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Oracle Optimized Data Center Reference Architecture

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Executive Overview

IT departments are under constant pressure to increase their ability to respond rapidly to business requirements while reducing cost and risk. In the IT department there is a constant need to select the “best technology” to meet these demands. The constant churn of new and better technologies eventually becomes an inhibitor to these key demands because IT is left with a plethora of technologies, from cutting edge to legacy. This results in complexity and integration challenges. These effects add up to drive agility, cost, and risk in the wrong directions. While it is clear that cloud computing offers many potential benefits, many people just don’t know where to start or simply consider that this latest technology is just not ready for prime time.

Oracle’s optimized data center is a pragmatic solution to these problems. By providing a fully integrated stack, “from Applications to Disk”, the data center is greatly simplified while integration is already built-in. This paves the way for reduced cost and risk. State-of-art applications and software provide the ultimate flexibility to IT, leading to true business agility. The core architectural strategies of cloud computing are fully exploited in the early stages, resulting in a “private cloud” and avoids concerns like “loss of control”.

The key drivers for the optimized datacenter can be summarized as follows:

- Cost management: Virtualization/consolidation, simplification
- Business growth: Removing barriers to infrastructure performance and flexibility
- Service continuity: Maximum availability architecture, disaster recovery planning
- Security and conformity: Comprehensive, end-to-end security and compliance approach

This paper will show in architectural terms how reduced risk, reduced cost, and increased agility can be achieved through consistent integration and reduced complexity. These in turn follow from the single stack, optimized solutions, and engineered systems.

This paper is it expected to provide information to both IT and business architects and managers throughout the enterprise.

Introduction

The purpose of architecture is to effectively communicate a solution to a variety of different stakeholders. Reference architectures accelerate the implementation of a solution by avoiding the lengthy process of creating an architecture from scratch for each project (or worse still, embarking on a project without an architecture). A reference architecture builds on the experiences of others and identifies best practices.

The primary objectives of the Oracle optimized data center are:

1. Lower operational costs
2. Reduced risk
3. Best performance and flexibility

These objectives (or high-level requirements) represent systemic qualities and the reference architecture must show how these qualities will be realized by the optimized data center.

The Oracle optimized data center combines the best-in-class products, solutions, and technologies, engineered together to create the most effective data center implementations.

- It is modular and standards-based to support a wide range of enterprise deployments
- It lowers complexity and improves integration
- It considers the full stack for integration efficiencies at every level
- It facilitates a longer-term cloud computing strategy

The purpose of this paper (and the Oracle optimized data center strategy) is to raise awareness of the benefits of a homogeneous environment and the efficiencies of a single vendor stack, moving emphasis from a traditional siloed data center towards a fully integrated environment. In this approach, the optimized data center reference architecture paves the way for a deeper cloud computing strategy by taking full advantage of features of Infrastructure-as-a-Service (IaaS) and Platform-as-a-Service (PaaS) architectures.

Cloud Computing is still new and largely misunderstood, however, the Oracle optimized data center is an incremental approach towards cloud rather than a big-bang transformation. This incremental approach reduces risk of IT change a carefully planned roadmap for data center optimization can ultimately deliver all the benefits of full scale transformation. While the optimized data center certainly incorporates some of the five NIST criteria for cloud computing, it does not enforce all its principles to the level that one would for a pure Cloud solution. For example, the optimized data center provides resource pooling and some degree of elasticity. It also includes some level of self-service and automation to the degree necessary to take advantage of these as optimizations, making the data center more responsive to the demands of rapid change. At the same time it avoids the risk of giving up control altogether or too quickly. Readiness for cloud computing becomes a question of maturity of the enterprise (and the tools) in many dimensions beyond architecture and infrastructure. In the meantime, the Oracle optimized data center provides a risk-free introduction to cloud computing without compromising longer-term strategies.

Ultimately, the Oracle optimized data center is a combination of a number of existing Oracle strategies and solutions, including

- Optimized Server
- Optimized Storage
- Engineered Systems
- Data center fabric
- Optimized Solutions

Together with optimizations for applications, middleware, and database, these make up the foundation for the Oracle optimized data center and provide the very best in performance, reliability, security, manageability, lower risk, and lower cost.

Scope

Much of what is written about data center optimization focuses on low-level details of the facility, such as power consumption and, cooling. In reality the scope of optimization should be much broader. This focus on facilities may be due to the narrow scope of control available to

data center managers or simply a lack of visibility across the broader stack. This is unfortunate because there is an opportunity to reduce costs and risk while increasing agility. This is done by taking a holistic view of all the concerns of the data center and ensuring end-to-end manageability through better integration of its components.

The diagram in Figure 1 indicates the broad scope of the Oracle optimized data center (dotted line) and its emphasis (darker color) towards the “infrastructure” i.e. storage, servers, system software (i.e. virtual machines and operating systems), and networks. The line is shown overlapping facilities at the bottom of the picture and business strategy at the top because it is necessary for an optimized data center to integrate into these layers.

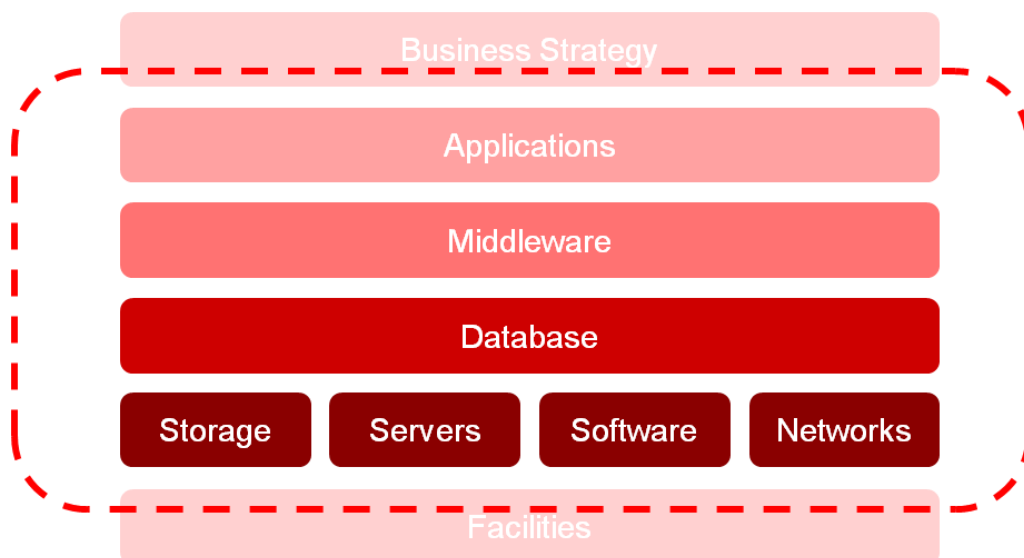


Figure 1 – Oracle optimized data center Scope

The lower layer, containing storage, servers, (system) software, and networks, is commonly called “infrastructure” in many architecture diagrams. Due to its importance here (and ambiguity of the term “infrastructure” in the data center context) this document instead names the main categories of components found in this layer.

Architectural approach

This white paper is organized along the lines of well established architectural strategies by starting with a high-level conceptual view that describes the architectural needs of the system in non-technical terms, and then establishes the capabilities and architectural principles necessary to meet those needs. The conceptual view section is followed by the logical view which introduces the technical components needed to provide the required capabilities. Every

effort is made throughout this paper to ensure alignment with the [IT Strategies from Oracle](#) (ITSO) approach described in the Oracle Reference Architecture (ORA) in order to maintain architectural integrity and consistency with other technology strategies. Oracle products are not described in this approach until the section covering the physical view, which includes a product mapping.

Reference Architecture Conceptual View

The conceptual architecture is important for describing the needs of the consumers of a system and identifying architectural requirements necessary to meet those needs. A complete reference architecture identifies architectural concepts, capabilities, principles and guidelines, and presents them through various architectural views, technical drill-downs, and product mappings. The architecture at this level must be presented in non-technical language that can be understood by the full range of stakeholders across the business and IT.

The fundamental drivers of an optimized data center have already been established in this document as:

- lower operational costs
- reduced risk
- best performance and flexibility

These drivers invariably have meaning beyond the scope of architecture. For example, cost may be influenced by geographic location, or risk may be influenced by organizational policies. For the sake of constructing a reference architecture these requirements should be considered in the context of “systemic qualities”. These systemic qualities can be used to identify the architectural capabilities and principles that must be applied throughout the development of the data center architecture and ultimate construction of its systems.

The following brief sections show how high-level architectural capabilities and principles, necessary to support these systemic qualities, are identified.

Reduced Cost

Within any data center, integration of heterogeneous components incurs substantial overhead and increases complexity. Conversely, vertically integrated solutions use components that are designed to work together, which simplifies IT overall, and lowers the cost of operations.

Capabilities required to support this systemic quality are:

- **vertical integration:** integration of known, standardized, modular components
- **pre-configured systems:** cost optimization achieved through specialization and standardization
- **consolidation:** built-in virtualization to substantially improve computing resource utilization

- **efficient utilization:** improved utilization of storage, servers, and networks are an important consideration in reducing cost

Reduced Risk

Reduced risk results from integrated security that eliminates gaps and provides defense in depth, highest levels of reliability and availability, and pre-tested solutions that lead to predictable deployments.

Capabilities required for reduced risk are expressed as follows:

- **comprehensive security:** a consistent security strategy is fully integrated at every layer of the architecture.
- **integrated monitoring with unified measurement:** a unified monitoring solution increases visibility and enables effective management of the data center.
- **highest reliability and availability:** the highest levels of reliability and availability can be achieved by eliminating single points of failure and establishing redundancy where appropriate.
- **pre-configured systems:** known configurations of components (including system software and applications), tested by a single vendor, eliminate uncertainties in configuration management, making systems (and the data center overall) more predictable.

Performance and Flexibility

Systems and software engineered for maximum flexibility and dynamic service levels are required for agility. These characteristics mandate the following architectural capabilities:

- **automation:** well managed automation enables the rapid configuration of systems and service levels.
- **shared services:** by making the IT infrastructure dynamically re-configurable data center resources can be shared in a way that not only leads to optimized utilization, but also supports rapid reuse.
- **pre-configured systems:** systems with known performance and operational characteristics support rapid implementations.
- **flexible components:** a system that can seamlessly move from IOPS intensive workloads to supporting large numbers of VMs to data streaming provides an intrinsic flexibility.
- **adherence to Open Standards:** conformity to Open Standards supports both flexibility and longevity.

There are a number of capabilities and themes that pervade all the required systemic qualities, “pre-configured systems”, for example, is repeated across all categories, providing different benefits in each case. **Reduced complexity** is critical to data center optimization and to all categories of systemic qualities; however, as such a high level expression it should be seen as an

overarching goal, supported by capabilities and principles, rather than a capability itself. One important principle supporting reduced complexity is isolation of architectural layers. **Isolation** ensures elements of the solution within any given layer can communicate only to adjacent layers and only through known, standardized interfaces. Applying this discipline as a fundamental data center principle ensures that all aspects of IT conform to it and unnecessary complexity is systematically eliminated.

Shared services is a capability from the architecture of cloud computing. Adoption of cloud computing capabilities does not imply full adoption of a cloud model however, but it is important to understand that a subset of Cloud strategies can be applied to support the systemic qualities of the optimized data center. In particular, *private cloud* provides many of the benefits of data center optimization while avoiding many of the concerns about cloud in general.

Other cloud computing capabilities that strongly support the required systemic qualities of an optimized data center include:

- **Resource pooling:** In a multi-tenant cloud environment both physical and virtual resources are dynamically assigned and reassigned according to consumer demand.
- **Rapid elasticity:** IT capabilities can be rapidly provisioned with great flexibility, in some cases automatically, to quickly scale out and rapidly released as demand reduces.
- **Measured Service:** Cloud systems automatically control and optimize resource use by leveraging a metering capability at a level of abstraction appropriate to the type of service.
- **Broad network access:** Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

Despite their categorization under cloud computing, it is reasonable to assume that such capabilities will be rolled out in a controlled and systematic fashion, thus avoiding the need for full adoption and maturity of Cloud in the early stages. Taking such a pragmatic approach ensures that some early benefits are realized without full implementation of Cloud strategies: for example, resource pooling, as an alternative to provisioning each consumer for peak load, can significantly improve flexibility while reducing cost before implementing a fully automated mechanism for assignment of resources. On the other hand, multi-tenancy (as defined by NIST) is a highly formalized approach to hosting disparate consumer communities, but is not immediately required to support our desired systemic qualities.

Other cloud computing capabilities that may optionally be included are:

- On-demand self-service
- Dev-Ops shift
- Scale and Velocity

Dependencies between these adopted capabilities may exist, however, a gradual implementation on a carefully planned roadmap will inevitably yield low hanging fruit in the early stages while establishing important first steps towards a broader cloud approach.

Full descriptions of the cloud computing capabilities can be found in the [IT Strategies from Oracle](#) (ITSO) Cloud ETS (Enterprise Technology Strategy) Foundation Architecture document.

A simple conceptual view is a starting point for an architectural description that represents the high-level capabilities before introducing technical considerations required to support those capabilities. The ORA model, shown in Figure 2, forms the basis of all conceptual architecture descriptions.

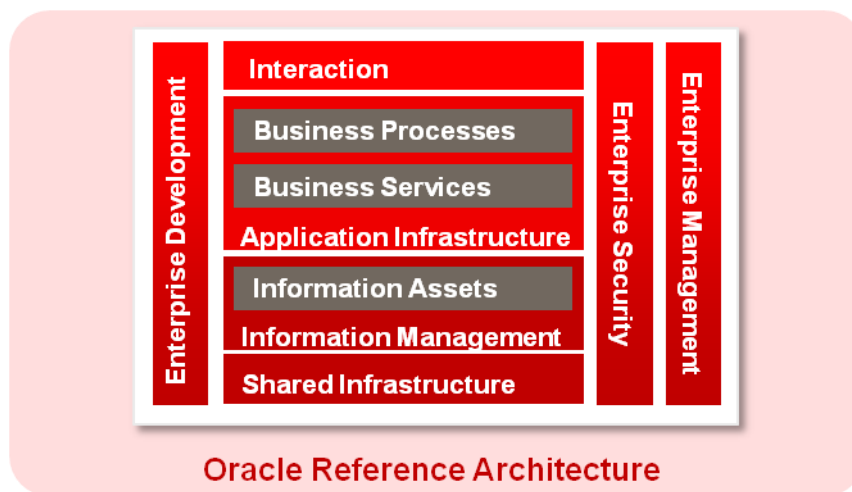


Figure 2 – The ORA Conceptual View

The ORA model represents the basic layers, or building blocks of any system. This view introduces encapsulation and isolation of layers that supports and enforces modularity.

Monitoring and security must be pervasive, fully integrated, and uniform across all these layers, so they are shown vertically. The ORA model can be redrawn to highlight particular aspects of the architecture. Figure 3 shows how the ORA model is used to separately highlight monitoring and security as fully integrated and pervasive layers.

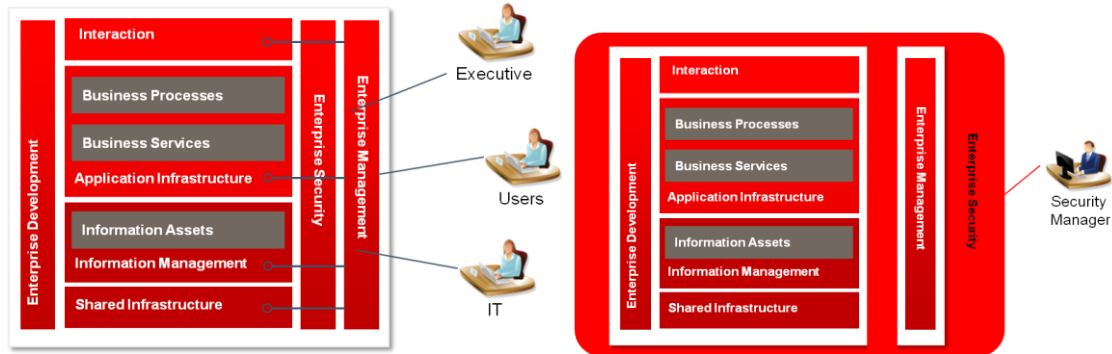


Figure 3 – Pervasive management and security

The diagrams in Figure 3 are used to emphasize (1) the broad stakeholder support found in fully integrated management dashboards providing tailored views for a full range of stakeholder needs and (2) the pervasive nature of the single, unified security solution across the full technology space.

Architectural Principles

In essence architecture principles translate business needs into statements of IT mandates that the solution must meet. Like architectural capabilities, architectural principles span the entire solution and they are at a much higher-level than functional requirements. Establishing architecture principles drives the overall technical solution. Some key architecture principles for the optimized data center solution are provided below.

FULLY INTEGRATED	
STATEMENT	All elements of the data center must be integrated across the full stack from storage through business applications.
RATIONALE	A solution that provides full integration to all aspects of the data center significantly reduces complexity and improves performance.
IMPLICATIONS	<ul style="list-style-type: none"> Standalone point solutions must not be permitted to add complexity to the data center. Standardization is required to ensure effective integration.

RAPID PROVISIONING	
STATEMENT	The data center must be able to provision platforms quickly, efficiently, and with consistency.
RATIONALE	IT flexibility (and ultimately business agility) should not be impaired by delays in provisioning of data center services.
IMPLICATIONS	<ul style="list-style-type: none"> Automation of data center operations is required. Virtualization is a valuable tool in supporting rapid provisioning. The system must support growth in all dimensions of its applications (e.g. new apps/modules, expansion of apps capabilities, etc.). The system must be sufficiently flexible to support rapid modification and repurposing of servers,

	storage, and networking to support dynamic workloads.
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CONFORMITY TO STANDARDS	
STATEMENT	Interfaces and formats must conform to relevant industry standards.
RATIONALE	Enforcement of standards minimizes integration efforts, increases flexibility, and reduces complexity in the data center.
IMPLICATIONS	<ul style="list-style-type: none"> Non-compliant exceptions should only be permitted if there is a strong business or technical case (such as when standards are lagging technological developments and impeding progress). Exceptions should be accompanied by a roadmap for future standards

MODULARITY	
STATEMENT	Data center components must be modular and self-contained.
RATIONALE	Modular, self-contained components ensure that complex dependencies are eliminated from the data center.
IMPLICATIONS	<ul style="list-style-type: none"> Components must provide a unique function without creating unnecessary dependencies on other components.

These are examples of architectural principles that a company might embrace. Ultimately it is up to each company to define the appropriate architectural principles to ensure that the data center solution meets the needs of the business while furthering the strategic direction of IT.

Many other principles can and should be identified for a complete architecture of an optimized data center: for example, a category for Reliability, Availability, Security, and Performance (RASP) alone should cover systems scalability, rapid provisioning, reliability, serviceability, comprehensive security, highest performance, and so on. Additional categories exist for management, integration, and reuse. These principles should be reviewed and selected according to the specific demands of any given data center, and periodically reviewed to make sure they conform to changing business and technical drivers.

Reference Architecture Logical View

The logical view expands the conceptual view of the system with technical details and introduces the idea of components. While the layers carried over from the conceptual view provide isolation, the components introduced by the logical view further develop and enforce the idea of modularity as an architectural capability.



Figure 4 – Oracle optimized data center Logical View

In the logical view the broad conceptual category of “shared infrastructure” is expanded in accordance with the emphasis of this reference architecture for optimized data center.

As the architectural description moves from the language of the conceptual model the logical model introduces more technical terms, but avoids specific product references. The conceptual shared infrastructure, having greatest significance in the optimized data center, is expanded here to show the main components organized into their own key layers: network, storage, services, and system software. Information management is provided by the database layer in the logical view while the application infrastructure becomes the middleware layer. The interaction layer is manifested through the applications layer as this is the interface to the end user.

While the logical model shows more specific technical detail, the key capabilities and architectural principles are further reinforced by its layering and modularity.

Integrated Machines

The term “integrated machine” refers to a hardware and software platform optimized to perform a particular class of work. In common with “appliances”, integrated machines are a preconfigured assembly of components, but they differ from “appliances” which lack configuration options and are designed for a single specific task. Integrated machines comprise purpose-built hardware and software sold and supported as a single system (pre-defined, pre-engineered, pre-assembled, focused configurations). This allows the hardware and software to be configured and even modified to provide the highest levels of inter-component compatibility and overall integration; thereby providing improved reliability, availability, security, and performance.

Compared to one-off platform designs, integrated machines offer substantially reduced time to deploy since they are pre-tested, provide known performance characteristics, and are pre-assembled. Also, since details such as operating system, hardware, network, storage, firmware, and patch levels are already known by technical support, problem diagnosis and resolution can be performed in a fraction of the time compared to general purpose systems that may have any

number of combinations of components and versions. Furthermore the support organizations' effectiveness is immediately improved when they can reproduce issues using identical configurations of hardware and software.

In the context of the logical view, integrated machines may encompass all layers of the stack, alternatively, they may provide specializations for subsets or even individual layers of the stack.

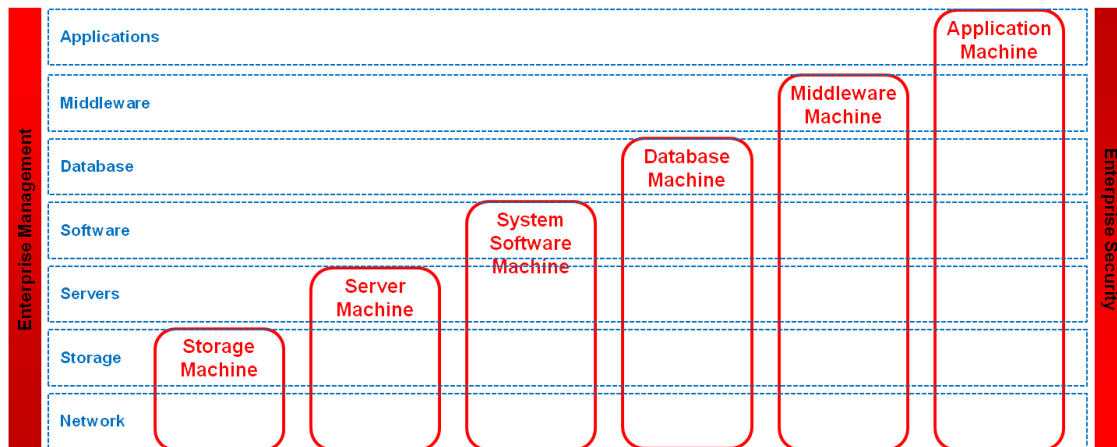


Figure 5 – Integrated machines Logical View

As the diagram in Figure 5 shows integrated machines may span any number of the layers of the logical model to create machines that provide specific capabilities or services in a pre-configured form. While still maintaining the disciplines of the optimized data center architectural principles internally, these aggregated solutions reinforce the principles of modularity and isolation and thereby significantly reduce complexity.

Patterns and best practices

The use of patterns and pre-tested, proven configurations is a requirement of any optimized data center solution in accordance with the architecture principles mentioned earlier for "full integration" and "modularity". To achieve this, IT departments can use existing best practices honed from years of optimizing their own existing data centers and/or employ industry and vendor best practices and solutions. In addition to providing fully integrated "engineered systems", Oracle also offers templates and fully tested configurations that can be leveraged such that IT staff can implement best of breed solutions.

Oracle Optimized Solutions provide templates for fully integrated and tested product configurations and, like integrated machines, provide pre-configured solutions that are tuned for optimal performance and availability for common IT requirements. These solutions incorporate engineering enhancements across the stack from low-level firmware to business systems applications at the top of the stack. In addition, the complexity and effort of creating, validating, tuning, and configuration management of these solutions has been absorbed as part of the

product. The benefits to the optimized data center resulting from these pre-tested solutions include:

- Lower costs – these pre-tested solutions are benchmarked for accurate capacity analysis so results are achieved rapidly without under or overbuying equipment and licenses. A single, integrated suite of management tools saves time and costs associated with ongoing systems management. Reduced complexity and increased modularity also reduce the cost of operations and maintenance.
- Reduce risk – the fully tested solutions, designed with high availability from the ground up, ensure business continuity and eliminate risk of incompatibilities between system components.
- Performance and flexibility – solutions are tuned and configured to eliminate bottlenecks and maximize performance while the fully documented, end-to-end solutions ensure rapid implementation.

Combined with Oracle Solaris, Oracle Database, Oracle Fusion Middleware and Oracle applications, Oracle Optimized Solutions ensure the running of business-critical enterprise applications with enhanced performance, availability, scalability, security, and ease of management. Oracle provides a wide range of Optimized Solutions spanning critical areas of Information Technology:

- Applications (PeopleSoft, JD Edwards, ...)
- Middleware (Weblogic, Oracle Unified Directory, ...)
- Data Management (Database)
- Core Infrastructure (Enterprise Cloud Infrastructure, Backup & Recovery)

This grouping of Optimized Solutions, shown in the diagram in Figure 6, corresponds to the layering introduced earlier in this document. It also shows Optimized Solutions in context with other Optimized Systems which described in more detail in the product mapping section.

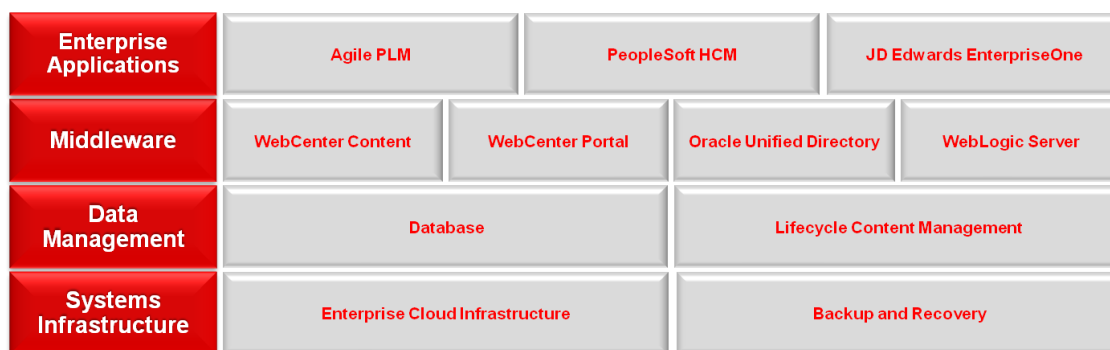


Figure 6 – Oracle Optimized Systems and Optimized Solutions

As an example, the Oracle Agile Product Lifecycle Management (PLM) has been consolidated into the smallest possible footprint providing an extremely cost-effective solution while supporting up

to 800 users. The Oracle Optimized Solution for Agile Product Lifecycle Management provides a well-tested, highly validated configuration designed to balance optimal performance with low total cost of ownership (TCO) and high reliability. The solution supports all the systemic qualities and architectural capabilities of the Oracle Optimized Datacenter along with corresponding business benefits:

- Reduced deployment time and risk due to the pre-tested environment and simplified deployment of a single Oracle Sun Fire X4800 M2 server and the Sun ZFS Storage Appliance.
- Improved user productivity resulting from higher service levels due to the enterprise-class reliability of the server and the Oracle Solaris operating system.
- Significant cost savings from faster deployment and lower operating costs.

Numerous other such optimized solutions can be seen in the diagram in Figure 6, all of which provide a similar set of systemic qualities and architectural capabilities.

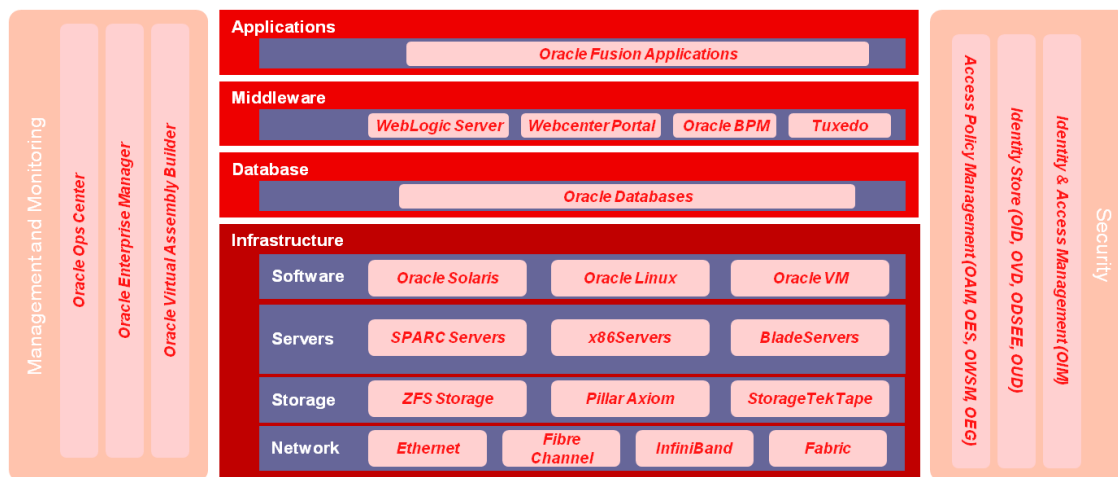
Oracle Product Mapping View

This section describes how the logical architecture can be implemented using Oracle products and describes some of the more coarse-grained products supporting the required capabilities and systemic qualities of the optimized datacenter.

The relationship between architecture components and products is not intended to reflect a one-to-one mapping since products have multiple features. Products are mapped to logical component(s) according to their capabilities. Likewise, components may map to multiple products that support different deployments or unique sets of capabilities. Also, the list of products presented in this section is not intended to be a comprehensive list of all products available from Oracle that could be applied to the optimized data center. Rather, they represent a best match to the scope of the architecture that is addressed by the conceptual and logical views. Likewise, not all products listed are required for any particular data center solution. The actual products required depend on the individual company's functional and non-functional requirements as well as their existing data center assets.

For more detailed information on Oracle products, or further information about product features, please consult the Oracle optimized data center website or an Oracle product specialist (references can be found in the appendix at the end of this document).

Figure 7 maps Oracle products onto components of the logical architecture to illustrate how the capabilities required for optimized data center can be realized using Oracle products.



• Figure 7 – Oracle optimized data center Management Product Mapping

Oracle provides complete solutions across all layers of the data center architecture with servers, storage, networking, systems software, and applications that are engineered to work together with greatest performance and efficiency. The result of these “optimized systems” includes simplified deployments and a reduced complexity compared with standalone products and services.

Optimized Servers

Oracle's servers are engineered to provide maximum performance, simplified management, high availability, cost-saving efficiencies, and end-to-end integration. These systems include built-in virtualization, cloud management and systems management, and are optimized to run Oracle Solaris, Oracle Linux, Oracle Virtual Machine, and Oracle Enterprise Manager Ops Center. In addition, Oracle servers support industry leading software for Oracle and non-Oracle applications and solutions.

Oracle's SPARC servers running Oracle Solaris are ideal for mission-critical applications requiring high performance, best-in-class availability, and unmatched scalability across all platform tiers. Oracle's Sun x86 systems are ideal for running Oracle software where x86 architectures are required and can be used with both Oracle Solaris and Oracle Linux. Both SPARC and x86 servers provide an optimized hardware and software stack that offers a choice of operating system software, virtualization software, and cloud management tools.

The Oracle SPARC-based product lines are made up of the SPARC T-Series, the SPARC Enterprise M-Series, and SPARC SuperCluster T4-4. Oracle's SPARC servers ensure datacenter efficiency with enterprise-tested technologies and support a range of demanding workloads (spanning all aspects of transaction processing and decision support) for the next generation of enterprise applications.

Oracle's latest generation of SPARC servers support business-critical demands with increased efficiency, a faster return on investment (ROI), and the ability to match the processor to the workload. Oracle's SPARC T-Series servers provide scalable, secure, and integrated platforms for deploying enterprise applications while SPARC Enterprise M-Series servers deliver "always-on" availability for mission-critical applications. The two SPARC server classes have complete binary compatibility, so system and application software can be deployed on the server that meets the systemic properties required by the application, without having to worry about compatibility issues or need to rebuild software.

Oracle's SPARC servers have been designed to support virtualization, workload consolidation, and comprehensive, highly granular management. They improve efficiency in data center concerns including scalability, virtualization, high availability, power, cooling, and IT staff time spent on deployment and maintenance. These efficiencies are inherent within the processor, operating system, and management software. Oracle SPARC servers combine these technologies to improve resource utilization, increase processing densities, and include reliability features that ensure business continuity.

SPARC T-Series servers provide a wide portfolio of hardware and software features that can be leveraged to dramatically improve efficiency and agility. SPARC T-Series processors use an innovative "system on a chip" architecture in which many formerly separate functions are now part of the processor itself. Along with the processor cores and cache typical for server products, SPARC T4 processors also have built-in virtualization, cryptographic security coprocessors, and I/O and networking capabilities. This reduces cost and improves reliability by reducing part counts. SPARC T-Series servers were traditionally deployed in dense arrays commonly found in telecommunications, financial services, and web service providers because of their ability to support highly parallelized workloads. With the fourth-generation SPARC T4 processor, SPARC T-Series servers have been optimized to support a much wider range of workloads, including application, batch processing, and database workloads requiring high single CPU thread performance. The resulting SPARC T-Series systems now support a diverse mix of workloads.

The SPARC Enterprise M-Series consists of scalable servers based on SPARC64 processors. These processors have been optimized for single-thread performance, massive scale, and reliability, which is why SPARC Enterprise M-Series systems are most often deployed to run highly demanding mission critical enterprise workloads. Today, the SPARC Enterprise M-Series servers are known for their support of very large databases and line-of-business (LOB) workloads, such as OLTP, ERP, CRM, and other forms of database-centric applications.

SPARC Enterprise M-Series servers are also used to support highly scalable databases and data warehouses, along with business intelligence workloads. SPARC Enterprise M-Series systems are highly scalable, but these servers can be grown as needed providing flexibility that limits energy consumption that would otherwise be incurred by running processors that are not in active use. Processors and memory on the SPARC Enterprise M8000 and SPARC Enterprise M9000 servers are hot swappable and can be added and removed while the system is in use. Newer SPARC64 processors can coexist with older SPARC64 processors, so processors and memory can be added easily and without downtime.

For deployment of mission-critical applications and services, an additional layer of security and high availability can be provided through the use of Oracle Solaris Cluster. Oracle Enterprise Manager Ops Center manages all these technologies, including creating, provisioning, and monitoring SPARC systems. The combination of SPARC, Oracle VM Server for SPARC, Oracle Solaris, and Oracle Enterprise Manager Ops Center provides a complete virtualization solution with end-to-end security and resource isolation solution on SPARC servers.

Oracle's Sun x86 systems, with Intel Xeon processors, provide the lowest Total Cost of Ownership (TCO) for virtualized x86 Systems with maximum performance, and simplified management and support. Oracle x86 servers provide vertically integrated enterprise solutions with built-in systems management and virtualization software with application and system software optimization.

Oracle's Sun Blade 6000 modular system uses an innovative, efficient chassis design that combines storage, networking, operating system, and virtualization software with comprehensive system management and unified support, all designed, engineered, and tested to work as a single system. The resulting servers deliver extraordinary levels of integration, extreme performance, outstanding flexibility, and the lowest TCO of any virtualized blade solution.

Optimized Storage

Oracle's portfolio of optimized storage systems reduces costs and risk while increasing performance and flexibility by simplifying storage deployments and integrating Oracle software enabling it to run faster and more efficiently. Like other optimized systems the key to optimized storage is how well it can be automated and integrated with the applications it supports.

Oracle optimized storage systems use innovative storage architectures to provide the capabilities required for optimized data centers and make it possible for customers running Oracle databases, middleware, or applications to purchase less storage and achieve a lower total cost of ownership (TCO). This is achieved through

- Unique points of integration between the storage and software that allow the storage systems to run faster and more efficiently
- Innovative data reduction, data services, and storage consolidation capabilities that maximize data center agility and further increase storage efficiency
- Leading-edge management and analytics tools that make Oracle optimized storage easy to deploy and manage
- Innovative architectures based on the latest technologies that enable linear scaling and industry-leading performance and capacity

In addition to achieving great efficiencies within individual storage technologies, data centers can further increase efficiency by moving from a single tier of disk storage to an Oracle tiered storage environment that automatically moves data among Flash storage, performance disk, capacity disk, and tape.

Oracle's Hybrid Columnar Compression technology is a new method of organizing data within a database. Originally designed for Oracle Exadata Storage Server, it is now supported on Oracle's Pillar Axiom and Sun ZFS Storage Appliances as well. Hybrid Columnar Compression dramatically improves the efficiency of Oracle Database deployments in NAS and SAN environments, making it easy for customers to integrate Oracle storage into their existing data center and immediately benefit from its increased storage efficiency.

Integration with Oracle Enterprise Manager enables administrators to monitor and manage these storage environments from a single console. For example, the Pillar Axiom plug-in for Oracle Enterprise Manager allows administrators to monitor one or more instances of Pillar Axiom systems and the applications that use their storage from within Oracle Enterprise Manager's Web-based console.

The Oracle Sun ZFS Storage Appliance features a Hybrid Storage Pool (HSP) architecture to automatically migrate data between DRAM, Flash, and disk. This innovative architecture continuously optimizes storage performance and efficiency while also simplifying management. In addition, its high-throughput design efficiently supports the massive number of virtual machines typically found in an optimized data center and provides performance optimization tools that report storage workloads for each VM that is using the appliance.

For SAN environments, Oracle offers unique Quality of Service (QoS) functionality with its Pillar Axiom solutions. These products implement automated, priority-based queuing. Users can set priorities for specific applications, and critical tasks gain priority access to the storage device. This approach is in stark contrast with traditional SAN storage solutions, which employ a "first in, first out" approach in which background tasks and business-critical applications are given the same priority. With Pillar Axiom QoS, you can confidently consolidate your SAN storage onto a single platform to simplify your data center and increase storage efficiency.

Oracle's StorageTek tape solutions employ industry-leading performance innovations at the library and drive levels. StorageTek T10000C is the world's highest capacity and fastest enterprise tape drive, offering up to 5TB in uncompressed capacity and 252MB/Sec in uncompressed raw data throughput. Additionally, the StorageTek SL8500 and StorageTek SL3000 libraries offer full electronics and robotics redundancy that enable continuous operations in the event of a failure and during service, expansion, or repair..

Both Pillar Axiom solutions and Sun ZFS Storage Appliances offer features that help reduce risk and protect data in storage environments, including snapshots, clones, and replication capabilities. In addition, Sun ZFS Storage Appliances offer end-to-end checksumming that constantly reads and checks data to ensure that it's correct, and predictive self-healing capabilities for automatically diagnosing, isolating, and recovering from faults. ZFS Storage Appliances also provide data compression and deduplication to reduce disk space consumption, and advanced analytics to understand and manage performance.

Optimized Networking

Oracle's Sun server networking products provide converged and virtualized network services that speed application performance while simplifying application infrastructures for enterprise data center deployments.

The networking products eliminate application performance bottlenecks by tightly integrating advanced network services across the application infrastructure, as demonstrated by the extreme performance capabilities of Oracle Engineered Systems, [Oracle Exalogic Elastic Cloud](#), [Oracle Exadata Database Machine](#), and SPARC SuperCluster. Some examples of reduced cost and increased performance include:

- Reduces network sprawl by 70% and cuts power and cooling costs in half
- Eliminates 60% of the network management tools required for application environments
- Produces 63% higher transaction per second with [Oracle Database 11g Real Application Clusters \(RAC\)](#)
- Delivers 10x performance improvement with Oracle Exalogic Elastic Cloud

Networking product lines span Ethernet, Fibre Channel, Infiniband, and now Oracle Fabric Interconnect for software defined networks, all of which can be combined for optimal support for data center solutions.

InfiniBand Network Solutions

Oracle's networking products offer performance, scalability, reliability, availability, and operational agility with Oracle's complete portfolio of Infiniband network fabric solutions. InfiniBand products reduce the cost and complexity of enterprise data center deployment, operations, and management with industry-leading density and cable aggregation. Infiniband provides the extreme scale, application isolation, and elasticity needed to consolidate and virtualize core enterprise business applications, as well as next-generation enterprise cloud computing infrastructures.

Oracle's InfiniBand network products are fundamental to Oracle's Exalogic Elastic Cloud, Exadata Database Machine, SPARC SuperCluster, and Big Data Appliance.

Ethernet

Oracle's Sun Ethernet line of networking solutions delivers Ethernet connectivity and switching between Oracle's Sun servers for maximum throughput and application performance. Providing high-performance interconnects between the servers, these cards and switches help eliminate network bottlenecks, simplify the IT infrastructure, and enable the creation of end-to-end integrated enterprise platforms.

- High-bandwidth, low-latency performance
- Highly available, scalable, and secure
- Reduced acquisition, operating, and management costs

- End-to-end integration and interoperability
- Optimized for multithreaded performance with Oracle Solaris and Oracle's Sun SPARC processors
- Designed for an eco-efficient data center

Fibre Channel

Oracle provides a complete range of networking products fully integrated with its servers and storage, for example, the Oracle StorageTek 8 Gb PCIe Fibre Channel (FC) Host Bus Adapters (HBAs). Oracle's HBAs, switches, directors, and routers enable streamlined installation and management, scalability, and virtualization.

Software Defined Networking and Oracle Fabric Interconnect

Oracle Software-Defined Networking (SDN) extends the concepts of virtualization to data center networking. Unlike traditional data center networking, which defines connectivity via physical components and complex router configurations, Oracle SDN defines connectivity entirely in software through, what is known as, a private virtual interconnect. A private virtual interconnect is a software-defined link between two resources: it enables network administrators to connect any virtual machine or server to any other resource, including virtual machines, virtual appliances, bare-metal servers, networks and storage, anywhere in the data center from a single console. This approach dramatically reduces the time to deploy and re-deploy systems in the data center, thereby increasing IT flexibility.

Oracle Fabric Interconnect provides the connectivity between servers, storage, and other data resources with a single cable and enables virtual network connectivity in software through a single, high performance network, eliminating the need for multiple cards, cables, routers, and other traditional networking gear. Using Oracle Fabric Interconnect multiple Network Interface Cards (NICs) and Host Bus Adapters (HBA) are virtualized and consolidated through a single physical adapter. Oracle Fabric Interconnect supports open standards ensuring interoperability across SPARC, x86 servers, blade and engineered systems while fully redundant, hot-swappable power, cooling, and I/O modules, along with a passive mid-plane ensuring reliability and serviceability.

Oracle Fabric Interconnect provides connectivity across the full range of Ethernet and Fibre Channel networks using Infiniband networking technology to provide high speed low latency converged connectivity between data center systems with data rates of up to 80 Gb/sec to each server in the fabric.

Oracle Fabric Manager provides a single interface to create and manage connectivity, monitor performance, and apply rapidly repeatable configurations to any number of servers. Resources, connectivity, and configuration settings within a server or across the data center can be managed from a single console. Bandwidth deficiencies can be identified in real time, so bottlenecks and other issues can be resolved non-disruptively in seconds. Oracle Fabric Manager and associated

monitoring capabilities provide the ability to simplify and manage large, complex configurations while role-based access ensures the data center network managed securely.

Oracle Solaris, Linux, and Virtual Machine Software

Oracle Solaris 11 is the #1 UNIX operating system and the first OS that allows customers to build large-scale, enterprise-class infrastructure clouds on a wide range of Oracle's SPARC and x86 servers, and Oracle engineered systems. It is designed for the enterprise, and has world class features for scale, performance, resiliency, security and manageability. Oracle Solaris has guaranteed binary compatibility from release to release, which means there is no need to rewrite applications for new operating system releases. Binary compatibility also makes it possible to move Solaris systems and software from one SPARC server to another, or from one x86 server to another, without requiring program changes or recompilation. Oracle Solaris 10 and Oracle Solaris 11 include virtualization in the form of Oracle Solaris Zones (formerly called Oracle Solaris Containers), which is an "OS virtualization" technology that provides multiple independent native performance virtual environments on a Solaris host. Oracle Solaris 10 enhances investment protection by supporting Oracle Solaris 8 and 9 environments re-hosted alongside Solaris 10 zones, using "physical to virtual (P2V)" tools. This simplifies consolidation of applications from older, less energy-efficient systems. Oracle Solaris 11 zones provide advanced network virtualization technology that permit systems staff to consolidate servers while providing separate virtual networks. Solaris 11 supports native Solaris 11 zones alongside Solaris 10 zones, further enhancing an institution's ability to consolidate servers with reduced effort while maintaining compatibility.

Oracle Linux provides the latest Linux innovations, delivering extreme performance, advanced scalability, and reliability for enterprise applications and systems along with worldwide, enterprise-class, low-cost support. Optimized for enterprise workloads, Oracle Linux offers the capability to provide zero-downtime updates. Oracle Linux is optimized for Oracle products, including Oracle Exadata Database Machine, Oracle Exalytics In-Memory Machine, Oracle Exalogic Elastic Cloud, and Oracle Database Appliance. Oracle Linux is certified for compliance with the Linux Standard Base (LSB Version 4.0), which greatly reduces the costs involved with porting third-party applications to different distributions, as well as lowering the cost and effort involved in after-market support of those applications.

Oracle Linux with the Unbreakable Enterprise Kernel includes many enhancements, including fixes to improve virtual memory performance, network and disk I/O performance as well as improvements for large NUMA (Non-Uniform Memory Access) systems. In addition to performance improvements for large systems, Oracle Linux contains many new features that are relevant to Linux running in the data center, such as, the latest Infiniband stack, network traffic control, and many more.

Oracle VM Server is a family of virtualization products for x86 and SPARC. Oracle VM Server for x86 is a free server virtualization and management solution that makes enterprise applications easier to deploy, manage, and support. Backed worldwide by affordable enterprise-quality support for both Oracle and non-Oracle environments, Oracle VM facilitates the deployment and

operation of enterprise applications in the data center. Oracle VM, on both x86 and SPARC, is the only fully certified platform for all Oracle software. Deployed and tested in real world enterprise datacenters, Oracle VM is proven to reduce operations and support costs while simultaneously increasing IT efficiency and agility.

Oracle VM Server for SPARC is a hypervisor-based virtualization technology available on SPARC T-Series servers and the SPARC SuperCluster T4-4. The Oracle VM Server for SPARC hypervisor is built into the T-series server, providing availability, efficiency and performance advantages not possible with software-based virtual machine systems. Oracle VM Server for SPARC supports secure live migration for moving virtual machines from server to server, making failover and availability easier to achieve and improving resource utilization. It also supports physical to virtual (P2V) tools for consolidating physical Solaris SPARC systems, and includes dynamic resource management and the ability to nondisruptively reconfigure guest virtual machines while they are running, so guests resources can be dynamically changed to meet application requirements. Oracle VM Server for SPARC can be configured for high availability using multiple service domains and multiple-path I/O to eliminate single points of failure. Oracle VM Server for SPARC supports advanced I/O via Single Root I/O Virtualization (SR-IOV), which eliminates the I/O overhead experienced by most virtual machine systems.

Oracle Solaris Zones technology facilitates combinations of applications for agility, consolidation, and improved server utilization, supporting highly granular management. Oracle Solaris Zones are available whether Solaris is running on x86 or SPARC, and whether in a physical or virtual machine. For example, systems running Oracle Solaris 11 can host applications and Oracle Solaris 10 system images inside Oracle Solaris Zones, on highly efficient SPARC T4-based servers for IT flexibility and reduced operational costs. Solaris Zones have powerful management capabilities and run with near-native performance. As a result, business benefits associated with this technical change include efficient server consolidation, quick application deployment, more efficient placement of applications within the datacenter, fewer IT staff hours spent managing older workloads, and improved uptime. Automation features permit cloning zones and managing resources assigned to them, so less effort is needed to manage applications and to run them efficiently with respect to compute resources, power/cooling and system administration. Due to binary compatibility at the processor instruction set level and at the operating system API between generations of SPARC operating systems and servers, redeployment of applications to newer, more efficient servers can also be done without having to rewrite the applications, which translates into savings on developer resources and potential downtime costs.

Dynamic Domains is a hardware partitioning technology available on the SPARC Enterprise M-Series servers providing failover support for memory, processor, and I/O resources. Dynamic Domains provide full resource, security, fault, and serviceability isolation with granularity down to an individual processor socket and can be resized while an application is running. They are ideal for hosting complex, mission-critical applications by providing a isolation of resources and effective workload consolidation. Dynamic domains run with native performance, and processor, memory, and I/O resources can be moved from one domain to another to meet changing

workload requirements while applications are running. Oracle Solaris Zones can be deployed inside Dynamic Domains to provide additional partition granularity.

Engineered Systems

Oracle's Engineered Systems is a product line of integrated machines (introduced in the logical architecture section of this document).

Oracle has embarked on a path to provide a variety of Engineered Systems and appliances to simplify the deployment of complex enterprise systems. Currently there are several examples of Engineered Systems that are available as products from Oracle: Oracle SPARC SuperCluster, Oracle Exalogic Elastic Cloud, Oracle Exadata Database Machine, Oracle Big Data Appliance, Oracle Database Appliance, Oracle Exalytics In-Memory Machine, and the Oracle Sun ZFS Storage Appliance. These are shown in the product mapping diagram in Figure 8 mapped to the layers of the logical architecture.

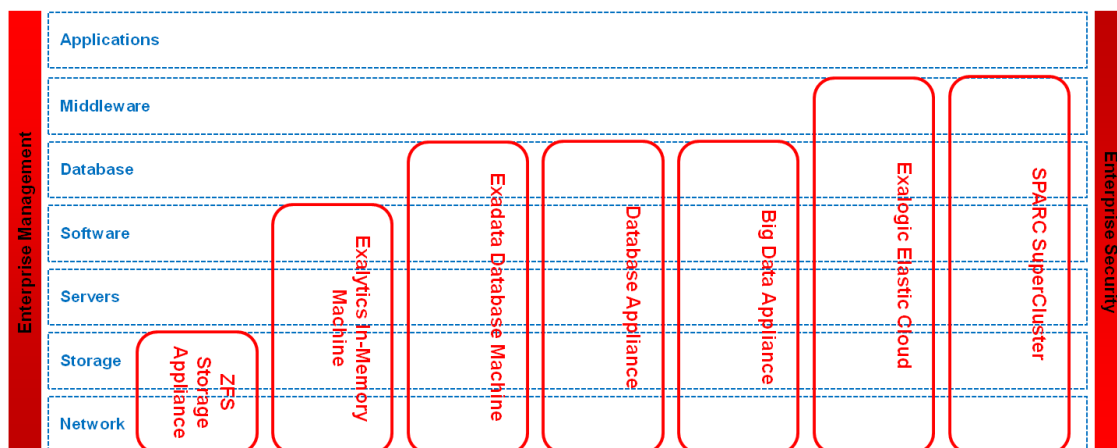


Figure 8 – Engineered Systems Product Mapping

Oracle Engineered Systems provide the highest performance, rapid deployment, reliability, and security, with the lowest total cost of ownership and include a full range of specialized services to simplify deployment, maintenance, and support.

The systemic quality and architectural capability referred to as “flexibility” is particularly apparent in the extreme scalability of the Oracle Engineered Systems. Oracle Engineered Systems are also “pre-configured” and “modular”, having many key components engineered together, optimizing their integration and performance, into larger components available for rapid assembly.

The Exadata Database Machine, shown in Figure 9, is described in more detail in the text that follows to highlight the systemic qualities provided by the Oracle Engineered Systems.

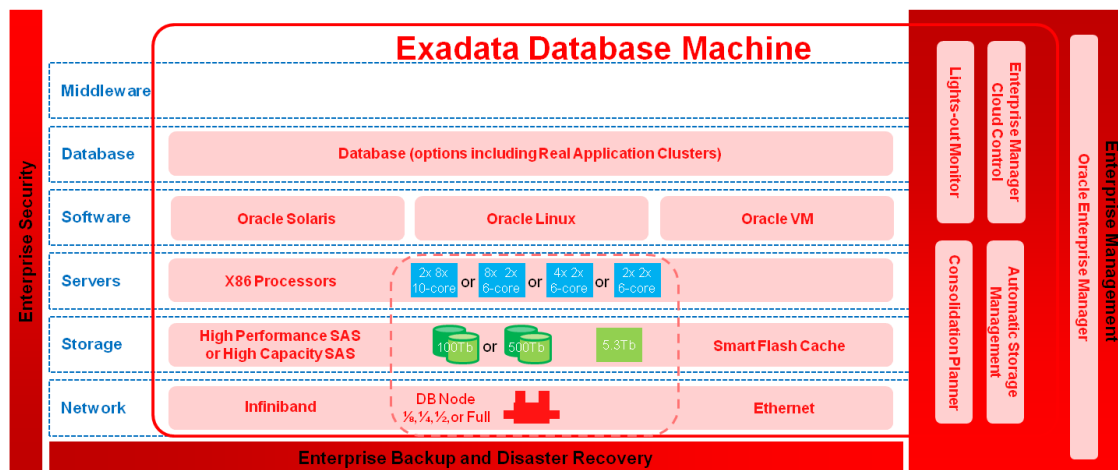


Figure 9 – Exadata Database Machine Product Mapping Detail

The Oracle Exadata database machine delivers performance and scalability for a wide range of applications including online transaction processing (OLTP), data warehousing (DW) and mixed workloads. It moves SQL processing to the Exadata storage server where all discs operate in parallel avoiding much of the overhead of moving data between storage and servers. Exadata Storage Servers provide a high-bandwidth, massively parallel solution delivering up to 75 GB per second of raw I/O bandwidth and up to 1,500,000 database I/O operations per second (IOPS). Much of these performance gains come from the incorporation of Exadata Smart Flash Cache in each Exadata Storage Server and the storage hierarchy within the Oracle Database. One Exadata Database Machine X2-8 scales to 14 Exadata Storage Servers in a 42U Rack, 5.3 TB of Exadata Smart Flash Cache, and 2 database servers each with 80 Intel CPU cores (8 x ten-core Intel® Xeon® E7-8870 processors) and 2 TB of memory. It is available with either 600 GB High Performance SAS (Serial Attached SCSI) disks or 3 TB High Capacity SAS disks.

Using the integrated InfiniBand network Exadata Database Machines can be connected together with near linear scalability. Oracle Real Application Clusters (RAC) can dynamically add more processing power and Automatic Storage Management (ASM) can dynamically rebalance the data across Exadata Storage Servers.

The Exadata Storage Expansion Rack, composed of standard Exadata Storage Servers and InfiniBand switches, seamlessly integrates with the Exadata Database Machine (or SPARC SuperCluster) enabling growth of their storage capacity and bandwidth. The Expansion Rack is designed for database deployments that require very large amounts of data. The Exadata Storage Expansion Rack is a high- performance, high-capacity, high-bandwidth, storage extension providing up to 288 TB of uncompressed, and mirrored, usable capacity with a corresponding improvement in I/O bandwidth for the Exadata Database Machine deployment. The Expansion Rack can be configured in a number of increments up to the full Rack with 18 Exadata Storage Servers. Up to 8 Exadata Database Machine racks and Exadata Storage Expansion Racks can be connected via InfiniBand cables. An 8 rack configuration has a raw disk capacity of 5,040 TB and

1,840 CPU cores dedicated to SQL processing. Larger configurations can be built with additional InfiniBand switches.

The Exadata Storage Server provides an advanced compression capability called Hybrid Columnar Compression (HCC) which enables the highest levels of data compression and provides substantial cost-savings and performance improvements due to reduced I/O within the Oracle Database. Typical storage savings can range from ten to fifteen times that of traditional disk systems.

Strongly supporting the optimized data center requirement for reduced risk, the Exadata Database Machine X2-8 has complete redundancy built-in and pre-configured to support the demands of mission critical applications. For high availability, each Exadata Database Machine has redundant InfiniBand connectivity, redundant Power Distribution Units, and the servers all have hot-swappable power supplies while data is mirrored across storage servers to protect against loss of data. Oracle RAC protects against database server failure and ASM provides disk mirroring to protect against disk failures.

Building on the high security capabilities already in every Oracle Database, the Exadata Database Machine provides the ability to query fully encrypted databases with near zero overhead at hundreds of gigabytes of user data per second. This is done by moving decryption processing from software into the Exadata Storage Server hardware thereby providing the highest levels of database security.

Fully integrated management can be seen in the Oracle Enterprise Manager Cloud Control which is used to manage the Exadata Database Machine, providing comprehensive lifecycle management from day-to-day operations to ongoing maintenance for the entire engineered system. From the holistic view of data center hardware and software, Oracle Enterprise Manager monitors Engineered Systems components such as compute nodes, Exadata cells, InfiniBand switches, and the placement of software running on them along with their resource utilization. Some examples of fully integrated management using Oracle Enterprise Manager include the following:

- Administrators can drill down from the database to the storage layer of Exadata to identify and diagnose problems such as performance bottlenecks or hardware faults.
- Lights-out monitoring within Enterprise Manager is optimized for Exadata where metrics and thresholds are predefined so that administrators can get timely notifications when issues arise.
- Hardware and software incidents are automatically detected and service requests logged to reduce problem resolution time.
- Administrators can use Consolidation Planner in Oracle Enterprise Manager to determine optimal consolidation strategies for different Exadata configurations.

In all the Oracle Engineered Systems, management is engineered together with hardware and software to provide not just high performance and availability but also ease of management and consolidation.

The SPARC SuperCluster T4-4 server is a multi-purpose Oracle engineered system in which compute nodes, storage nodes, networking, and software are tightly integrated to provide high performance, availability, and simplified deployment. The compute nodes are SPARC T4-4 servers while the storage nodes are available in two types (1) Exadata Storage Servers optimized for performance with Oracle Database 11g and (2) Sun ZFS Storage Appliances for non-Oracle Database data. SPARC SuperCluster machines have the same virtualization capabilities as standalone SPARC T4 servers, supporting Oracle Solaris Zones and Oracle VM Server for SPARC with the flexibility to run Oracle Solaris 10 and Oracle Solaris 11. The tight integration of storage, computing, networking, and software inside a SPARC SuperCluster engineered system reduces application deployment time which increases datacenter efficiency. These components are represented in Figure 10.

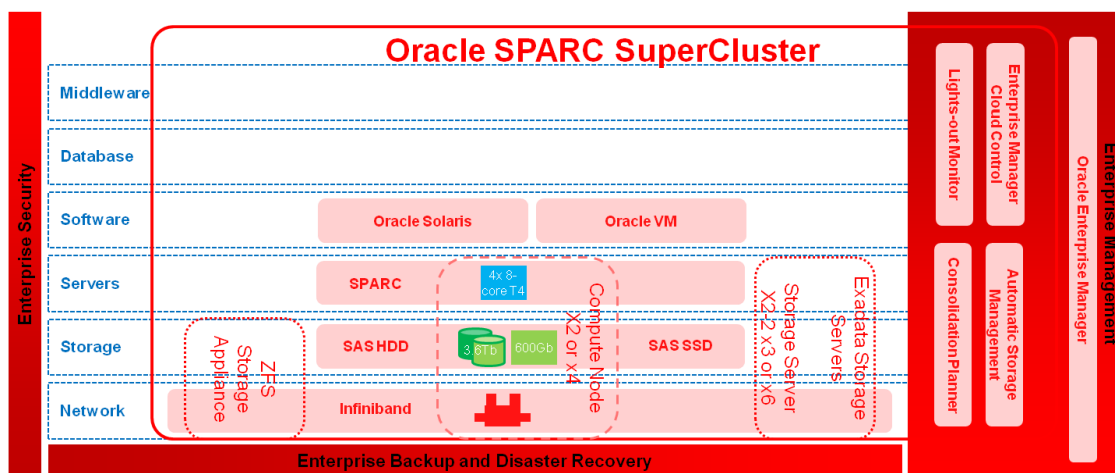


Figure 10 – SPARC SuperCluster Product Mapping Detail

By acquiring engineered systems IT avoids many time-consuming tasks associated with integrating and testing servers, storage, networking, and software making substantial cost savings. In addition, the single management console provided by Oracle Enterprise Manager greatly reduces the time spent by system administrators otherwise covering whole-rack management.

Conclusion

Oracle achieves the industry's best performance, scalability and manageability by providing a tightly integrated stack from low-level networking infrastructure all the way to a complete set of business applications. All this is managed by Oracle Enterprise Manager Ops Center and supported by pre-configured Engineered Systems and Optimized Solutions. This paper has shown that the integration engineered into all these critical elements lead to substantially reduced complexity, increased IT flexibility and business agility, while reducing both cost and risk.

The Oracle products that provide the capabilities were described and mapped onto the logical architecture to illustrate how they can be used to realize the optimized data center reference architecture. The breadth of Oracle's products related to the data center is unmatched in the

industry today and therefore, Oracle can uniquely help companies deliver exceptional data center solutions.

Further Reading

IT Strategies from Oracle

IT Strategies from Oracle (ITSO) is a series of documentation and supporting material designed to enable organizations to develop an architecture-centric approach to enterprise-class IT initiatives. ITSO presents successful technology strategies and solution designs by defining architecture concepts, principles, guidelines, standards, and best practices.

There are several documents in the ITSO library that are particularly relevant to the customer experience reference architecture including:

- Oracle Reference Architecture User Interaction
- Oracle Reference Architecture BPM Foundation
- Oracle Reference Architecture BPM Infrastructure
- Oracle Reference Architecture Service-Oriented Integration
- Oracle Reference Architecture Security
- Oracle Reference Architecture Management and Monitoring

All of these topics are important to customer experience but were only briefly discussed in this paper. Please consult the [ITSO web site](#) for a complete listing of documents as well as other materials in the ITSO series.

Other References

Oracle Optimized Data Center

<http://www.oracle.com/us/corporate/features/optimized-data-center/index.html>

Oracle Optimized Solutions

<http://www.oracle.com/us/solutions/oos/overview/index.html>

Oracle Engineered Systems

<http://www.oracle.com/us/products/engineered-systems/index.html>

Oracle Database

<http://www.oracle.com/us/products/database/overview/index.html>

Oracle Sun Servers

<http://www.oracle.com/us/products/servers/overview/index.html>

Oracle Sun Server Networking

<http://www.oracle.com/us/products/servers-storage/networking/index.html>

Oracle Storage and Tape Systems

<http://www.oracle.com/us/products/storage/overview/index.html>

Oracle Solaris

<http://www.oracle.com/us/products/servers-storage/solaris/solaris11/overview/index.html>

Oracle Linux

<http://www.oracle.com/us/technologies/linux/overview/index.html>

Oracle Virtualization

www.oracle.com/us/technologies/virtualization/overview/index.html

Oracle Enterprise Manager Ops Center

<http://www.oracle.com/technetwork/oem/ops-center/index.html>

Further information about all other products described in this paper can be found on Oracle's web site at: <http://www.oracle.com/us/products/index.html>



Oracle Optimized Data Center Reference Architecture

– Your data center. Optimized.

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Hardware and Software, Engineered to Work Together