



Oracle Database Consolidation on FlashStack with VMware

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Executive Summary

Introduction

The current trend in data center design is toward shared infrastructure with multitenant workloads. Enterprise customers are moving away from silos of information and moving toward shared infrastructure, to virtualized environments, and eventually to the cloud to increase agility and operation efficiency, optimize resource utilization, and reduce costs. Combining Cisco Unified Computing System™ (Cisco UCS®), Pure Storage FlashArrays, and VMware, FlashStack Converged Infrastructure (CI) delivers best in-class storage, server, and network components. This combined solution can serve as the foundation for a variety of workloads, enabling efficient architectural designs that can be quickly and confidently deployed.

This document describes a FlashStack reference architecture to consolidate and deploy multiple standalone Oracle databases on Pure Storage FlashArray//m using Cisco UCS computing servers and Oracle Linux in a VMware environment. This solution has been deployed and tested on a defined set of hardware and software.

Purpose of This Document

IT departments are increasingly turning to converged infrastructure solutions to simplify the design and repeatability of their data center infrastructure investments. Until now, the vast majority of converged infrastructure solutions have suffered from complexity, inefficiency, and poor performance. Cisco and Pure Storage have partnered to deliver FlashStack solutions, which simplify the selection, planning, design, implementation, and support of complete data center infrastructure stacks powered by virtualization and flash memory. Fueled by FlashArray, FlashStack CI uniquely eliminates performance bottlenecks; increases infrastructure reliability; and provides dramatic rack space, power, and cooling savings.

This document demonstrates the scalability, performance, and consolidation aspects of the solution by running Swingbench on an online transaction processing (OLTP) database as a benchmark. The tests are run with varying numbers of users and read and update workload characteristics on multiple Oracle databases on the same physical server.

The main benefits of this solution deployment are as follows:

- Consolidate hundreds of enterprise-class Oracle database virtual machines in a single rack.
- Potentially increase utilization of Oracle licenses, depending on the degree of consolidation implemented.
- Reduce business disruption and increase Oracle database efficiency by deploying a pretested and validated solution.
- Transparently scale performance and capacity to accommodate the growth of the Oracle database.

Business Needs

Business applications are moving into the consolidated computing, network, and storage environments. The deployment of data center infrastructure can be complex, time consuming, and costly. Implementing the FlashStack for VMware architecture helps reduce the costs and complexity of every component of a traditional Oracle Database 12c deployment. It also reduces the complexity of integration management needed to maintain multiple Oracle databases.

Organizations deploy Oracle Database 12c in a virtualized environment to meet the following business needs:

- Save costs, power, and lab space by reducing the number of physical servers.
- Consolidate multiple Oracle Database 12c databases on the same physical server.

- Reduce Oracle licensing costs by consolidating multiple Oracle Database 12c databases on the same physical server.
- Increase the database administrator's productivity by using Pure Storage FlashArray features such as Snapshot and Clone.
- Enable the use of a global virtualization policy and eliminate the need to manage bare-metal servers to run Oracle databases.
- Create a balanced configuration that yields predictable purchasing guidelines at the computing, network, and storage tiers for a given workload.

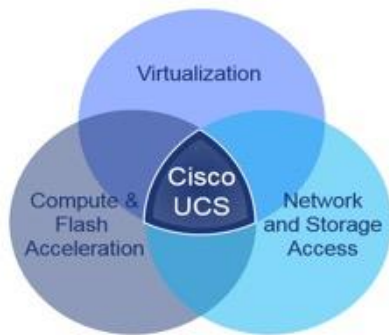
Solution Overview

Cisco UCS is an excellent platform for mission-critical database workloads. The combination of Cisco UCS, Pure Storage, and VMware architecture can accelerate your IT transformation by enabling faster deployments, greater flexibility of choice, more efficiency, and lower risk.

Cisco Unified Computing System

Cisco UCS is a next-generation data center platform that unites computing, network, storage access, and virtualization resources in a single cohesive system (Figure 1).

Figure 1. Cisco UCS System



The system integrates a low-latency, lossless 10 and 40 Gigabit Ethernet unified network fabric with enterprise-class, x86-architecture servers. The system is an integrated, scalable, multi-chassis platform in which all resources participate in a unified management domain. The system unleashes the full potential of virtualization by enhancing the scalability, performance, and operational control of virtual environments.

The system provides consolidated access to both SAN storage and network-attached storage (NAS) over the unified fabric. By unifying the storage access, Cisco UCS can access storage over Ethernet (Network File System [NFS] or Small Computer System Interface over IP [iSCSI]), Fibre Channel over Ethernet (FCoE), and Fibre Channel.

The system uniquely integrates all system components to enable the entire solution to be managed as a single entity by the Cisco UCS Manager. Cisco UCS Manager provides unified, centralized, embedded management of all Cisco UCS software and hardware components across multiple chassis and thousands of virtual machines. Administrators use the software to manage the entire Cisco UCS instance as a single logical entity through an intuitive GUI, a command-line interface (CLI), or an XML API. For more information about Cisco UCS configuration,

refer to <http://www.cisco.com/c/en/us/support/servers-unified-computing/ucs-manager/products-installation-and-configuration-guides-list.html>.

The main elements managed by Cisco UCS Manager include:

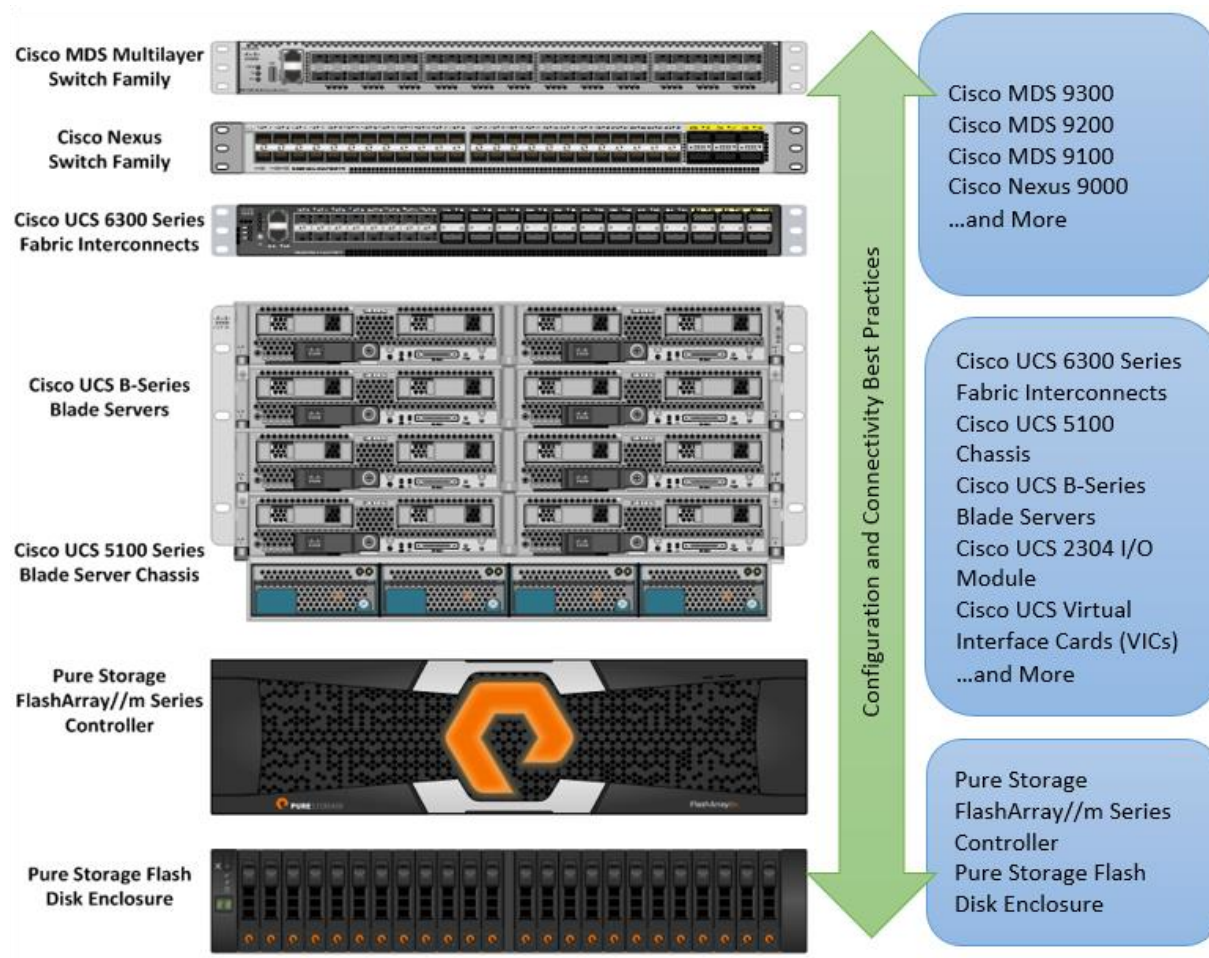
- Cisco UCS® Integrated Management Controller (CIMC) firmware
- RAID controller firmware and settings
- BIOS firmware and settings, including server universal user ID (UUID) and boot order
- Converged network adapter (CNA) firmware and settings, including MAC addresses and worldwide names (WWNs) and SAN boot settings
- Virtual port groups used by virtual machines, using Cisco Data Center Virtual Machine Fabric Extender (VM-FEX) technology
- Interconnect configuration, including uplink and downlink definitions, MAC address and WWN pinning, VLANs, VSANs, quality of service (QoS), bandwidth allocations, VM-FEX settings, and EtherChannels to upstream LAN switches

Service profiles are essential to the automation functions in Cisco UCS Manager. They provision and manage Cisco UCS and its I/O properties within a Cisco UCS domain. Infrastructure policies are created by server, network, and storage administrators and are stored in the Cisco UCS fabric interconnects. The infrastructure policies needed to deploy applications are encapsulated in the service profile templates, which are collections of policies needed for the specific applications. The service profile templates are then used to create one or more service profiles, which provide the complete definition of the server. The policies coordinate and automate element management at every layer of the hardware stack, including RAID levels, BIOS settings, firmware revisions and settings, server identities, adapter settings, VLAN and VSAN network settings, QoS, and data center connectivity.

FlashStack Architecture

The reference architecture for this solution uses Cisco UCS B-Series Blade Servers with Pure Storage FlashArray//m 70, Cisco Nexus® 9000 Series Switches, Cisco MDS 9100 Series Multilayer Fabric Switches for the switching element, and Cisco UCS 6300 Series Fabric Interconnects for system management (Figure 2).

Figure 2. FlashStack System Components



Each of the component groups in this solution (Cisco UCS, Cisco Nexus, Cisco MDS, Cisco UCS fabric interconnects, and Pure Storage) offers platform and resource options to scale the infrastructure up or down. They all support the features and functions that are required by the configuration and connectivity best practices for FlashStack.

The following components are used in the design and deployment:

- **Network:** Cisco Nexus 9372PX-E Switch, Cisco MDS 9148S 16G Multilayer Switch, and Cisco UCS 6332-16UP Fabric Interconnect for external and internal connectivity of the IP and Fibre Channel network
- **Storage:** Pure Storage FlashArray//m (base shelves comes with four NVRAM modules with //m70 model) with 16-Gbps Fibre Channel connectivity
- **Computing:** Cisco UCS B200 M4 Blade Server with Cisco UCS VIC 1340 and 1380
- **Software:** Oracle Linux 7.2, Oracle Database 12c, and Swingbench benchmark kit for OLTP workload
- **Virtualization:** VMware vSphere 6.0 virtualized platform

A pair of Cisco UCS 6332-16UP Fabric Interconnects carries both storage and network traffic from the blades with the help of Cisco Nexus 9372PX-E and Cisco MDS 9148S switches. For these solution, four ports (ports 1 to 4) of MDS switch A are connected to fabric interconnect A (ports 1 to 4). Similarly, four ports (ports 1 to 4) of MDS switch B are connected to fabric interconnect B (ports 1 to 4). All ports carry 16-Gbps Fibre Channel traffic. The SAN ports CT0.FC0 and CT0.FC2 of Pure Storage controller 0 are connected to MDS 9148S switch A, and CT0.FC1 and CT0.FC3 are connected to MDS 9148S switch B. Similarly, the SAN ports CT1.FC0 and CT1.FC2 of Pure Storage controller 1 are connected to MDS 9148S switch A, and CT1.FC1 and CT1.FC3 are connected to MDS 9148S switch B. These ports also carry 16-Gbps Fibre Channel storage traffic. We strongly recommend that you use “boot from SAN” to achieve the full benefits of Cisco UCS stateless computing features such as service profile mobility.

Cisco UCS B200 M4 Blade Server Configuration

The solution described here uses one Cisco UCS B200 M4 Blade Server to consolidate and host multiple virtual machines running standalone Oracle Database 12c. The server has Cisco UCS VIC 1340 and 1380 cards. These cards are connected to four ports from each Cisco fabric extender of the Cisco UCS chassis to the Cisco fabric interconnects. The fabric interconnects, in turn, are connected to the MDS 9148S for upstream connectivity to access the Pure Storage FlashArray//m logical unit numbers (LUNs). Figure 3 shows the blade server.

Figure 3. Cisco UCS B200 M4 Blade Server Configured for the Solution



The below table (table 1) summarizes the server configuration.

Table 1. Cisco UCS B200 M4 Server Configuration

Server Configuration	
Processor	2 Intel® Xeon® processor E5-2697 v3 CPUs at 2.6 GHz (2 CPUs with 14 cores each)
Memory	256 GB at 2.1 GHz (16 x 16 GB), 16-GB DDR4 2133-MHz RDIMM, PC4-17000 module, dual rank, x4, 1.2V
VIC 1340	2 ports: 40-Gbps unified I/O ports on Cisco UCS VIC 1380 deliver 80 Gbps to the server
VIC 1380	2 ports: 40-Gbps unified I/O ports on Cisco UCS VIC 1340 deliver 80 Gbps to the server

This section describes how to configure the service profile to boot the VMware ESXi OS from the Pure Storage FlashArray Fibre Channel target on the Cisco UCS B200 M4 server.

Follow these high-level steps to configure Cisco UCS:

1. Configure fabric interconnects for a cluster setup.
2. Configure fabric interconnects for chassis and blade discovery.
 - a. Configure global policies.
 - b. Configure server ports.
3. Configure the LAN and SAN on Cisco UCS Manager.
 - a. Configure Ethernet LAN uplink ports.
 - b. Configure Fibre Channel SAN uplink ports.
 - c. Configure the VLAN.
 - d. Configure the VSAN.
4. Configure UUID, IP address, MAC address, worldwide node name (WWNN), and worldwide port name (WWPN) pools.
 - a. Create the UUID pool.
 - b. Create IP and MAC address pools.
 - c. Create WWNN and WWPN pools.
5. Configure virtual network interface card (vNIC) and virtual host bus adapter (vHBA) templates.
 - a. Create the public vNIC template.
 - b. Create the private vNIC template.
 - c. Create the storage vHBA template.
6. Configure Ethernet uplink port channels.
7. Create server boot policy for SAN boot.
8. Configure and create the service profile template.
9. Configure and create the service profile from the service profile template.
10. Assign the service profile to the server.

For more detailed FlashStack configuration information, refer to the Cisco Validated Design at http://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/ucs_flashstack_oracleRAC.html.

The service profiles represent all the attributes of a logical server in the Cisco UCS model. The use of logical servers that are disassociated from the physical hardware removes many limiting constraints in the way that servers are provisioned.

In addition to the benefits provided by service profiles, Pure Storage's FlashRecover snapshots with SAN boot policy provide the following benefits:

- **Scalability:** Rapidly deploy new servers to the environment in just a few steps.
- **Manageability:** Transparently perform hardware maintenance and upgrade operations without any restrictions.
- **Flexibility:** Easily repurpose physical servers for different applications and services as needed.
- **Availability:** Hardware failures typically have little impact and are not critical. In the rare case of a server failure, you can easily associate the logical service profile with another healthy physical server to reduce the impact.

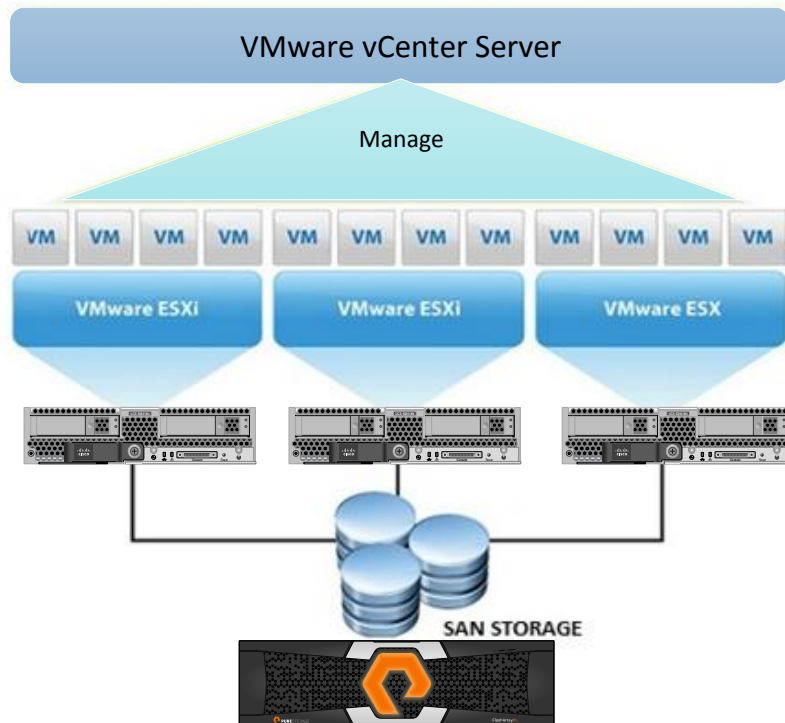
For the deployment here, you create SAN boot policy and assign the SAN boot primary (hba0) and SAN boot secondary (hba1) by entering the WWPNs of the Pure Storage Fibre Channel ports. You then create the service profile ORASAN using the SAN boot policy in Cisco UCS Manager. You assign this service profile (ORASAN) to the ESX server. You also configure the MDS switch for Fibre Channel zoning. To assign the storage LUN to the server, extract the WWPN for each HBA from each server and configure the Fibre Channel zone and zone set for the MDS switch. Activate the zone set to establish the Fibre Channel connection between the storage and the server. The design here uses four HBAs for each server. Two HBAs (HBA0 and HBA2) are connected to MDS switch A, and the other two HBAs (HBA1 and HBA3) are connected to MDS switch B. The SAN boot volume for this server is hosted on the same Pure Storage FlashArray.

You create one LUN (N2_ESXI_OS) with 250 GB and assign it to the B200 M4 server node to install and configure ESXi 6.0.

VMware ESXi Configuration

Virtualization using ESXi provides an abstraction layer that decouples the physical hardware from the operating system to deliver greater IT resource utilization and flexibility. With VMware infrastructure, IT departments can build a virtual data center using their existing industry-standard technology and hardware (Figure 4).

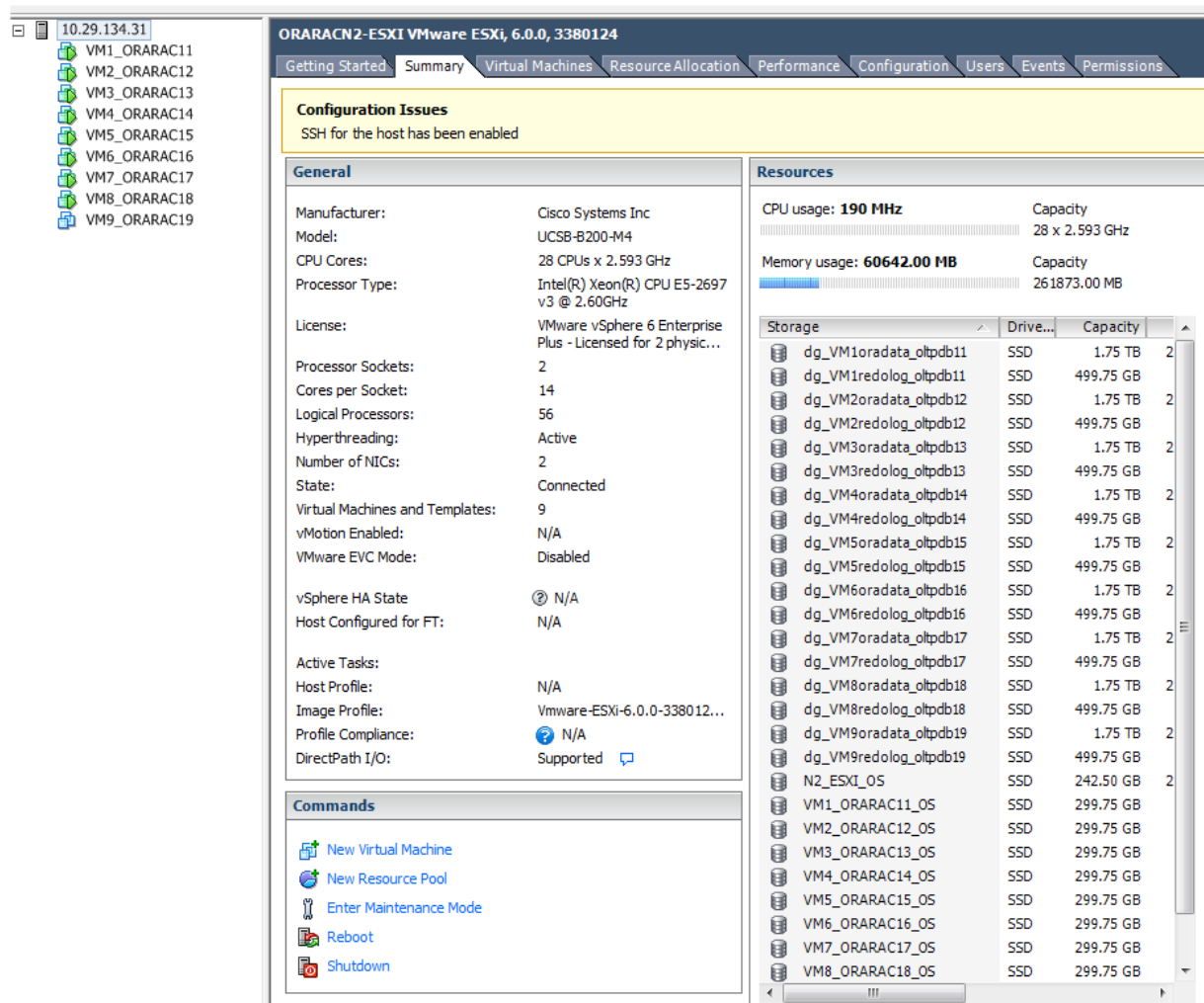
Figure 4. VMware ESXi Design



Virtualization allows multiple virtual machines with heterogeneous operating systems (Oracle Linux, Red Hat Enterprise Linux [RHEL], Microsoft Windows 2008 Server, etc.) and applications to run in isolation side by side on the same physical machine. A virtual machine is the representation of a physical machine by software. It has its own set of virtual hardware (RAM, CPU, NICs, hard disks, etc.) on which an operating system and applications are loaded. The operating system sees a consistent, normalized set of hardware regardless of the actual physical hardware components.

To consolidate multiple standalone Oracle databases on the same physical server, you first install and configure ESXi 6.0 on the B200 M4 server. Then you create up to eight virtual machines, as shown in Figure 5.

Figure 5. VMware ESXi Configuration



Virtual Machine Configuration

Splitting the physical hardware into several virtual machines provides hardware consolidation. It maintains the separation between the systems, with each able to run a different OS and database version if required.

Each virtual machine has one network interface card for the public network interface and three LUNs for the OS, database files, and redo log files, as shown in Table 2.

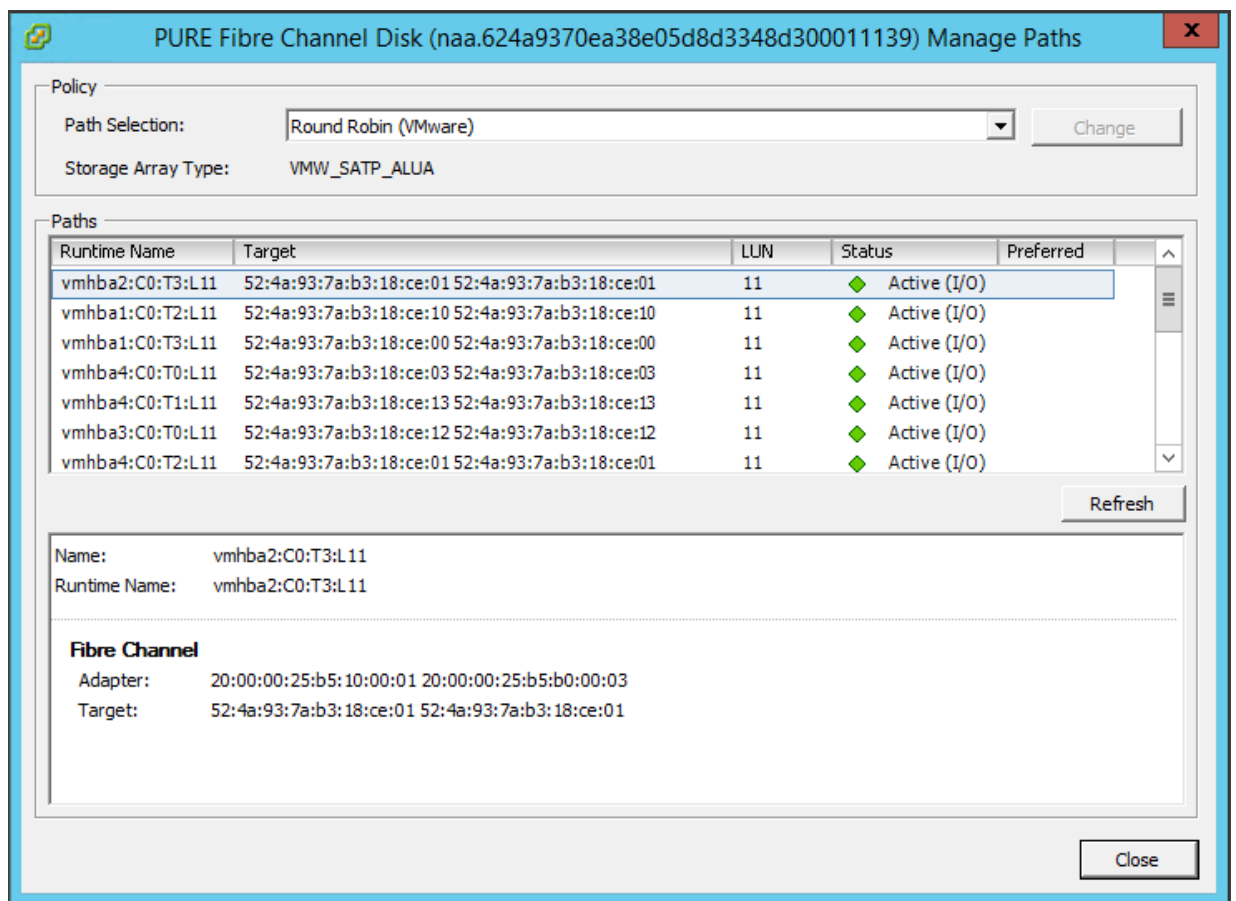
Table 2. Virtual Machine Disk Configuration

	OS LUN (300 GB)	Data LUN (1.75 TB)	Redo LUN (500 GB)
Virtual Machine 1	VM1_ORARAC11_OS	dg_VM1oradata_oltpdb11	dg_VM1redolog_oltpdb11
Virtual Machine 2	VM2_ORARAC12_OS	dg_VM2oradata_oltpdb12	dg_VM2redolog_oltpdb12
Virtual Machine 3	VM3_ORARAC13_OS	dg_VM3oradata_oltpdb13	dg_VM3redolog_oltpdb13
Virtual Machine 4	VM4_ORARAC14_OS	dg_VM4oradata_oltpdb14	dg_VM4redolog_oltpdb14
Virtual Machine 5	VM5_ORARAC15_OS	dg_VM5oradata_oltpdb15	dg_VM5redolog_oltpdb15

Virtual Machine 6	VM6_ORARAC16_OS	dg_VM6oradata_oltpdb16	dg_VM6redolog_oltpdb16
Virtual Machine 7	VM7_ORARAC17_OS	dg_VM7oradata_oltpdb17	dg_VM7redolog_oltpdb17
Virtual Machine 8	VM8_ORARAC18_OS	dg_VM8oradata_oltpdb18	dg_VM8redolog_oltpdb18

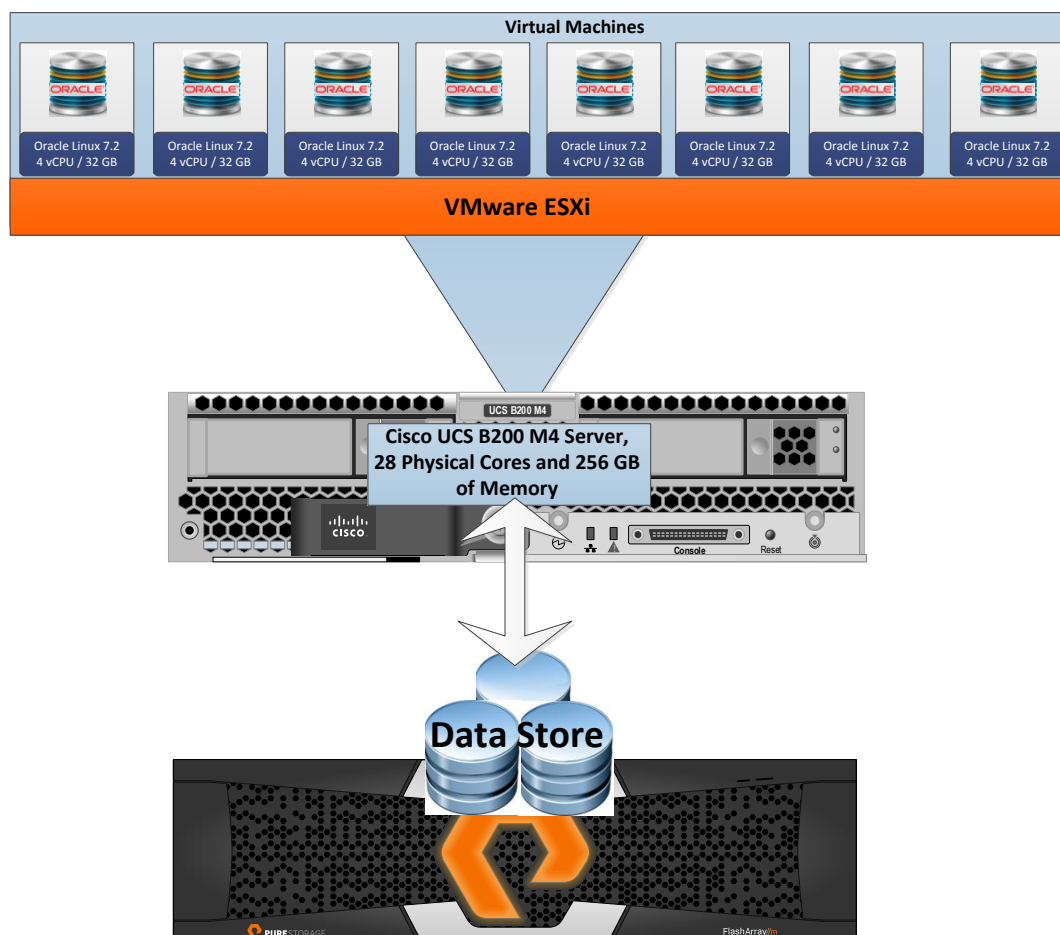
As mentioned earlier, each server uses four HBAs. Two HBAs (HBA0 and HBA2) are connected to MDS switch A, and other two HBAs (HBA1 and HBA3) are connected to MDS switch B. They carry storage I/O traffic to Pure Storage FlashArray. The path policy is configured as Round Robin to use all Fibre Channel paths on the data and redo LUNs, as shown in Figure 6.

Figure 6. Data Store Path Selection Policy for Data and Redo LUNs



As shown in Figure 7, each virtual machine is configured as four vCPUs with 32 GB of memory to run Oracle Linux 7.2 and standalone Oracle Database 12c.

Figure 7. Standalone Oracle Database Consolidation on Cisco UCS B200 M4 Server



On each virtual machine, an Oracle 12cR1 single-instance database was deployed, and one OLTP database of approximately 1.7 TB was created. In the OLTP database, one Swingbench user tablespace of 1.7 TB was created. The Swingbench Order Entry schema data is loaded into this tablespace. The data LUN is used to store all the database files, and the redo LUN is used to store all the redo log files for the database.

Scalability Testing and Results

Before configuring any database for workload tests, you must verify that this is indeed a balanced configuration that can deliver the expected performance. The design described here used Swingbench for workload testing. Swingbench is a simple-to-use, free, Java-based tool for generating database workloads and performing stress tests using different benchmarks in Oracle database environments. For the tests described in this solution, the Order Entry benchmark was used for OLTP workload testing. The Order Entry benchmark is based on the Swingbench Order Entry schema and is similar to Transaction Processing Performance Council Benchmark C (TPC-C), by types of transactions. The workload uses a balanced read:write ratio of about 60:40 and can be designed to run continuously to test the performance of a typical order-entry workload against a small set of tables producing contention for database resources.

Database Workload Configuration

The first step after the databases are created is calibration: the number of concurrent users, the virtual machines, the OS, and database optimization. For Pure Storage FlashArray //m70, the system is scaled starting from two virtual machines and moving to eight virtual machines on one B200 M4 server. For each virtual machine, the number of transactions per minute (TPM), latency, and CPU utilization are captured by adding two virtual machines at a time, each running a standalone database. The results are described in the next section.

For the OLTP database workload, a 28-GB system global area (SGA) was used. The OLTP database consolidation test was run for at least 12 hours to help ensure that the results are consistent over the entire run. For OLTP workloads, the common measurements are TPM and I/O operations per second (IOPS) scalability. For the test, the SOE benchmark was run to generate workload on each virtual machine and to record Oracle Automatic Workload Repository (AWR) reports for each scenario.

Oracle Database Consolidation

As explained earlier, each virtual machine is configured with four vCPUs and 32 GB of memory to run standalone Oracle Database 12c. Each virtual machine is running an OLTP database of 1.5 TB. The Order Entry benchmark is run to generate workload on each virtual machine with 30, 35, 40, and 45 users to saturate the virtual machine CPU and capture the results. The Order Entry benchmark is configured to run the database workloads on the virtual machine at the same time, and the concurrent users are spread equally across the database.

For two virtual machines running database workloads together, the tests demonstrated an average of 202,000 TPM with an average virtual machine CPU utilization of 89 percent. Similarly for four, six, and eight virtual machines, the tests demonstrated an average of, respectively, 435,000, 615,000, and 652,000 TPM, with an average virtual machine CPU utilization of about 90 percent, as shown in Tables 3 and 4.

Table 3. Oracle Database Consolidation TPM Results

	2 Virtual Machines and 80 Users	4 Virtual Machines and 160 Users	6 Virtual Machines and 240 Users	8 Virtual Machines and 320 Users
VM1	103,728	103,357	100,750	84,571
VM2	98,412	112,840	109,378	81,935
VM3	0	109,098	109,905	83,571
VM4	0	110,293	96,907	85,597
VM5	0	0	100,063	83,048
VM6	0	0	98,741	66,829
VM7	0	0	0	83,337
VM8	0	0	0	83,113
Total TPM	202,140	435,588	615,744	652,001

Table 4 shows virtual machine CPU utilization when running two, four, six, and eight virtual machines, each with a standalone Oracle database workload, at the same time. The Order Entry benchmark was run on each virtual machine with the number of users increasing from 30 to 45 to saturate virtual machine CPU.

Table 4. Virtual Machine CPU Utilization (Percent)

	2 Virtual Machines and 80 Users	4 Virtual Machines and 160 Users	6 Virtual Machines and 240 Users	8 Virtual Machines and 320 Users
VM1	89.6	91.3	91.4	93.5
VM2	89.2	89.8	90.9	94.6

VM3	0	88.2	91.2	93.9
VM4	0	90.5	90.6	93.4
VM5	0	0	91.3	93.6
VM6	0	0	91.6	92.5
VM7	0	0	0	94
VM8	0	0	0	94.5
Average CPU Utilization (%)	89.4	89.95	91.2	93.8

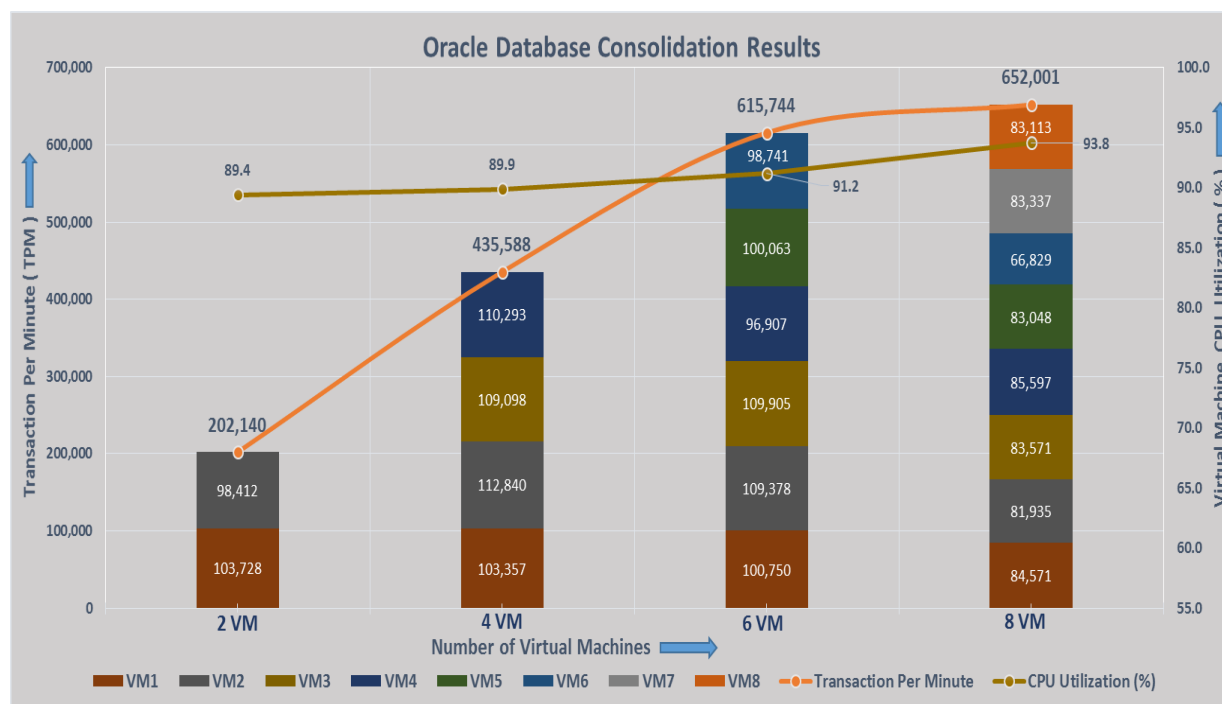
Table 5 shows the IOPS, TPM, and virtual machine CPU utilization for all eight virtual machines running the Order Entry workload together.

Table 5. Oracle Database Consolidation Results with Eight Virtual Machines

8 Virtual Machines and 320 Users	TPM	Physical Read Operations	Physical Write Operations	Total IOPS	Virtual Machine CPU Utilization (%)
VM1_OLTPDB11	84,571	8,411	3,666	12,077	93.5
VM2_OLTPDB12	81,935	8,245	3,520	11,765	94.6
VM3_OLTPDB13	83,571	8,336	3,593	11,929	93.9
VM4_OLTPDB14	85,597	8,334	3,656	11,990	93.4
VM5_OLTPDB15	83,048	8,251	3,511	11,762	93.6
VM6_OLTPDB16	66,829	6,889	2,801	9,690	92.5
VM7_OLTPDB17	83,337	8,153	3,235	11,388	94
VM8_OLTPDB18	83,113	8,132	3,230	11,362	94.5

The graph in Figure 8 shows the TPM and virtual machine CPU utilization (percentage) for 1.5-TB OLTP database consolidation from two virtual machines to eight virtual machines.

Figure 8. TPM and System Utilization for Multiple Oracle Databases



As expected, the graph demonstrates the linear scalability of the TPM value with the increasing number of database and virtual machines. The tests saturated the virtual machine CPU until 93 percent utilization was reached across all workloads, and the tests revealed latency of always less than 1 millisecond. With eight virtual machines running database workloads together, the solution achieved up to 652,000 TPM.

No performance dips or degradation were evident over the run-time period. Note, too, that the numbers presented in the tests are not the peak values for Pure Storage. The results from the tests reported here show that one Cisco UCS B200 M4 server with Intel Xeon processor v3 CPUs (two CPUs with 14 cores each) can consolidate up to with virtual machines running a standalone Oracle database with an average of 82,000 TPM per virtual machine.

Conclusion

Organizations can achieve database consolidation in several ways, but all of them have specific advantages and disadvantages. Most basic to note is that this type of consolidation works only if enough resources are available to complete the total workload. This is true for all resources, including CPU, memory, disk, and network. When you seek to consolidate databases, you must make sure that all the workload profiles are compatible.

For increased complexity and extreme performance requirements, FlashStack can reduce business risk and increase data center efficiency, protecting current investments and scaling for future growth. The FlashStack solution uses best-in-class storage, server, and network components as the foundation for a variety of workloads, enabling efficient architectural designs that organizations can quickly and confidently deploy. The FlashStack solution is predesigned to provide agility to large enterprise data centers with high availability and storage scalability.

Oracle database consolidation using virtualization technology has tremendous benefits, helping organizations optimize data center resources. This document demonstrated validation and consolidation of multiple Oracle 12c

databases on the same physical server in a virtualized environment. Linear scaling of resource utilization was observed for both the storage and server resources when multiple standalone Oracle databases were consolidated.

Customers should accelerate their transition to the cloud with the FlashStack data center solution. This solution scales to fit a variety of virtualized and nonvirtualized customer environments. With a FlashStack solution, customers gain a secure, integrated, and optimized stack that includes computing, network, and storage resources that are sized, configured, and deployed as a fully tested unit running industry-standard applications such as Oracle databases.

For More Information

Customers can find more information about Cisco Data Center design for Oracle Applications and Pure Storage products at the links listed here:

- Best practices for Oracle databases on VMware:
<http://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/solutions/vmware-oracle-databases-on-vmware-best-practices-guide.pdf>
- Cisco UCS servers:
<http://www.cisco.com/c/en/us/products/servers-unified-computing/product-listing.html>
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http://www.cisco.com/c/en/us/solutions/enterprise/data-center-designs-application-networking/landing_oracle.html
- Cisco Validated Designs for data center:
<http://www.cisco.com/c/en/us/solutions/enterprise/design-zone-data-centers/index.html>
- Pure Storage infrastructure solution:
<https://www.purestorage.com/solutions/infrastructure/flashstack.html>
- Pure Storage FlashArray //m:
<https://www.purestorage.com/products/flash-array-m.html>



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