 =
 dax_minor_get                                                 4 =
 dax_open                                                      4 =
 dax_state_create                                              4 =
 dax_ccb_search                                              481 =
 dax_ccb_search_contig                                       481 =
 dax_hma_unload                                              481 =
 dax_sfmmu_wait_matching_ccbs                                481 =
 dax_thr_search_ccbs                                         481 =
 dax_ccb_contains_va                                         719 =
```

After setting `PARALLEL_DEGREE_POLICY=AUTO` for the session, the number of DAX operations increased:

```
# dtrace -n 'fbt:dax::entry { @num[probefunc] = count(); }'
dtrace: description 'fbt:dax::entry ' matched 69 probes
^C =
  dax_close                                                    27 =
  dax_minor_get                                                27 =
  dax_minor_rele                                               27 =
  dax_open                                                     27 =
  dax_sfmmu_hash_remove_state                                  27 =
  dax_state_create                                             27 =
  dax_state_destroy                                            27 =
  dax_ccb_search                                               28 =
  dax_ccb_search_contig                                        28 =
  dax_hma_unload                                               28 =
  dax_sfmmu_wait_matching_ccbs                                 28 =
  dax_thr_search_ccbs                                          28 =
  dax_ccb_contains_va                                         551 =
  dax_ccb_buffer_decommit                                    1110 =
  dax_ccb_buffer_get_contig_block                            1110 =
  dax_ioctl                                                  1110 =
  dax_ioctl_ca_dequeue                                       1110 =
  dax_validate_ca_dequeue_args                               1110 =
```

In addition to DTrace, another way to observe DAX activity is with the `busstat(1M)` command provided in Oracle Solaris that accesses bus-related performance counters in the system. The following excerpt of `busstat` output reports the number of DAX cache coherency buffer fetches when `PARALLEL_DEGREE_POLICY=MANUAL`:

```
# busstat -a -w dax,pic0=DAX_SCH_ccb_fetch 5 &
. =
. =
. =
25  dax114 DAX_SCH_ccb_fetch  0  DAX_QRY0_output_valid 0    DAX_QRY0_output_valid 0
25  dax115 DAX_SCH_ccb_fetch  1  DAX_QRY0_output_valid 32   DAX_QRY0_output_valid 32
25  dax116 DAX_SCH_ccb_fetch  0  DAX_QRY0_output_valid 0    DAX_QRY0_output_valid 0
25  dax117 DAX_SCH_ccb_fetch  0  DAX_QRY0_output_valid 0    DAX_QRY0_output_valid 0
. =
. =
. =
```

Running the same command when `PARALLEL_DEGREE_POLICY=AUTO` produces output that shows how all eight DAX coprocessors were engaged in the execution of the parallelized IM query:

```
# busstat -a -w dax,pic0=DAX_SCH_ccb_fetch 5 &
. =
. =
. =
30 dax38 DAX_SCH_ccb_fetch  0 DAX_QRY0_output_valid    0      DAX_QRY0_output_valid 0
30 dax39 DAX_SCH_ccb_fetch  0 DAX_QRY0_output_valid    0      DAX_QRY0_output_valid 0
30 dax40 DAX_SCH_ccb_fetch  2286 DAX_QRY0_output_valid 621776 DAX_QRY0_output_valid 621776 &
30 dax41 DAX_SCH_ccb_fetch  2287 DAX_QRY0_output_valid 622800 DAX_QRY0_output_valid 622800 &
30 dax42 DAX_SCH_ccb_fetch  2287 DAX_QRY0_output_valid 621360 DAX_QRY0_output_valid 621360 &
30 dax43 DAX_SCH_ccb_fetch  2287 DAX_QRY0_output_valid 622640 DAX_QRY0_output_valid 622640 &
30 dax44 DAX_SCH_ccb_fetch  2289 DAX_QRY0_output_valid 622448 DAX_QRY0_output_valid 622448 &
30 dax45 DAX_SCH_ccb_fetch  2286 DAX_QRY0_output_valid 621664 DAX_QRY0_output_valid 621664
30 dax46 DAX_SCH_ccb_fetch  2286 DAX_QRY0_output_valid 621712 DAX_QRY0_output_valid 621712 &
30 dax47 DAX_SCH_ccb_fetch  2288 DAX_QRY0_output_valid 622176 DAX_QRY0_output_valid 622176
30 dax48 DAX_SCH_ccb_fetch  0    DAX_QRY0_output_valid 0      DAX_QRY0_output_valid 0
. =
. =
. =
```

When automatic DOP is set for a database session, available cores and DAX coprocessors are applied to parallelize an IM query. It is recommended that Oracle In-Memory Database workloads be evaluated with automatic parallelization as a part of standard testing protocols to determine the potential for efficiency gains.

Compression Efficiency

When investigating compression efficiency for the Oracle Database In-Memory option, the DBMS_COMPRESSION PL/SQL package (available for both Oracle Database 11*g* Release 2 and Oracle Database 12*c*) calculates estimates of a table's compressibility and row-level compression efficiencies for previously compressed tables. To learn how the Oracle Database In-Memory option conserves memory, the following SQL statement shows compression statistics for in-memory segments of a sample database (specifically the Sales database used in the previous analytical query example):

```
SQL> SELECT v.owner, v.segment_name, v.bytes orig_size, v.inmemory_size in_mem_size, v.bytes /
v.inmemory_size comp_ratio FROM v$im_segments v;
OWNER =
--------------------------------------------------------------------------------
SEGMENT_NAME =
--------------------------------------------------------------------------------
 ORIG_SIZE IN_MEM_SIZE COMP_RATIO =
---------- ----------- ----------
SH =
CUSTOMERS =
 311427072   127205376 2.44822257 =

SH =
TIMES =
   1048576     1179648 .888888889 =

OWNER =
--------------------------------------------------------------------------------
SEGMENT_NAME =
--------------------------------------------------------------------------------
 ORIG_SIZE IN_MEM_SIZE COMP_RATIO =
---------- ----------- ----------
```

```
SH =
SALES =
1202716672   488898560 2.46005362
```

The Oracle Database In-Memory option reduced the 1.2 GB Sales table in memory to 489 MB, almost two and a half times smaller. Compression efficiencies will vary, of course, depending on the actual table data.

Optimizing for Security

Incidents of payment card fraud, intrusion attempts, and system and data compromise are rampant and recurring events. Widespread system attacks and exposures are prompting companies to increase detection efforts, strengthen policies, and implement new security practices to eliminate vulnerabilities. To avoid fines and criminal prosecution, many organizations must strictly comply with government and regulatory mandates, including the Health Insurance Portability and Accountability Act (HIPAA), the Gramm-Leach-Bliley Act (GLBA), Sarbanes Oxley (SOX), and the Payment Card Industry-Data Security Standard (PCI DSS). These industry standards and regulations stipulate rigid requirements for business processes, practices, and IT system configurations.

Oracle delivers advanced and integrated technologies to protect Oracle Database applications and data assets. Comprehensive security features are engineered into the Oracle infrastructure stack, helping to safeguard data in motion, data in process, and data at rest:

» **Oracle Database security features**. Oracle Database 12*c* introduces advanced built-in security capabilities such as conditional auditing, data redaction, real application security, privilege analysis, stronger application bypass controls, and new administrative roles. These controls are fully integrated with Oracle Multitenant and can be customized for PDBs. Oracle Database 12*c* (Release 12.1.0.2) also introduces a new embedded FIPS 140-certified software module and advanced hashing support using a SHA-512 hashing algorithm.

» **The Oracle Solaris Cryptographic Framework.** The Oracle Solaris Cryptographic Framework, which has achieved FIPS 140-2 validation, provides a common store of algorithms and PKCS #11 libraries to handle cryptographic requirements. It allows applications to directly access hardware-accelerated on-core cryptographic functions in the SPARC M7 processor without requiring the use of special drivers, the kernel environment, or root permissions. Encryption operations can automatically leverage cryptographic acceleration in hardware. On Oracle ZFS Storage Appliance, ZFS encryption can be implemented to rapidly encrypt data at the project, share, or LUN level for granular efficiency and control. The Key Management Framework (KMF) feature of Oracle Solaris provides tools and programming interfaces for managing public key objects, such as X.509 certificates and public/private key pairs. (To provide enterprise key management across a number of Oracle software products, Oracle Wallet Manager is typically implemented.) Additionally, the PKCS #11 libraries in the Oracle Solaris Cryptographic Framework are also used for the Transparent Data Encryption (TDE) feature of Oracle Database, which encrypts database components at rest and also in transit.

» **No-cost operating system and server virtualization technologies.** As discussed previously, Oracle provides no-charge virtualization—Oracle Solaris Zones, Oracle VM Server for SPARC, and physical domains—for workload segmentation and isolation. In the event that a virtual server is compromised, isolation prevents impacts to other servers and application processes.

» **Hardware acceleration for encryption.** Oracle Database uses authentication, authorization, and auditing mechanisms to secure data within the database, but not in operating system data files where data is stored. To protect these files, Oracle Advanced Security (an Oracle Database option) supports Transparent Data Encryption (TDE) that takes advantage of on-core cryptography features in Oracle's SPARC M7 processor to encrypt data. On-chip encryption occurs at high speeds, allowing organizations to use encryption pervasively to protect sensitive data and reduce risk. Increased memory bandwidths in SPARC M7 processor–based servers also help to facilitate extremely fast encryption and decryption rates.

» **Silicon Secured Memory**. The SPARC M7 processor provides hardware-based memory protection called Silicon Secured Memory. Implemented directly on the chip, Silicon Secured Memory performs dynamic pointer checking that can detect memory reference errors. This technology safeguards against bad pointers, invalid or stale references, and buffer overruns, preventing silent data corruption and application problems that can consume significant development time to diagnose and correct. The ability to take advantage of Silicon Secured Memory is implemented in application-specific memory allocators, such as in SGA memory allocation for Oracle Database 12*c* (12.1.0.2) client applications and in general-purpose memory allocators (such as `malloc`) in Oracle Solaris.

Figure 13 illustrates how these technologies work together to protect Oracle Database applications and data.

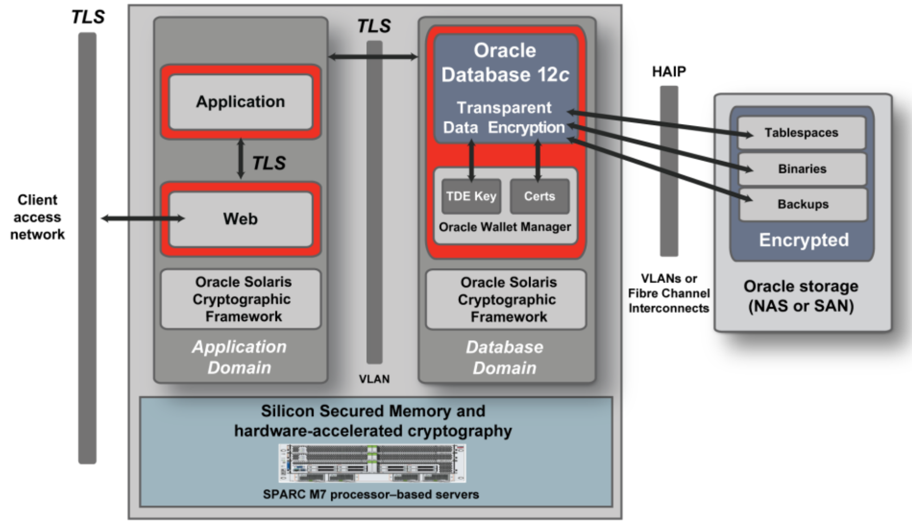

Figure 13. In-depth and multiple layers security controls help to safeguard Oracle Database applications and data.

To safeguard data in motion, Oracle Database inherently uses network encryption (TLS/SSL) to encrypt traffic between connections (between clients and the database, between middleware and the database, and also between databases). Transparent Data Encryption (TDE) automatically encrypts individual table columns and entire tablespaces using cryptographic acceleration capabilities in the SPARC M7 processor—without any change to database applications. Encrypted data stays encrypted in the data files, redo logs, undo, and temp tablespaces and backups. Oracle Wallet Manager can create an encrypted container (called a wallet) that is used to store authentication and signing credentials such as passwords, the TDE master key, PKI private keys, certificates, and SSL trusted certificates. Oracle Database, Oracle Application Server, and the Oracle Identity Management infrastructure can access Oracle wallets to store credentials safely.

Oracle provides a complete portfolio of security solutions, including the following products, to ensure data privacy, protect against insider threats, and enable regulatory compliance:

» Oracle Advanced Security provides Transparent Data Encryption and redaction within Oracle Database, which may be mandated for applications to meet requirements for protecting data such as payment card numbers or identity information.

» Oracle Key Vault enables customers to deploy encryption and other security solutions by centrally managing encryption keys, Oracle wallets, Java Keystores, and credential files.

» Oracle Database Firewall monitors Oracle Database traffic to detect and block threats such as SQL injection attacks.

» Oracle Audit Vault improves audit management and reviews by consolidating audit trails from multiple sources, including different database instances and multiple operating system instances across the enterprise.

» Oracle Database Vault proactively protects application data stored in Oracle Database from being accessed by unauthorized privileged database users.

» Oracle Label Security is designed to meet public-sector requirements for multilevel security and mandatory access control at the database level.

The paper "Oracle Database 12c Security and Compliance" describes how these Oracle technologies can deliver a comprehensive and multilayered security model that encompasses a broad range of preventive, detective, and administrative controls.

In addition, Oracle Enterprise Manager 12*c* includes a new security menu that can simplify the configuration of Oracle Database security mechanisms and help security administrators manage Oracle Database environments that must meet strict compliance standards. Oracle Enterprise Manager Cloud Control offers lifecycle management functionality that automates many time-consuming administrative tasks—including discovery, initial provisioning and cloning, patching, configuration management, and ongoing change management—across large and complex data centers. In addition, it provides a single console that does the following for effective compliance management of data center systems:

- Evaluating the compliance of targets and systems as they relate to business best practices for configuration, security, and storage
- Advising how to change configurations to bring targets and systems into compliance
- Helping to define, customize, and manage compliance frameworks, compliance standards, and rules
- Helping to test systems against corporate policy or criteria defined by regulatory standards

Best Practices for Secure System Configurations

Installation nuances and configuring deployment options are essential security requirements, especially with respect to best practices for software, hardware, operating system, and Oracle Database configuration. Oracle Optimized Solutions advocate implementation practices that optimize security and take advantage of features built into the Oracle technology stack.

Table 2 lists Security Technical Implementation Guides (STIGS) and relevant Oracle documentation that outline recommended security practices at each layer of the solution stack. When deploying Oracle Optimized Solution for Secure Oracle Database, Oracle strongly recommends best practices and guidelines outlined in these documents.

TABLE 2. SECURITY GUIDELINE DOCUMENTS

Component	STIGs and Best Practice Documents
Oracle Database	» *iase.disa.mil/stigs/Documents/U_Oracle_Database_11-2g_V1R2_STIG.zip*
Oracle Solaris	» *iase.disa.mil/stigs/Documents/U_Solaris_11_SPARC_V1R2_STIG.zip* and » *oracle.com/technetwork/server-storage/solaris11/technologies/security-422888.html*
Oracle VM Server for SPARC	» *docs.oracle.com/cd/E38405_01/html/E38407/index.html*
10 GbE switches	» *docs.oracle.com/cd/E39109_01/html/E39117/index.html*
Oracle Integrated Lights Out Manager (Oracle ILOM)	» *iasecontent.disa.mil/stigs/pdf/SecurityReport-ILOM-v1.3.pdf*
Oracle ZFS Storage Appliance	» *iasecontent.disa.mil/stigs/pdf/SecurityReport-ZFSSA-v1.3.pdf*

Best Practices for Operating System Configuration

By following recommendations in the *Oracle Solaris 11 Security and Hardening Guidelines*, administrators can harden and protect deployed systems and applications. Typical best practices include the following:

- **Implementing secure boot.** Defining passwords for the system EEPROM and Oracle ILOM management interfaces makes it possible to restrict booting to authorized administrators. In addition to physical security (keeping servers in locked data centers), preventing systems from unauthorized booting can help to avoid compromise.

- **Installing only the minimal set of operating system software packages**. Software minimization is a common best practice for security. After installation, administrators can use BART (a rule-based file integrity scanning and reporting tool in Oracle Solaris) to generate a manifest that can later be used for comparisons to detect file changes or tampering.
- **Deploying applications using Oracle Solaris Zones, Oracle VM Server for SPARC, and PDoms.** These built-in technologies provide segmentation and isolation—critical defense mechanisms to protect applications.
- **Disabling unneeded network services.** Limiting services to those required reduces the number of potential attack vectors. Implementing TCP wrappers restricts network services to legitimate users.
- **Implementing strong passwords.** In addition to establishing strong passwords for regular users, it's critical to define strong passwords for special user accounts (for example, for `oracle`, `grid`, and `root` users). A centralized user authentication method (such as the Lightweight Directory Access Protocol, LDAP) can simplify authentication administration and management tasks, lowering the risk of unused accounts and accounts with null passwords that could be possible attack vectors.
- **Using Role-Based Access Controls (RBAC).** Oracle Solaris defines roles that can be assigned to users, granting them special rights to perform certain privileged operations. For example, a user assigned to the role of System Administrator might be authorized to create user accounts while the role of Security Officer is used to assign passwords.
- **Configuring immutable zones.** Oracle Solaris 11 provides the ability to configure read-only root file systems. This can prevent tampering with system files in the event a system is compromised.
- **Encrypting file systems and backups.** Using encryption can add an additional level of protection. Oracle Recovery Manager (Oracle RMAN) encryption of backup data before it leaves the database server reduces the risk of theft or unauthorized data access (the backup data is encrypted at the source, in transit, and at rest).
- **Configuring system logs and auditing.** Oracle Solaris supports system log captures and auditing of security-relevant events. Best practice is to collect logs and audit trails and conduct periodic reviews to detect intrusion attempts or malicious activity.
- **Conducting regular security assessments.** On individual systems, the Oracle Solaris `compliance(1M)` utility (described below) checks running Oracle Solaris system configurations against defined policies and security requirements. In larger environments, Oracle Enterprise Manager Cloud Control can also be used to track system compliance.
- **Managing systems and system lifecycles.** Oracle Enterprise Manager 12*c* helps to manage Oracle Solaris provisioning, patching, monitoring, administration, and configuration management. Staying informed about security vulnerabilities, available errata, and pertinent security-related announcements—***and applying security errata quickly***—can help to reduce potential attack vectors. Oracle provides email notification for errata and maintains a web page listing errata and Common Vulnerabilities and Exposures (CVEs) for all Oracle products.

Maintaining Compliant System Configurations

Achieving effective IT system security is dependent on a combination of deploying hardened technologies (such as Oracle Solaris), adhering to configuration guidelines, and following best practices. In most deployments, systems are installed, configured using best practices, and tested under application loads. During this testing process, it often becomes necessary to adjust configurations, sometimes consciously reversing a configuration change or enabling a previously disabled service to support an application or simplify management tasks. While such practices in test environments are often the reality, it's critical that administrators revisit such configuration changes before moving database workloads and systems into production, and conduct periodic compliance checks to inspect configurations for signs of weakness or tampering.

Oracle Solaris 11 supplies a security compliance framework based on the Security Content Automation Protocol (SCAP), which is a NIST standard, and includes the `compliance` utility, which is an implementation of the OpenSCAP toolkit. The `compliance` utility automates security assessments, providing a way to check Oracle

Solaris configurations against a defined security profile. Oracle Solaris provides several predefined compliance profiles, including one tailored for analyzing PCI DSS requirements. Profiles can also be customized to match site and security requirements. The `compliance` utility generates reports that include suggested steps to remediate detected noncompliance issues. As an example, Figure 14 shows suggested remediation steps for a rule that failed during a compliance check.

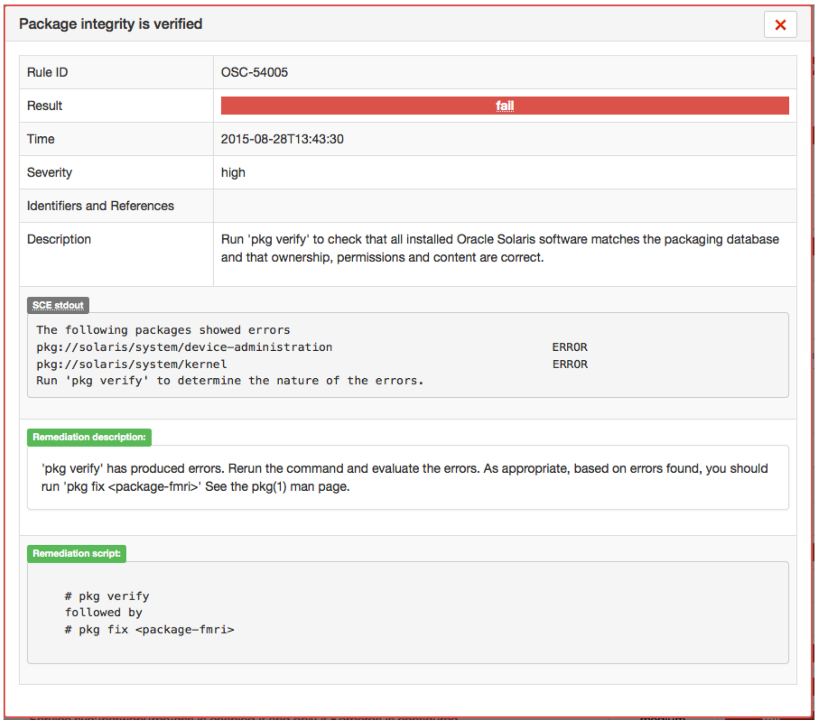

Figure 14. Rule details, including remediation steps, from a failed Oracle Solaris `compliance` assessment.

By using the Service Management Facility (SMF) in Oracle Solaris, an administrator can easily define a service that runs compliance checks on a regular schedule against a specific profile. Oracle Solaris also features Unified Archives that can capture a proven compliant system image in an archive format for cloning. By capturing an approved configuration (either a complete system or a zone), it's possible to propagate secure and compliant server configurations more easily.

When testing Oracle Optimized Solution for Secure Oracle Database, Oracle engineers validated security-hardened configurations. Engineers followed best practices documented in Oracle Solaris STIGs for SPARC platforms and used the Oracle Solaris `compliance` command to conduct compliance checks. Security innovations in hardware—built-in Silicon Secured Memory and encryption support in the SPARC M7 processor—work together with robust security features in software—such as Transparent Database Encryption, which protects database tables and columns. Oracle's deep integration of hardware and software yields the most advanced security platform.

Optimizing for Availability

Oracle Optimized Solutions offer more than simply a collection of redundant and highly resilient components—they represent a comprehensive availability architecture that merges coengineered technologies in a converged Oracle infrastructure stack. Integrating technologies from multiple vendors can be time-consuming and expensive, and mistakes can result in expensive and catastrophic failures and downtime. Oracle Optimized Solution for Secure

Oracle Database defines a solution that combines clustered Oracle systems and storage technologies with a highly reliable and secure operating system, virtualization technologies, clustering software, and database technologies.

SPARC T7 and M7 servers provide advanced high-availability features that work intimately with complementary high availability and virtualization features in Oracle Solaris. Oracle's advanced database technologies take advantage of virtual and physical system elements to support highly available applications. While system reliability features are important, application availability is largely dependent on a layered combination of hardware and software. Each element builds on the strengths of the layer below to enhance the overall reliability, availability, and serviceability (RAS) capability within a complex system. In addition to the reliability and redundancy of the underlying hardware, virtualized server isolation, server cloning, and software clustering technologies help to increase application availability while providing an optimally secure environment.

RAS Features in SPARC T7 and M7 Servers

The white paper "Oracle's SPARC T7 and SPARC M7 Server Reliability, Availability, and Serviceability" (available on oracle.com/sparc) describes RAS features of the server family, including the following:

» **Error detection, diagnosis, and recovery features.** End-to-end data protection detects and corrects errors throughout the system, ensuring complete data integrity. Fault isolation and monitoring can detect and initiate recovery. The SPARC M7 processor can dynamically degrade CPU resources (such as a core), for example, without application downtime.

» **Redundant components.** SPARC T7 and M7 servers feature redundant, hot-swappable power supply and fan units, as well as the option to configure multiple storage devices, memory DIMMs, and I/O cards.

» **Multiple PCIe root complexes.** Each SPARC M7 processor is connected to one or more I/O controller ASICs, and each ASIC provides five PCIe 3.0 root complexes. This capability enables flexible I/O virtualization with separate root domains providing redundant, highly available networking and storage connectivity.

» **DIMM sparing.** Each SPARC M7 processor supports up to 16 DDR4 memory DIMMs, and memory is interleaved for performance. When DIMMs are fully populated, the processor supports memory sparing, allowing a DIMM to be dynamically deconfigured, changing the memory configuration from 16- to 15-way interleaving. The process works by leaving 1/16th of the each DIMM's capacity unused in the initial configuration. DIMM sparing is done automatically when a DIMM is determined to be faulty, with no interruption of service.

» **Redundant service processors and Oracle ILOM.** SPARC M7 servers support redundant, hot-swappable service processors. All system telemetry and health diagnostics are recorded by Oracle ILOM and forwarded to Oracle Enterprise Manager Ops Center for further analysis and action.

Availability Features in Oracle Solaris

Oracle Solaris includes many features that strengthen reliability and availability, including the following:

» **Fault Management Architecture (FMA)**. FMA capabilities improve availability by automatically diagnosing faults in the system and initiating self-healing actions to help prevent service interruptions.

» **Service Management Facility (SMF).** SMF describes conditions under which failed services may be automatically restarted, and can make sure that all dependencies are met when services are restarted.

» **Oracle Solaris ZFS.** Oracle Solaris ZFS provides unparalleled data integrity, capacity, performance, and manageability for storage. It also enables fast cloning to support the resiliency of database environments.

» **Oracle Solaris Multipathing**. In Oracle Optimized Solution for Secure Oracle Database, Oracle Solaris offers a number of different multipathing software options, including Network Multipathing (IPMP), Datalink Multipathing (DLMP), I/O Multipathing (MPxIO), and Oracle VM Server for SPARC Virtual Disk Multipathing. These options provide redundant physical paths to I/O devices such as network interfaces and storage devices.

Oracle Solaris Cluster

For application and web tiers, Oracle Solaris Cluster enables highly available application services. (At the database tier, Oracle RAC is used.) To limit outages due to single points of failure, application and web services need to be run in clustered physical servers that efficiently and smoothly take over application or web services from failing nodes, with minimal interruption. Oracle Solaris Cluster detects failures and provides fast notification, application failover, and reconfiguration.

Oracle Real Application Clusters (Oracle RAC)

At the database tier, Oracle RAC is a shared-cache clustered database architecture that overcomes the limitations of traditional shared-nothing and shared-disk architectures. Oracle RAC offers database performance, scalability, and reliability without requiring changes to existing Oracle Database applications. It can be used for online transaction processing, data warehousing applications, and mixed workloads. It can also be deployed with complementary database technologies, including Oracle Multitenant and Oracle Active Data Guard.

Other Oracle Optimized Solutions

Other Oracle Optimized Solutions can extend an Oracle Optimized Solution for Secure Oracle Database deployment:

» **Oracle Optimized Solution for Oracle Database as a Service.** This solution builds a database cloud infrastructure that can consolidate applications and development, test, and QA environments.

» **Oracle Optimized Solution for Secure Backup and Recovery.** This solution delivers secure next-generation data protection for Oracle's engineered systems and other Oracle Optimized Solutions in heterogeneous environments.

» **Oracle Optimized Solution for Secure Disaster Recovery.** This solution can be used to make sure database deployments are always available. It implements technologies such as the secure replication capabilities of Oracle ZFS Storage Appliance and software options such as Oracle Data Guard or Oracle GoldenGate.

Oracle Maximum Availability Architectures

Complementing Oracle Optimized Solutions, Oracle Maximum Availability Architectures are best-practices blueprints based on proven Oracle high availability technologies, expert recommendations, and customer experiences. The goal of each Oracle Maximum Availability Architecture is to provide optimal high availability at the lowest cost and complexity. (For more information, see the white paper "Oracle MAA Reference Architectures.")

Oracle Best Practices for Highly Available Databases

Oracle documents best practices for deploying a highly available database environment in the *Oracle Database High Availability Overview*. Because availability requirements can vary greatly between different customers and applications, this document defines tiers of objectives that are commonly set in Service Level Agreements (SLAs), such as recovery time objectives (RTOs) and recovery point objectives (RPOs). It also describes Oracle Database products and architectures that can help to maximize availability.

Configuring Oracle Optimized Solutions for High Availability

Oracle Optimized Solution for Secure Oracle Database embodies many best practices that increase database application availability. Solution configurations that support mission-critical Oracle Database applications typically include redundant servers and hardware components, redundant networks, multipathing for networks and storage, RAID configurations, and Oracle RAC to support database node failover.

While SAN storage is often deployed in conjunction with Oracle Automatic Storage Management to maximize availability, Figure 15 depicts an Oracle Optimized Solution for Secure Oracle Database configuration that uses NAS storage and 10 GbE—a configuration that offers excellent availability characteristics at an attractive price-performance point.

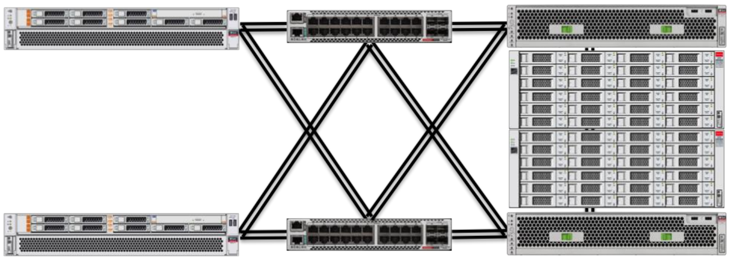

Figure 15. A 10 GbE configuration can be configured for high availability using Oracle RAC.

The architecture has no single point of failure and features dual redundant hardware components: SPARC M7 processor–based servers, 10 GbE switches, Oracle ZFS Storage Appliance controllers, and disk arrays. Multiple isolated VLANS are implemented to secure network traffic, and IP network multipathing (IPMP) is used for networks that require critical access, such as public client access and paths to storage. Figure 16 depicts five VLANs that are typically implemented: VLANs for public access, storage access, management, inter-switch networks, and cluster node communication (for Oracle RAC communications).

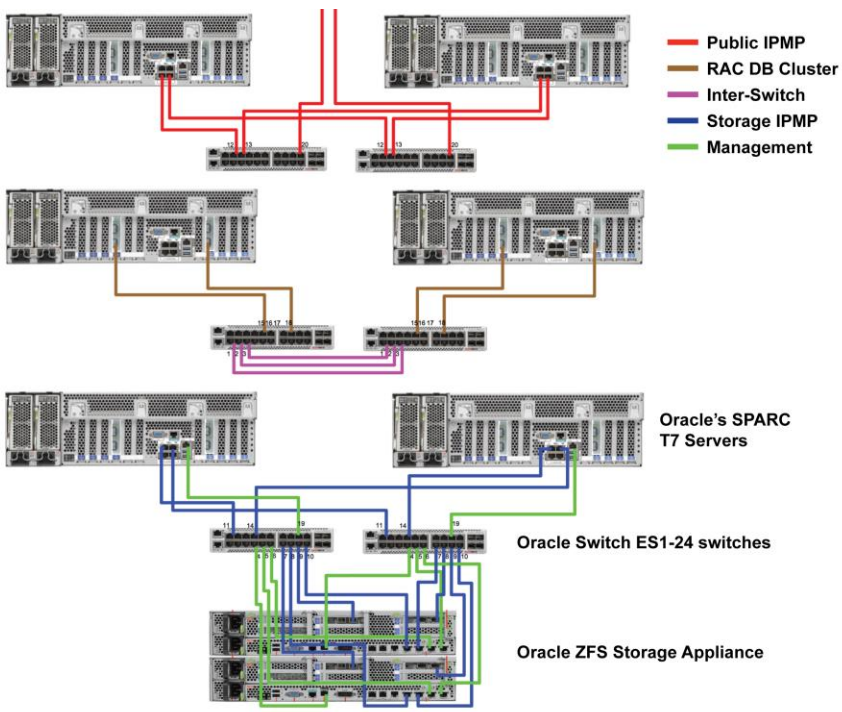

Figure 16. For NAS connectivity, VLAN separation is a best practice to optimize security, throughput, and availability.

Oracle Optimized Solution engineers have tested such a 10 GbE configuration running Oracle Database workloads to evaluate a variety of possible failover scenarios, including the failure of a server, an Oracle ZFS Storage Appliance controller, and an Oracle RAC node. As an example, a database connection to one of the Oracle RAC nodes was abruptly stopped at the operating system level (by killing the `pmon` process) after the database transaction rate reached a steady state. As expected, ongoing transactions continued, processing on an alternate Oracle RAC node. After the failed Oracle RAC node restarted, new database connections were established and load balancing restored transaction performance across multiple nodes. During the availability testing, many of the tests showed that this cost-effective NAS configuration could offer availability characteristics that were as good or better than those provided by SAN. Notable differences included failover time (subsecond for SAN, seconds for NAS) and a variance in redo log response times (although times for the NAS configuration averaged to about the same as with SAN).

In addition to a NAS configuration, Oracle Optimized Solution engineers fully tested a SAN configuration based on the Oracle FS1-2 storage system. In this effort, they were able to validate a highly available configuration with advanced, larger-scale SAN storage, which would likely be deployed in conjunction with Oracle's highly scalable SPARC M7 servers.

Conclusion

Across industries and market segments, Oracle Database systems are at the heart of strategic business decision-making and day-to-day operations. Oracle Optimized Solution for Secure Oracle Database defines a proven blueprint for consolidating database systems using a highly optimized, secured, and cloud-ready Oracle infrastructure. Because Oracle products and technologies are engineered in tandem, an Oracle infrastructure can lower the total cost of ownership, reduce integration risk, boost administrator and user productivity, and decrease time to production.

Oracle-only technologies and optimizations make this solution a superior choice for a secure enterprise Oracle Database infrastructure. At each tier of the solution stack, Oracle has invested to provide deep integration of its technologies that help to accelerate Oracle Database performance, increase security, enhance availability, and simplify IT operations. For organizations that need to run critical analytical queries in real time and accelerate the pace of business decisions—but still achieve high OLTP transaction throughput and superior data protection—this solution provides a proven and validated architecture. Based on the world's fastest microprocessor and a converged infrastructure that extends database acceleration and intrusion protection into silicon, this solution supports exceptional mixed workload performance and advanced security protection for business-critical database applications.

Appendix A: Key Solution Components and Technologies

This appendix examines architectural components at each tier of the solution stack that contribute to performance, security, reliability, and manageability, and provides additional details and references for more information. It describes the following:

» Oracle's SPARC M7 processor–based server family: the SPARC T7 and SPARC M7 servers

» The Oracle Solaris operating system, which contributes to the solution's security and scalability

» No-charge server virtualization technologies: Oracle Solaris Zones, Oracle VM Server for SPARC, and physical domains

» NAS- and SAN-based storage options: Oracle ZFS Storage Appliances and the Oracle FS1-2 flash storage system

» Solution interconnectivity options: 10 GbE and InfiniBand

» Management technologies and options: Oracle Integrated Lights Out Manager, Oracle Enterprise Manager Ops Center, and database management options

Oracle's SPARC M7 Processor–Based Servers

» Oracle Optimized Solution for Secure Oracle Database includes validated small and medium configurations based on rackmounted SPARC T7-1 and T7-2 servers, respectively. Large and extra large configurations are grounded on the larger and more scalable SPARC M7-8 and M7-16 servers. However, the solution architecture is flexible and can accommodate different servers in the SPARC T7 server and SPARC M7 server families (such as SPARC T7-4 servers)—consult an Oracle representative for recommendations on customizing configurations to meet site and business requirements.

Table 3 compares models in the SPARC T7 and SPARC M7 server families. Common hardware features in the new SPARC T7 and SPARC M7 server lines include:

» SPARC M7 32-core 4.13 GHz processors with Software in Silicon features, a new cache and memory hierarchy, (with larger L2 and L3 caches), and a high-bandwidth and low-latency on-chip network.

» Faster memory technology than that used in previous server generations (16 GB or 32 GB DDR4-2133 memory DIMMs) and memory advancements such as DIMM sparing.

» An advanced and reliable I/O design based on one or two I/O controller ASICs that each support five high-bandwidth PCIe 3.0 root complexes. The servers also support PCIe 3.0 x16 capable expansion slots.

» Support for NVM Express (NVMe) flash devices and onboard 12 Gb/sec SAS3 I/O controllers in the SPARC T7-1, T7-2, and T7-4 servers.

» Embedded USB storage device (eUSB) that can support booting over an InfiniBand network.

TABLE 3. A COMPARISON OF ORACLE'S SPARC M7 PROCESSOR–BASED SERVERS

Feature	SPARC T7-1 Server	SPARC T7-2 Server	SPARC T7-4 Server	SPARC M7-8 Server	SPARC M7-16 Server
Form Factor	2U	3U	5U	1 CPU, Memory, and I/O Unit (CMIOU) Chassis (10U) factory-mounted along with dual Power Distribution Units (PDUs); requires 16U of total 26U	2 CMIOU chassis factory-mounted with dual PDUs; requires 26U
Physical Domains	One			1 or 2 (factory-installed and fixed)	1, 2, 3, or 4
Processor Quantity	One	Two	Two or four	2–8 (2–4 per PDom)	4–16

Feature	SPARC T7-1 Server	SPARC T7-2 Server	SPARC T7-4 Server	SPARC M7-8 Server	SPARC M7-16 Server
Maximum Cores/Threads	32/256	64/512	128/1024	128 per PDom/1024 per PDom	512/4096
Max/Min Memory	512 GB/128 GB	1 TB/256 GB	2 TB/256 GB	4 TB/512 GB	8 TB/1TB
Int. 2.5 Drive Bays	Eight	Six	Eight	NA	
SAS support	One integrated SAS3 HBA with RAID 0/1/10/1E supporting up to eight 2.5-inch SAS HDDs/SSDs	Two integrated SAS3 HBAs with RAID 0/1/10/1E supporting up to six (2 + 4) SAS HDDs/SSDs	Two integrated SAS3 HBAs with RAID 0/1/10/1E supporting up to eight (4 + 4) SAS HDDs/SSDs	NA	
NVMe support	One optional factory-configured PCIe switch supporting up to four 2.5" NVMe SSDs	One or two optional factory configured PCIe switch supporting up to four 2.5" NVMe SSDs	Two optional factory configured PCIe switches supporting up to eight (4 + 4) 2.5" NVMe SSDs	NA	
Maximum Oracle Flash Accelerator F160 PCIe Cards (NVMe)	6	6	8	10	20
Management Ports	One Ethernet 100BASE-T port, one serial RJ45 port			Two Ethernet 100BASE-T ports (active/standby), two serial RJ45 ports (active/standby)	
USB Ports	Two USB 2.0 (front) and two USB 3.0 (rear)	Four USB 3.0		NA	
Ethernet	Four integrated 10GBASE-T ports; two integrated Ethernet controllers			Via PCIe adapter cards	
PCIe 3.0 Low-Profile Slots	Six slots Six x8 slots, or two x16 and two x8 slots Supported by four PCIe root complexes	Eight slots Four x8 and four x16 slots Supported by eight PCIe root complexes	16 hot-pluggable slots Eight x8 and eight x16 slots Supported by 12 PCIe root complexes	Up to 24 hot-pluggable slots Three x16 slots per processor One PCIe root complex per slot	Up to 48 hot-pluggable slots Three x16 slots per processor One PCIe root complex per slot
PCIe Root Complexes	5	10	20	Up to 32	Up to 64
N+N Redundant Power Supplies	Two redundant hot-swappable AC 1000 W power supplies	Two redundant hot-swappable AC 2000 W power supplies	Four hot-swappable AC 3000 W power supplies	Six hot-swappable AC 3000 W power supplies	16 hot-swappable AC 3000 W power supplies
N+1 Redundant Hot-Swappable Fans	Four dual-fan modules, top loading	Six fans, top loading	Five dual-fan modules, rear loading	Eight dual-fan modules, front loading	52 dual-fan modules, front and rear loading

For additional details about SPARC M7 processors and the servers in which they are integrated, see the white paper "Oracle's SPARC M7 Processor–Based Server Architecture" available on oracle.com/sparc.

Oracle Solaris

The latest Oracle Solaris 11 release is specifically designed to take full advantage of the SPARC M7 processor–based servers, including the latest Software in Silicon innovations. Oracle Solaris provides strategic functionality for virtualization, availability, security, and performance for vertically and horizontally scaled environments.

SPARC T7 and M7 servers appear as familiar SMP systems to Oracle Solaris and applications. Oracle Solaris supports features that enable rich Oracle Database and application environments, including:

- **OpenStack cloud management**. Oracle Solaris 11 includes a complete OpenStack distribution, allowing administrators to centrally share and manage data center resources through a single management pane, including infrastructure and virtualization offerings provided by other vendors. Integrated into core technologies such as Oracle Solaris Zones, the ZFS file system, Unified Archives, and comprehensive software defined networking, Oracle OpenStack for Oracle Solaris provides self-service computing, allowing IT organizations to deliver services in minutes rather than weeks, with enterprise-grade reliability, security, and performance.
- **Oracle Solaris software defined networking.** Oracle Solaris 11 provides integrated software defined networking technology to provide greater application agility without the overhead of expensive network hardware. It enables application-driven, multitenant cloud virtual networking across a distributed set of systems, decoupling physical network infrastructure and application-level network SLAs. Built-in features include the following:
    - Network virtualization with virtual NICs (VNICs) and virtual switching
    - Network resource management and integrated quality of service (QoS) to enforce bandwidth limits on VNICs and traffic flows
    - Cloud readiness, a core feature of the OpenStack distribution included in Oracle Solaris 11
    - Application-driven, multitenant cloud virtual networking with Elastic Virtual Switch and VXLANs
    - Application-level QoS with application-driven software defined networking
    - Tight integration with Oracle Solaris Zones, including Oracle Solaris 10 Zones
- **Lifecycle management.** Oracle Solaris 11 includes a complete and integrated set of technologies for managing the platform’s software lifecycle. With support for secure end-to-end provisioning with the Oracle Solaris Automated Installer, failsafe software updates with the Oracle Solaris Image Packaging System and ZFS boot environments, rapid application deployment using Unified Archives, and a comprehensive compliance framework, Oracle Solaris 11 helps to increase productivity, reduce human error, and reduce IT costs.
- **Accelerated cryptography**. Accelerated cryptography is supported through the cryptographic framework in Oracle Solaris as well as in the SPARC M7 processor. The SPARC M7 processor supports cryptographic cipher hardware implementations. The ciphers are implemented through user-level instructions within the appropriate pipeline itself, rather than as a coprocessor. This means a more efficient implementation of hardware-based ciphers as well as no privilege-level changes, resulting in a large increase in efficiency in cryptographic algorithm calculations. In addition, database operations can make much more efficient use of various cryptographic ciphers implemented within the instruction pipeline itself.
- **Critical thread optimization**. Oracle Solaris 11 permits either a user or a programmer to allow the Oracle Solaris scheduler to recognize a critical thread by means of raising its priority to 60 or above through the use of either the command line or through system calls to a function. If this is done, that thread will run by itself on a single core, garnering the core’s resources for itself. (The one situation that prevents a single thread from executing on a single core is when there are more runnable threads than available CPUs. This limit was put in place to prevent resource starvation to other threads.)
- **Multicore/multithreaded awareness**. Oracle Solaris 11 is aware of the SPARC M7 processor memory hierarchy, so the scheduler can effectively balance load across all available pipelines. Even though it exposes each SPARC M7 processor as 256 logical processors, Oracle Solaris understands the correlation between cores and the threads they support, and provides a fast and efficient thread implementation. Oracle Solaris 11 has the ability to enable or disable individual logical processors, and features such as processor sets provide the ability to define a group of these logical processors and specifically allocate processes to them.

- **Non-uniform memory access optimization (NUMA) in Oracle Solaris**. With memory managed by each SPARC M7 processor, these systems implement a NUMA architecture. In NUMA architectures, the time needed for a processor to access its local memory is slightly shorter than that required to access memory managed by another processor. Oracle Solaris provides the following optimizations that help to decrease the impact of NUMA on Oracle Database applications and improve performance:
  - **Memory placement optimization (MPO)**. Oracle Solaris uses MPO to improve memory placement across the physical memory, increasing performance. Through MPO, Oracle Solaris allocates memory as close as possible to the processors that access it, while still maintaining balance within the system. As a result, Oracle Database applications are often able to run considerably faster.
  - **Hierarchical Lgroup Support (HLS)**. HLS improves the MPO feature in Oracle Solaris by optimizing performance for systems with more-complex memory latency hierarchies. HLS lets Oracle Solaris distinguish between degrees of memory remoteness, allocating resources with the lowest-possible latency. If local resources are not available by default, HLS helps Oracle Solaris allocate the nearest remote resources.
- **Kernel acceleration in Oracle Solaris for Oracle RAC.** The Oracle RAC distributed database uses the Lock Management System (LMS), a user-level distributed lock protocol that mediates requests for database blocks between processes on cluster nodes. Fulfilling a request requires traversing and copying data across the user/kernel boundary on the requesting and serving nodes, even for the significant number of requests for blocks with uncontended locks. Oracle Solaris includes a kernel accelerator to filter database block requests destined for LMS processes. LMS kernel acceleration directly grants requests for blocks with uncontended locks, which eliminates user-kernel context switches, associated data copying tasks, and LMS application-level processing.
- **Oracle Solaris ZFS**. Oracle Solaris ZFS offers a dramatic advance in data management, automating and consolidating complicated storage administration concepts and providing unlimited scalability with the world’s only 128-bit file system. Oracle Solaris ZFS is based on a transactional object model that removes most of the traditional constraints on I/O issue order, resulting in dramatic performance gains. Oracle Solaris ZFS also provides data integrity, protecting all data with 64-bit checksums that detect and correct silent data corruption.
- **Multipathing software**. Multipathing software in Oracle Solaris allows organizations to define and control redundant physical paths to I/O devices, such as storage devices and network interfaces. If the active path to a device becomes unavailable, the software can automatically switch to an alternate path to maintain availability.
- **A secure and robust enterprise-class environment**. Best of all, Oracle Solaris does not require arbitrary sacrifices. Existing SPARC applications continue to run unchanged on SPARC T7 and M7 platforms, protecting software investments. Embedded security features help to protect Oracle Solaris environments from intrusion. The fault management architecture in Oracle Solaris means that elements such as Oracle Solaris Predictive Self Healing can communicate directly with the hardware to help reduce both planned and unplanned downtime. Tools, such as Oracle Solaris DTrace, also help DBAs troubleshoot and tune applications effectively to get the best performance and optimal use of system resources.

Virtualization Technologies

Oracle Optimized Solution for Secure Oracle Database helps to increase service levels and business agility through its use of lightweight virtualization technologies. SPARC M7 processor–based servers are designed specifically for virtualization, and support three types of partitioning and virtualization technologies: physical domains (PDoms), Oracle VM Server for SPARC logical domains (LDoms), and Oracle Solaris Zones. This solution outlines a layered virtualization approach in which these technologies are combined to optimize security, availability, performance, and manageability.

Physical Domains

A single SPARC M7-8 or M7-16 system can be divided into multiple fault-isolated PDoms, each running independent instances of the Oracle Solaris operating system with access to designated I/O devices. Compute, memory, and I/O resources are assigned to different PDoms. In Oracle Optimized Solution for Secure Oracle Database, the SPARC M7-8 is factory-configured with two fixed PDoms of up to 4 processors each. (A physical wireframe harness maintains reliable electrical connections for the factory-installed PDom configurations.) With the

SPARC M7-16 server, best practice for Oracle RAC workloads is to configure multiple PDoms; for example, two PDoms can be configured with up to 8 processors each or four PDoms can be configured with four processors each.

When system components are exclusively dedicated to individual PDoms, hardware or software faults in one domain remain isolated and unable to impact the operation of other domains. Each PDom runs an independent version of the Oracle Solaris operating system, making this technology extremely useful for preproduction testing of new or modified applications or for consolidating database, application, and web tiers.

Multiple, fully isolated PDoms can separate Oracle Database instances that require strict isolation. Configuring CPU resources in a PDom can be useful when hosting extremely compute-intensive applications. In addition, with the Oracle In-Memory Database option, it might be desirable to allocate a large amount of memory to a PDom so that a database will achieve much better results running in memory, eliminating I/O latencies that occur in traditional database implementations.

Oracle VM Server for SPARC

Oracle VM Server for SPARC is a lightweight virtualization technology supported on all Oracle chip multithreading (CMT) servers, including earlier SPARC T4, T5, and M6 processor–based servers as well as the SPARC T7 and M7 servers. Oracle VM Server for SPARC leverages a built-in hypervisor that subdivides system resources down to the processor thread, cryptographic processor, memory, and PCI bus, creating virtual partitions called logical domains (LDoms). Each LDom runs in one or more dedicated CPU threads, has isolated I/O domains, and runs its own separate copy of the Oracle Solaris operating system.

Oracle VM Server for SPARC delivers the following features and capabilities:

» **Live migration** clones and migrates an active domain to another physical machine while maintaining application services. On-chip cryptographic accelerators enable secure wire-speed encryption—without any additional hardware—allowing domains (and any sensitive data they contain) to be migrated securely, even across public networks. This capability is extremely useful when migrating database environments to other servers for backup and disaster recovery support.

» **PCIe direct I/O** assigns either individual PCIe cards or entire PCIe buses to a guest domain. This delivers native I/O throughput.

» **Advanced RAS capabilities** for the logical domain include virtual disk multipathing and failover, as well as faster network failover with link-based IP multipathing (IPMP) support. The logical domain can also handle path failure between an I/O domain and storage. Moreover, the domain is fully integrated with the Oracle Solaris Fault Management Architecture (FMA), which enables predictive self-healing.

» **CPU whole core allocation and core affinity capabilities** allow the assignment of virtual CPUs to deliver higher and more-predictable performance for database application workloads.

» **CPU dynamic resource management (DRM)** enables a resource management policy and domain workload to trigger the automatic addition and removal of CPUs, which helps to better align business priorities.

» **Physical-to-virtual (P2V) conversion** transforms an existing SPARC server running the Oracle Solaris 8, Oracle Solaris 9, or Oracle Solaris 10 operating system into a compatible virtual environment running on Oracle Solaris 10. In this way, legacy applications can be consolidated onto virtualized environments and take advantage of a new hardware platform without the need for an immediate migration or upgrade.

» **CPU power management** conserves power by disabling each core when all of its CPU threads are idle. Adjusting CPU clock speed, managing memory power, and establishing power-use limits help to match energy consumption to utilization.

» **Advanced network configuration** supports greater flexibility, higher network performance, and scalability with these features: jumbo frames, VLANs, virtual switches for link aggregations, and network interface unit (NIU) hybrid I/O.

Oracle Solaris Zones

Lightweight Oracle Solaris Zones are private execution environments within Oracle Solaris. Oracle Database instances or applications running within zones are isolated, preventing processes in one zone from affecting processes running in another. Virtual networks in zones can isolate client access to databases, which can be a requirement in some deployments.

Oracle Solaris Zones feature extremely fast initialization, and can be configured to instantly start, stop, or restart Oracle Database and Oracle RAC services. Oracle Solaris Zones provide deployment flexibility, allowing easy configuration changes for resources within defined physical or logical domains. Zones also simplify the cloning and instantiation of new database environments, making it possible to prioritize database workloads within domains and allowing system resources to be easily reassigned to handle peak or seasonal workloads. Administrators can also provision an Oracle Solaris 10 operating system instance using a special type of zone (an Oracle Solaris 10 Zone). With Oracle Solaris Zones, it is possible to maintain a one-application-per-virtual-server deployment model to achieve workload isolation while simultaneously sharing hardware resources.

Oracle NAS and SAN Storage Options

When deploying Oracle Optimized Solution for Secure Oracle Database, customers have a choice for the underlying shared storage in the solution. Sites may choose to leverage existing investments in SAN storage, or they can take advantage of Oracle's highly integrated NAS or SAN storage solutions: Oracle ZFS Storage Appliance or the Oracle FS1-2 flash storage system.

For database applications, these Oracle storage products are optimized for price-performance and throughput:

» **Oracle ZFS Storage Appliances** leverage a DRAM-centric architecture and a symmetric multiprocessing (SMP) operating system to deliver record performance and help enterprises realize up to a 75 percent cost savings over traditional storage solutions. These appliances also optimize Oracle Database storage for capacity, enabling up to 50x data compression rates using Hybrid Columnar Compression.

» **Oracle FS1-2 flash storage system** is an enterprise-grade SAN storage system that is coengineered with Oracle software. Based on usage profiles and business priorities, it can optimize data placement across flash and disk storage to maximize performance and efficiency and reduce cost.

Oracle storage products feature these Oracle-only optimizations that enable significant performance and capacity advantages for Oracle Database workloads:

» **Oracle Intelligent Storage Protocol**. A feature of Oracle Database 12*c*, Oracle Intelligent Storage Protocol is an Oracle-only optimization for Oracle storage products such as Oracle ZFS Storage Appliances. Oracle storage receives cues from Oracle Database about database operations, allowing the storage to intelligently process I/O and automatically and dynamically optimize for performance. This greatly reduces risk and speeds database provisioning because it eliminates manual storage tuning that can be subject to human error. The protocol supports per-database analytics, including analytics for pluggable databases in Oracle Database 12*c* Multitenant. Storage analytics help administrators drill down to database-specific statistics and more quickly resolve issues, especially in consolidated systems.

» **Hybrid Columnar Compression.** Hybrid Columnar Compression with Oracle ZFS Storage Appliances or the Oracle FS1-2 flash storage system can achieve a 10x to 50x reduction in data volumes and accelerate queries by 3x to 8x. Implemented with the Oracle Advanced Compression option for Oracle Database and only on Oracle storage products, this capability enables a 3x to 5x reduction in storage footprint and associated data center costs. Furthermore, with Oracle Database 12*c*, the Automatic Data Optimization feature enables you to set policies to initiate Hybrid Columnar Compression and data tiering based on actual data usage to manage data throughout its lifecycle. (For both Oracle Database 11*g* Release 2 and Oracle Database 12*c*, the DBMS_COMPRESSION PL/SQL package gathers compression-related information within a database environment, such as estimates of a table's compressibility and row-level compression information on previously compressed tables.)

Oracle ZFS Storage Appliance Overview

Oracle ZFS Storage Appliance is an excellent storage option for Oracle Optimized Solution for Secure Oracle Database, especially for environments that require high throughput and superior cost efficiency. The appliance provides enterprise-class NAS capabilities and a complete suite of data services including snapshots, clones, replication, and industry-leading performance analytics, as well as native compression, deduplication, Oracle Database integration, Hybrid Columnar Compression (HCC), and Direct NFS (dNFS) support. The appliance features a comprehensive and intuitive user interface and storage analytics environment that helps to simplify storage management and reduce operating costs and complexity.

The appliance is based on an advanced hardware and software architecture, including a highly intelligent multithreading storage operating system that supports multiple workloads and advanced data services without performance detriment. The Hybrid Storage Pool architecture automatically caches data on dynamic random access memory (DRAM) or flash to provide optimal performance and exceptional efficiency, while storing data safely on cost-effective, high-capacity hard-disk drive (HDD) storage. This enables heavily accessed data to be served mostly (up to 90 percent) from cache for high performance independent of spindle speeds. The Hybrid Storage Pool design provides compelling throughput as well as cost-effective database storage. (For more information on the Hybrid Storage Pool architecture, see the paper "Architectural Overview of the Oracle ZFS Storage Appliance.")

High-availability features such as active-active controller clustering for failover, a self-healing file system architecture for end-to-end data integrity, and a rich set of enterprise-class data services make Oracle ZFS Storage Appliance an ideal choice for Oracle Database and Oracle RAC applications. In Oracle Optimized Solution for Secure Oracle Database configurations, each controller sends traffic to and receives traffic from storage clients via a high-performance network. Ethernet, Fibre Channel, or InfiniBand connectivity options are supported.

Two models of Oracle ZFS Storage Appliance are available for the solution:

» **Oracle ZFS Storage ZS3-2**, a mid-range enterprise multiprotocol storage system, ideal for use in performance-intensive workloads at a cost-effective price point
» **Oracle ZFS Storage ZS4-4**, a high-end enterprise multiprotocol storage system for workloads demanding extreme performance and scalability at a competitive price point compared to other midrange and high-end systems

Both models use the same intelligent storage OS and enterprise SAS-2 disk enclosures but feature different controllers to meet different storage requirements. In summary, Oracle ZFS Storage Appliance offers significant advantages as a storage system for Oracle Optimized Solution deployments:

» Direct NFS (dNFS) improves I/O efficiency and performance (see the following description).
» Storage shares all use LZJB compression to improve capacity and performance.
» Support is provided for 10 GbE or 40 Gb/sec quad data rate (QDR) InfiniBand.
» Oracle Intelligent Storage Protocol is supported in Oracle Database 12c to optimize database I/O without manual intervention, eliminating the risk of human error in the process of tuning storage parameters.
» There is observability at the PDB level for Oracle Multitenant.
» The appliance provides the ability to efficiently snapshot and clone database files for DTAP provisioning.

Direct NFS—Enabling A Simple and Cost-Effective Storage Architecture

Running Oracle Database on Oracle ZFS Storage Appliance over Ethernet-based NFS provides an easy-to-manage and flexible infrastructure that can support a large number of database instances. Ethernet-based NFS facilitates simple provisioning, management, and sharing. In addition, it offers the flexibility to move and repurpose database and storage resources rapidly. NFS implementations are also typically advantageous from a price/performance standpoint: they do not require special Fibre Channel SAN installation, expertise, or training; and they allow IT teams to leverage standard Ethernet knowledge.

Oracle provides a database-centric Direct NFS (dNFS) client for Oracle Database that speeds database accesses over NFS protocols. Available for both the Oracle Database 11*g* and Oracle Database 12*c* releases, the dNFS client improves performance while accessing NFS-based storage, optimizing the storage architecture's scalability while eliminating the need for other complex NFS administration and optimization tasks. For more information on dNFS, consult the *Oracle Database Installation Guide for Oracle Solaris*. The white paper "Optimizing Storage for Oracle Database 11*g* Release 2 with the Oracle ZFS Storage Appliance" gives best practices for implementing dNFS with Oracle ZFS Storage Appliance and Oracle Database 11*g*.

Oracle FS1-2 Flash Storage System

Oracle FS1-2 flash storage system, Oracle's premier SAN storage solution, delivers enterprise-grade storage. It is optimized for Oracle Database and Oracle application workloads, leveraging unique features such as Hybrid Columnar Compression and one-click provisioning based on best practices. The system's Quality of Service Plus (QoS Plus) feature optimizes data placement across flash and disk devices to maximize performance, efficiency, and cost based on usage profiles and business priorities. Additionally, Oracle's FS1-2 Flash Storage System also provides an All Flash Oracle Database capability. Please see the IDC report "Oracle Enters the High-Growth All-Flash Array Market" for further information.

Key features of the Oracle FS1-2 flash storage system include the following:

» **Flash-optimized performance.** The Oracle FS1-2 flash storage system is designed to exploit flash characteristics to provide high IOPS and throughput without compromising expandability. It scales to 912 TB of flash and up to 2.8 PB of combined flash and disk to meet demanding performance and capacity requirements. Flash tiers that combine performance-optimized flash and capacity-optimized flash help to optimize read-intensive and mixed-use I/O operations.

» **QoS Plus.** QoS Plus is a policy-based virtualization feature that incorporates business priority I/O queue management with sub-LUN automatic tiering into a single management framework. Built on Oracle's patented storage quality-of-service technology, QoS Plus collects detailed information on storage usage, evaluates data chunk movement to different storage tiers, and then automatically migrates data to the most cost-effective media (flash or disk) based on the usage profile and the importance of that data to the business. QoS Plus performs data collection, evaluation, and movement based on efficient data granularity.

» **Application profiles.** The Oracle FS1-2 flash storage system comes with predefined application profiles that provide tuned and tested out-of-the-box storage optimization for Oracle Database and other enterprise applications. One-click provisioning can optimize flash performance and manage Oracle applications with minimal administrative effort. Database storage profiles can disaggregate database components such as index files, database tables, archive logs, redo logs, control files, and temp files, allowing automatic provisioning to optimize Oracle Database performance without requiring detailed knowledge about the database components. New application profiles can be added to standardize storage provisioning across data centers.

» **Storage domains.** Storage domain software enables multiple, virtual storage systems within a single Oracle FS1-2 flash storage system. Each storage domain is a data container that isolates data from other storage domains, providing independence in multitenant environments for private or public cloud deployments, regulatory compliance requirements, or chargeback models. With storage domains, QoS settings can be customized for multiple environments, with all domains residing on a single physical Oracle FS1-2 flash storage system to reduce power, cooling, and administrative expense.

For configurations that require SAN performability and failover behavior, as well as optional synchronous replication, SAN storage can be implemented with Oracle Optimized Solution for Secure Oracle Database. Additional advantages are available, however, by deploying an Oracle SAN solution such as the Oracle FS1-2 flash storage system. An Oracle SAN storage architecture that uses the Oracle FS1-2 storage system features the following:

- Oracle Automatic Storage Management (Oracle ASM) can be used to improve solution management efficiency and performance.
- 16 Gb Fibre Channel connectivity is implemented using physical or virtual HBAs and SR-IOV under Oracle VM Server for SPARC logical domains.
- The Oracle FS1-2 storage system includes storage pools containing flash and HDDs or all-flash devices.
- The patented Quality of Service Plus (QoS Plus) feature tunes data placement and access priority based on business value of the data.
- Database Storage Profiles provide one-click provisioning for Oracle Database and key Oracle application workloads, simplifying storage provisioning.
- Optionally, storage domains can be defined to isolate critical use cases.

Cloning Oracle Databases on Shared Storage

There are a many reasons that IT organizations might need to clone a production Oracle Database, including the following:

- Application development and testing. Customers often clone a production databases to support a typical DTAP application lifecycle. Databases are often cloned to create environments for development and testing, to evaluate performance, and to conduct regression testing.
- Infrastructure updates without downtime. Mission-critical applications require continuous availability, so system updates or upgrades must occur without imposing downtime. Database clones enable upgrades while production systems continue to run.
- Troubleshooting. Replicating an existing software environment can help in identifying and resolving a problem.

One classic method of creating a copy of an Oracle Database instance is to restore a database from a recent backup to a different server. This approach can often be extremely time-consuming. Using the fast cloning capabilities of Oracle storage products can help to streamline the database duplication process. Alternatively, for pluggable databases, the Database Configuration Assistant in Oracle Database 12*c* can easily clone a pluggable database.

Hosting an Oracle Database instance using an Oracle Solaris Zone and Oracle ZFS Storage Appliance also facilitates fast database cloning. A golden image for the database is first created in an Oracle Solaris Zone that can then be replicated as needed. Oracle ZFS Storage Appliance features snapshot and cloning capabilities that simplify the cloning process.

I/O Connectivity and Networking

Oracle Optimized Solution for Secure Oracle Database is typically deployed with 10 GbE networking. Performance requirements for I/O connectivity (to support system connections to storage) and for the Oracle RAC private interconnect might also necessitate the addition of InfiniBand technology. In many cases, 10 GbE can provide the required connectivity.

Ethernet Connectivity

Ethernet-connected NAS storage is frequently chosen over SAN technologies in deployments of Oracle Optimized Solution for Secure Oracle Database. NAS is often the preferred storage choice because Ethernet networking offers greater familiarity, architectural simplicity, and significantly lower cost while still providing reasonable performance. In addition, NAS storage connectivity over 10 GbE supports the ability to snapshot and clone database files efficiently using Oracle ZFS Storage Appliance.

When Oracle ZFS Storage Appliance is implemented, it is a best practice to implement multiple separate Ethernet networks for optimal security and data throughput. IP multipathing is also recommended for networks that require greater reliability, such as networks that support client access and storage I/O. An earlier section in this paper describes an example deployment, showing how multiple 10 GbE networks can be configured for greater availability (see “Oracle Best Practices for Highly Available Databases” earlier in this paper).

Oracle Switch ES1-24

Oracle Switch ES1-24 is commonly implemented as a part of an Oracle Optimized Solution for Secure Oracle Database configuration. Designed to harness the capabilities of Oracle's server systems and 10 GbE NICs, Oracle Switch ES1-24 brings advanced 10 GbE top-of-rack (ToR) switching to data centers. It delivers comprehensive Layer 2 and Layer 3 features and wire-speed switching for high performance and maximum availability, eliminating networking bottlenecks and reducing costs.

InfiniBand for Private Oracle RAC Interconnectivity and Fabric Convergence

With traditional network technologies, moving data between applications can sometimes be time-consuming and drain precious server resources. Application latencies can result because of system calls, buffer copies, and interrupts. InfiniBand Remote Direct Memory Access (RDMA) technology provides a direct channel from the source application to the destination application, bypassing operating systems on both servers. An InfiniBand channel architecture eliminates the need for operating system intervention in network and storage communication. As a result, InfiniBand can provide a very high-speed, low-latency interface for efficient data movement between Oracle RAC nodes. InfiniBand networking is often implemented because it offloads busy servers, preserving compute power for demanding database workloads.

Quad data rate (QDR) InfiniBand technology delivers 40 Gb/sec connectivity and can supply application-to-application latencies as low as one microsecond. It has become the dominant interconnect fabric for high-performance enterprise clusters. InfiniBand provides ultra-low latency and near-zero CPU utilization for remote data transfers, making it ideal for high-performance clustered applications. In addition to providing fast remote data access, InfiniBand’s industry-leading bandwidth enables fabric convergence, allowing all network, storage, and interprocess communication traffic to be carried over a single fabric. Converged fabrics aggregate the functions of dedicated, sole-purposed networks and alleviate the associated expense of building and operating multiple networks and their associated network interfaces. In addition, InfiniBand, along with Oracle Solaris, supports IPoIB (Internet Protocol over InfiniBand) for application and Oracle RAC database access, which can supply higher bandwidth and lower latencies than Ethernet networking. Oracle ZFS Storage Appliance can also support InfiniBand to take advantage of low-latency, high-bandwidth I/O operations for database services.

Sun Datacenter InfiniBand Switch 36

Sun Datacenter InfiniBand Switch 36 from Oracle offers low-latency, quad data rate (QDR), 40 Gb/sec fabric and cable aggregation for Oracle servers and storage. It supports a fully non-blocking architecture, and acts as a self-contained fabric solution for InfiniBand clusters of up to 36 nodes. The switch provides hardware support for adaptive routing, including InfiniBand 1.2 congestion control that helps to eliminate fabric hotspots and drive maximum throughput at the lowest possible latencies. It is ideal for deployment with clustered databases and converged data center fabrics.

Advanced features support the creation of logically isolated subclusters, as well as traffic isolation and quality of service management. The embedded InfiniBand fabric management module is enabled to support active/hot-standby dual-manager configurations, ensuring a seamless migration of the fabric management service in the event of a management module failure. Sun Datacenter InfiniBand Switch 36 is provisioned with redundant power and cooling for high availability. When deployed in pairs, the switches provide a highly available and resilient fabric for business-critical applications.

System and Database Management

SPARC M7 processor–based servers feature powerful service processors (SPs) that run the Oracle Integrated Lights Out Manager (Oracle ILOM) software. Using Oracle Enterprise Manager Ops Center software, administrators can execute almost all administrative tasks remotely, except for a very few that actually require physical hardware access. By simplifying remote management, Oracle Enterprise Manager Ops Center eases administration, helping to save time and reduce operational costs.

Oracle Integrated Lights Out Manager

The Oracle ILOM software on each server's SP provides the heart of remote monitoring and management capabilities for SPARC servers. SPARC M7-8 and M7-16 servers feature redundant SPs that are capable of automatic failover and support hot-serviceability for continuous SP operation.

The SPs regularly monitor system environmental sensors, warn of potential error conditions, and execute proactive system maintenance. For example, SPs can initiate a server shutdown in response to temperature conditions that might induce system damage. The Oracle ILOM software helps administrators remotely control and monitor the health of physical domains, virtual machines, and the hardware platform itself.

The Oracle ILOM software also accesses SPs to perform power management tasks that can reduce energy-related costs. The SPARC M7 processor incorporates unique power management features at both the core and memory levels of the processor. These features include reduced instruction rates, parking of idle threads and cores, and the ability to turn off clocks in both cores and memory to reduce power consumption. In addition, while previous SPARC processors allowed power management at the chip level, the SPARC M7 processor supports subchip power management.

Oracle ILOM provides full remote keyboard, video, mouse, and storage (rKVMS) support together with remote media functionality. In addition, Oracle ILOM is also an integral part of Oracle Enterprise Manager Ops Center, which controls Oracle servers, operating systems, and virtualization technologies.

Oracle Enterprise Manager Ops Center

Oracle Enterprise Manager Ops Center delivers a converged hardware management solution that integrates management across the infrastructure stack. It is included with every SPARC server at no charge, allowing data center administrators to monitor and manage servers, storage, networks, Oracle Solaris, and virtualized environments from a single console. The interface even permits control over logical domain and zone provisioning as well as resource allocation for virtualized environments.

Oracle Enterprise Manager Ops Center is a key component in the Oracle Enterprise Manager product family. The product line provides the industry's only complete, integrated, and business-driven enterprise cloud management solution. It enables the transformation of enterprise IT into a dynamic, self-service enterprise cloud by providing a complete cloud lifecycle management solution. It also provides a unified, deep, and comprehensive view of the entire IT infrastructure through its integrated applications-to-disk management capabilities. Finally, it is the only product family that truly provides the capabilities needed to manage IT from a business perspective, thanks to deep application awareness and insights into user experience, business transactions, and business services.

Oracle Enterprise Manager's cross-stack capabilities include complete application performance management, lifecycle management, quality management, and integrated systems management and support. Oracle provides advanced, out-of-the-box application management solutions for applications such as Oracle E-Business Suite and Oracle's PeopleSoft, JD Edwards EnterpriseOne, and Siebel CRM product families. The Oracle Cloud Management Pack for Oracle Fusion Middleware offers all the capability necessary for deploying and managing middleware-centric platform as a service (PaaS) clouds within the enterprise.

Of note, Oracle Cloud Management Pack for Oracle Database is the industry's first complete database as a service (DBaaS) cloud management solution—it includes self-service provisioning balanced against centralized, policy-based resource management, integrated chargeback and capacity planning, and complete visibility of physical and virtual environments from applications to disk. Oracle also offers Oracle Optimized Solution for Oracle Database as a Service, which is a blueprint that constructs an advanced DBaaS platform for database self-service provisioning.

Database Management Options

Oracle provides the following options that enhance the management of Oracle Database environments:

- **Oracle Enterprise Manager Database Express.** Oracle Enterprise Manager Database Express is a web-based database management tool embedded in Oracle Database 12*c*. It supports basic database administration tasks and a set of performance management functions. While it provides a limited range of administrative functions, it can be used against non-CDBs, CDBs, PDBs, or Oracle RAC database instances, and is especially useful in small deployments. See *Introducing Oracle Enterprise Manager Database Express*.
- **Oracle Enterprise Manager Cloud Control.** Oracle Enterprise Manager Cloud Control is a complete cloud lifecycle management solution allowing administrators to quickly set up, manage, and support enterprise clouds and traditional Oracle IT environments from applications to disk. It supports Oracle Database 12*c* targets, including multitenant container databases (CDBs), pluggable databases (PDBs), non-CDBs, Oracle Real Application Clusters (Oracle RAC) databases, and Oracle Automatic Storage Management (Oracle ASM). This product is also a key element in Oracle Optimized Solution for Secure Oracle Database as a Service.

For additional information, see the website for Oracle Database management.

References

TABLE 4. REFERENCES FOR MORE INFORMATION

Websites

Oracle Optimized Solution for Secure Oracle Database	oracle.com/us/solutions/oos/database/
Oracle's SPARC M7 processor–based servers	oracle.com/servers/sparc/
Oracle Solaris	oracle.com/solaris
Oracle ZFS Storage Appliance	oracle.com/storage/nas/index.html
Oracle FS1-2 flash storage system	oracle.com/storage/flash/fs1/
Oracle Database 12*c* Enterprise Edition	oracle.com/us/products/database/enterprise-edition/
Oracle Enterprise Manager Ops Center	oracle.com/technetwork/oem/ops-center
Oracle Technology Network	oracle.com/technetwork/
Oracle Consulting	oracle.com/us/products/consulting/
Oracle Migration Factory	oracle.com/us/products/consulting/migration-factory/overview/index.html
Oracle Benchmark Results	oracle.com/benchmarks
Oracle Help Center for product documentation	docs.oracle.com
Security	oracle.com/technetwork/topics/security
Virtualization	oracle.com/technetwork/topics/virtualization

White papers

"Oracle's SPARC M7 Processor–Based Server Architecture"	Available on oracle.com/sparc
"Oracle's SPARC T7 and SPARC M7 Server Reliability, Availability, and Serviceability"	Available on oracle.com/sparc
"Oracle Database In-Memory"	oracle.com/technetwork/database/in-memory/overview/twp-oracle-database-in-memory-2245633.html
"When to Use Oracle Database In-Memory: Identifying Use Cases for Application Acceleration"	oracle.com/technetwork/database/in-memory/overview/twp-dbim-usage-2441076.html?ssSourceSiteId=ocomen
"Oracle Database 12*c* Security and Compliance"	oracle.com/technetwork/database/security/security-compliance-wp-12c-1896112.pdf
"Architectural Overview of the Oracle ZFS Storage Appliance"	oracle.com/technetwork/server-storage/sun-unified-storage/documentation/o14-001-architecture-overview-zfsa-2099942.pdf
"Optimizing Storage for Oracle Database 11*g* Release 2 with the Oracle ZFS Storage Appliance"	oracle.com/technetwork/server-storage/sun-unified-storage/documentation/oracle11gr2-zfssa-bestprac-2255303.pdf
"Oracle Partitioning Policy"	oracle.com/us/corporate/pricing/partitioning-070609.pdf
"Hard Partitioning With Oracle VM Server for SPARC"	oracle.com/technetwork/server-storage/vm/ovm-sparc-hard-partitioning-1403135.pdf

Oracle Corporation, World Headquarters
500 Oracle Parkway
Redwood Shores, CA 94065, USA

Worldwide Inquiries
Phone: +1.650.506.7000
Fax: +1.650.506.7200

CONNECT WITH US

blogs.oracle.com/oracle

facebook.com/oracle

twitter.com/oracle

oracle.com

Integrated Cloud Applications & Platform Services

Deploy a Fast and Secure Database Architecture: Oracle Optimized Solution for Secure Oracle Database
March 2016