

Hitachi Solution for Databases - Reference Architecture for Oracle RAC Database 19c with VSP E1090 and HA820 G2

Reference Architecture Guide

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Revision history

Changes	Date
Updated high-level architecture and IP network switch connection illustrations.	February 16, 2024
Updated peakmarks information.	October 23, 2023
Updated peakmarks information.	August 5, 2022

Reference Architecture Guide

Use this reference architecture guide to understand how Hitachi Solution for Databases provides a high-performance, low latency, integrated, converged solution for Oracle Database using Hitachi Virtual Storage Platform E1090 (VSP E1090). The environment uses VSP E1090, Hitachi Advanced Server HA820 G2, and Hitachi Advanced Server DS120 G2 with Ice Lake Server Scalable Processors. With these products, you can design an Oracle converged infrastructure to meet your requirements and budget.

This solution uses the high-performing Hitachi Advanced Server HA820 G2 to boost performance and lower I/O latency. The VSP E1090 storage system with NVMe SSDs is also used in this reference architecture to run a dedicated Oracle Database 19c with the Oracle Real Application Clusters (RAC) option on the Oracle Linux 8.5 operating system. Hitachi Advanced Server DS120 G2 is dedicated for management applications. This document is intended for:

- Database administrators
- Storage administrators
- Database performance analyzers
- IT professionals responsible for planning and deploying an Oracle Database solution

To use this reference architecture guide, you must be familiar with the following:

- Hitachi Virtual Storage Platform E1090
- Hitachi Advanced Server HA820 G2
- Hitachi Advanced Server DS120 G2
- Storage area networks
- Oracle 19c RAC Database
- Oracle Automatic Storage Management (Oracle ASM)
- Oracle Linux



Note: This configuration was tested in a lab environment. Many factors affect production environments beyond prediction or duplication in a lab environment. Before deployment of this solution, follow the recommended practice of conducting proof-of-concept testing for acceptable results in a non-production, isolated test environment that otherwise matches your production environment and workload.

Solution overview

The Hitachi solution for Oracle RAC databases on Hitachi Unified Compute Platform (UCP) for Oracle Database is engineered, pre-tested, and qualified to provide high performance and high reliability in demanding and dynamic Oracle environments.

This reference architecture implements Hitachi Unified Compute Platform for Oracle Real Application Clusters on two nodes using Hitachi Virtual Storage Platform E1090. It addresses the high availability, performance, and scalability requirements for OLTP and OLAP workloads. This solution was developed using Intel Whitley Platform-based Hitachi Advanced Server HA820 G2, DS120 G2, and VSP E990 storage systems for the management server environment.

Business benefits

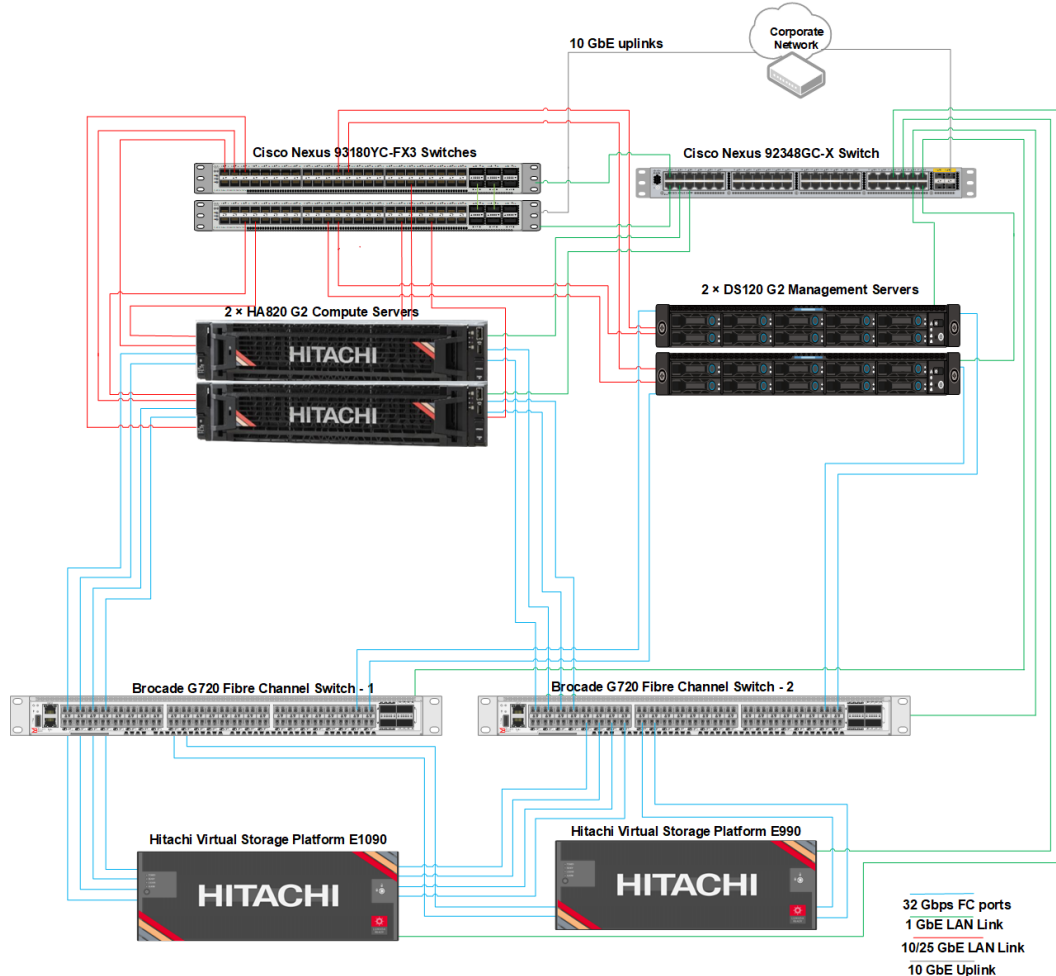
Here are some benefits of this reference architecture:

- Achieves high Oracle Database performance with VSP E990.
- Provides a solution for customers who are looking for very low I/O latency for Oracle RAC database.

High level infrastructure

VSP E1090 and HA820 G2 were configured with fully redundant hardware for dual fabric connectivity between hosts and storage.

The following figure shows the high-level architecture diagram using VSP E1090 and HA820 G2 for a two-node Oracle 19c RAC configuration, and two DS120 G2 servers for management of the architecture. Data volumes for the management servers were configured on a VSP E990, which was shared across different management nodes. The VSP E990 is not required in your environment. Data volumes can also be configured on the VSP E1090 or other VSP storage systems.



To avoid a performance impact to the production database, Hitachi Vantara recommends using a configuration with the following:

- A dedicated storage system for the production database.
- A dedicated storage system for data replication at a different site for business continuity, if needed.

Hitachi Vantara recommends using pairs of 25 Gbps NICs for the cluster interconnect network and public network.

Uplink speed to the corporate network depends on the customer environment and requirements. The Cisco Nexus 93180YC-FX3 switches can support uplink speeds of 40 GbE or 100 GbE if higher bandwidth is required.

Key solution components

The key components for this solution are listed in the following tables.

Table 1 Hardware Components

Vendor	Hardware	Detailed Description	Version	Quantity
Hitachi Vantara	VSP E1090	2 × CHB pairs 8 × 32 Gbps Fibre Channel ports 836 GB cache memory 48 × 1.9 TB NVMe SSDs	93-06-21-80/01	1
	VSP E990	4 × 32 Gbps Fibre Channel ports 903 GB cache memory 17 × 3.8 TB NVMe SSDs*	93_02_02_60/00	1
Hitachi Vantara	HA820 G2	2 × Intel Xeon Platinum 8368 38C CPU @ 2.40GHz 768 GB (64 GB × 12) DIMM DDR4-3200 Synchronous Registered (buffered) 3200 MHz	System ROM: U46 v1.52 (09/22/2021) iLO 5: 2.55 Oct 01 2021	2
		2 × HPE Ethernet 10/25Gb 2-port FLR-SFP28 BCM57414 adapters	Driver: bnxt_en Driver version: 1.10.2 (inbox) Firmware: 218.0.166.0	
		2 × HPE SN1610E 32Gb 2p Fibre Channel HBAs	Driver: lpfc Driver version: 12.8.0.10 Firmware: 12.8.528.12	
	DS120 G2	2 × Intel Xeon processors 4310, 12-core, 2.10 GHz, 120W 256 GB (32 GB × 8) DIMM DDR4-3200 Synchronous Registered (Buffered) 3200 MHz	BIOS: S5XH3A12.H03 BMC: 3.16.06 CPLD: 07	2

Vendor	Hardware	Detailed Description	Version	Quantity
		1 × 256 GB NVMe 0.3DWPD M.2 SSD for boot		
		1 × Dual Port 25 GbE NIC Intel E810 PCIe card	Driver version: ice 0.8.2-k Firmware: 2.42	
		1 × Emulex LightPulse LPe35002-M2 2-Port 32 Gb Fibre Channel adapters	Driver: lpfc Driver version: 12.8.0.10 Firmware: 12.8.542.26	
Brocade	G720 Fibre Channel switches	48 × 32 Gbps ports Fibre Channel switches 32 Gbps SFPs	Fabric OS: v9.0.1c	2
Cisco Systems	Nexus 93180YC- FX3	48 × 10/25 GbE ports 6 × 40/100 Gbps Quad SFP (QSFP28) ports	NXOS: version 9.3.8	2
	Cisco Nexus 92348GC-X	48 × 1 GbE ports Ethernet switches	NXOS: version 9.3.8	1

*Customers can choose larger capacity SSDs to fit their business requirements.

Certain components are optional depending on the existing infrastructure and required interconnect topology. This might include the SAN, IP switches, and the management servers. However, this reference architecture documents the environment tested in the lab to support a full deployment of the architecture including supporting components.

Table 2 Software Components

Software	Version	Function
Oracle Linux	8.5 with UEK kernel 6.3	Operating system
Oracle Database	19.14.0.0.0	Database software
Oracle Real Application Cluster	19.14.0.0.0	Cluster software
Oracle Grid Infrastructure	19.14.0.0.0	Volume management, file system software, and Oracle Automatic Storage Management (ASM)
Oracle ASMLib	2.1.12	Oracle software for ASM

Table 3 Management Node Software Components

Software	Version	Function
ESXi	7.0 U2	Hypervisor for management server
vCenter Server	7.0 U2	VMware cluster management server
Hitachi Device Manager - Storage Navigator	Microcode dependent	Storage management software
Hitachi Ops Center	10.8.1	Hitachi infrastructure management software

Solution design

This section describes the reference architecture environments used to implement Hitachi Unified Compute Platform (UCP) for Oracle with the Real Application Clusters option. Each environment uses a single Hitachi Virtual Storage Platform E1090.

The infrastructure configuration includes the following:

- Oracle RAC Servers – There are two server nodes configured in an Oracle Real Application Cluster.
- Management Servers – Two servers are used in the management server cluster.
- Storage System – There are vVols mapped to each port that are presented to the servers as LUNs.
- SAN Connection – There are SAN connections to connect the Fibre Channel HBA ports to the storage through Brocade G720 switches.

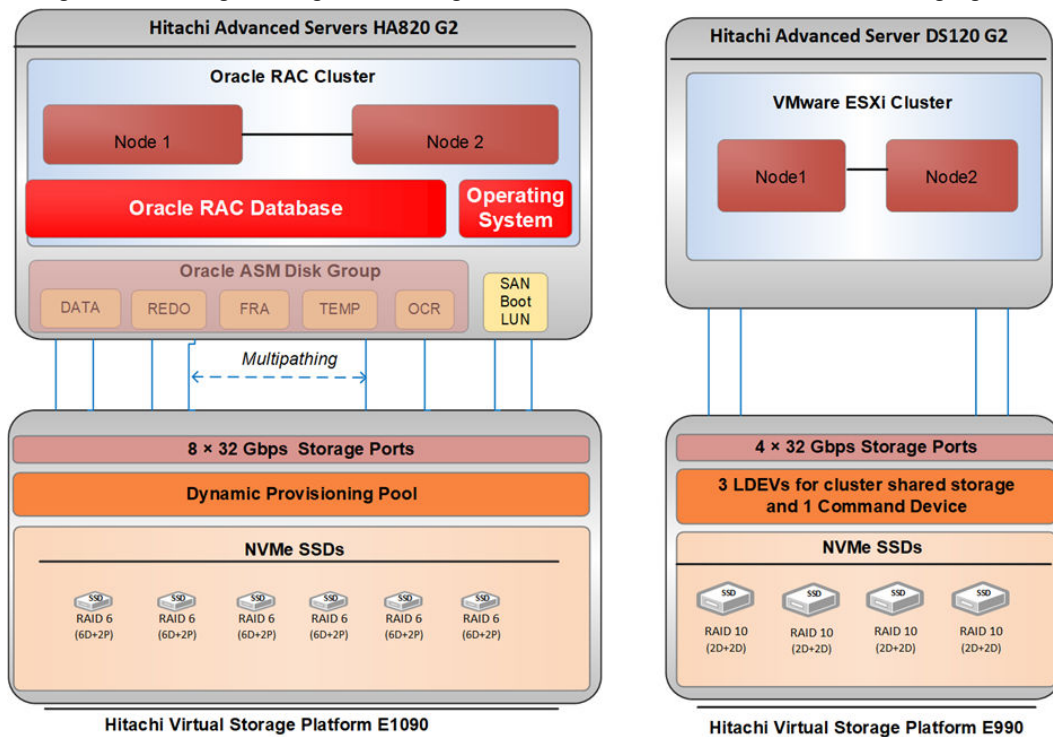
Storage architecture

This section describes the storage architecture for this solution.

Storage configuration

The storage configuration takes into consideration Hitachi Vantara and Oracle recommended best practices for the design and deployment of database storage.

The high-level storage configuration diagram for this solution is shown in following figure.



The following table lists the storage pool configuration used for this solution and lab verification.

Table 4 Storage Pool Configuration

Pool ID	Oracle(0)
Pool Type	Dynamic Provisioning Pool
RAID Group	1-1 to 1-6
RAID Protection Type	RAID 6 (6D+2P)
Drive Type/Capacity	1.9 TB NVMe SSD
Number of Drives	48
Number of LDEVs	48
LDEV Size(s)	1320 GB
Pool Capacity	61.86 TB

The following table lists the logical storage configuration used in this solution.

Table 5 Logical Storage Configuration

Item	Value/Description					
Total number of DPVols	128	3	32	16	16	2
DPVols size (GB)	250	15	20	200	2000	380
ASM diskgroup	DATA	OCR	REDO	TEMP	FRA	N/A
Purpose	OLTP application tablespaces System Sysaux Undo	Oracle Cluster Registry	Online redo Logs Control files	Temp	Incremental backups Archived redo Logs Control file Auto backups	SAN boot OS volumes
Storage Port	3A, 3B, 7A, 7B, 4A, 4B, 8A, 8B					

The following table lists the VSP E990 management server configuration.

Table 6 VSP E990 Configuration for Management Servers

Item	Value/Description
Purpose	VMware Datastores CCI device
RAID level	RAID 10 (2D+2D)
Drive type	3.8 TB NVMe SSD
Number of drives	16
Number of spare drives	1
Number of Pool DEVs	4
LDEV size(s)	1 × 3000 GB
Number and size of CCI devices	1 × 100 MB
Storage port for management servers	7A, 7B, 8A, 8B

4 × RAID 10 groups consisting of 12 × 3.84 TB NVMe SSD drives configured as RAID 10 (2D +2D) were used as shared storage for the management server cluster. A 3 TB LUN and a command device were mapped to four storage ports.

Additional LUNs can be mapped if necessary. The test environment was configured using a dedicated RAID group for the management cluster. You can also configure this solution using dedicated RAID groups, a dedicated HDP pool, or capacity on the HDP pool configured for the Oracle environment according to customer requirements.

Database layout

The database layout design uses recommended best practices from Hitachi Vantara for Hitachi Virtual Storage Platform storage systems for small random I/O traffic, such as OLTP transactions. The layout design also considers Oracle ASM best practices when using Hitachi storage.

The storage design for the database layout should be based on application-specific requirements. Design can vary greatly across implementations based on RAID configuration and number of drives allocated. The components in this solution have the flexibility to accommodate various deployment scenarios by providing the right balance between performance and ease of management.

Oracle configuration

- Data and Index Tablespaces - Assign an ASM diskgroup with external redundancy for data and index tablespaces.
- TEMP Tablespace - Place the TEMP tablespace in the TEMP ASM diskgroup.
- Undo Tablespace - Create an UNDO tablespace in the Oracle Data ASM diskgroup. Assign one UNDO tablespace for each node in the Oracle RAC environment.
- Online Redo Logs - Create an ASM diskgroup with external redundancy for Oracle online Redo logs.
- Oracle Cluster Registry and Voting Disk - Create an ASM diskgroup with normal redundancy to contain the OCR and voting disks and to protect against single disk failure and loss of cluster availability. Place each of these files in the OCR ASM diskgroups.

Oracle initial parameters

The following table lists Oracle ASM and database parameters.

Table 7 Oracle ASM and Database Parameters

Category	Item	Value
Oracle RAC option	RAC configuration	Yes
	ASM	Yes – to support Oracle RAC database
Oracle Database environment parameters	SGA_TARGET	384 GB
	PGA_AGGREGATE_TARGET	154 GB
	DB_CACHE_SIZE	172 GB
	DB_KEEP_CACHE_SIZE	76 GB
	DB_RECYCLE_CACHE_SIZE	20 GB
	LOG_BUFFER	512 MB
	USE_LARGE_PAGES	TRUE
	FILESYSTEMIO_OPTIONS	SETALL
	DB_FILE_MULTIBLOCK_READ_COUNT	128
	DISK_ASYNCH_IO	TRUE

Oracle ASM disk mappings

The following table lists volumes, LUNs, and ASM diskgroups.

Table 8 Volumes, LUNS, and ASM Diskgroups

ASM Diskgroup	ASM Disk	LUN Details	Purpose
OCR	OCR1 - OCR3	3 × 15 GB	Oracle cluster registry and voting disk
REDO	REDO01 - REDO16	32 × 20 GB	Online REDO log group
FRA	FRA01 - FRA16	16 × 2000 GB	Flash recovery area
TEMP	TEMP1 – TEMP16	16 × 200 GB	Temp
DATA	DATA001 – DATA128	128 × 200 GB	Application data

Oracle server configuration

The following table lists the operating system configurations for Oracle servers.

Table 9 Oracle Server OS Configurations

Server Configuration	Server OS Setting Details
RPMs for Oracle Database 19c	bc binutils compat-libcap1 compat-libstdc++ elfutils-libelf elfutils-libelf-devel fontconfig-devel glibc glibc-devel ksh libaio libaio-devel libXrender libXrender-devel libX11 libXau libXi libXtst

Server Configuration	Server OS Setting Details
	libgcc libstdc++ libstdc++-devel libxcb make net-tools (for Oracle RAC and Oracle Clusterware) nfs-utils (for Oracle ACFS) python (for Oracle ACFS Remote) python-configshell (for Oracle ACFS Remote) python-rtslib (for Oracle ACFS Remote) python-six (for Oracle ACFS Remote) targetcli (for Oracle ACFS Remote) openssh smartmontools sysstat oracleasm-support (2.1.12) oracleasm-lib (2.0.17)
/etc/multipath.conf	user_friendly_names: yes find_multipaths: yes path_grouping_policy: multibus path_selector: "service-time 0"
Swap space	64 GB
ORACLEASM_SCANORDER	For the current environment, the value is set to 'mpath' Modify the 'ORACLEASM_SCANORDER' value in the <i>/etc/sysconfig/oracleasm</i> file according to the multipath disk name string in the environment.
Parameter 'path_selector'	For OLTP Database, set "service-time 0" for path_selector in the <i>/etc/multipath.conf</i> file for the best performance.

Management server configuration

The following table lists the VSP E990 configuration for the management server cluster.

Table 10 VSP E990 Management Server Cluster Configuration

Attribute	Value
Purpose	VMware shared datastores Command device
Number and size of LDEVs for datastores	1 × 3000 GB
Number and size of command devices	1 × 100 MB
Storage port for management servers	7A, 7B, 8A, 8B

Server and application architecture

This reference architecture uses two Hitachi Advanced Server HA820 G2 servers with 3rd Generation Intel Xeon Scalable Processors (Ice Lake) for each storage system architecture that was tested. Two Hitachi Advanced Server DS120 G2 servers were used for VMware ESXi management server configuration.

This provides the compute power for the Oracle RAC database to manage complex database queries and a large volume of transaction processing in parallel.

The following table lists the details of the server configurations for this solution.

Table 11 Hitachi Advanced Server HA820 G2 and DS120 G2 Server Specifications

Hitachi Advanced Server	Server	Host Name	Role	CPU Core	RAM
HA820 G2	Oracle Server 1	sgrac01	Oracle RAC node 1	76 (2 × 38C)	768 GB (32 GB × 24)
	Oracle Server 2	sgrac02	Oracle RAC node 2	76 (2 × 38C)	768 GB (64 GB × 24)
DS120 G2	Management Server 1	VMware ESXi 1	Management VM hosts	24 (2 × 12C)	256 GB (32 GB × 8)
	Management Server 2	VMware ESXi 2		24 (2 × 12C)	256 GB (32 GB × 8)

SAN architecture

Map the provisioned LDEVs to multiple ports on each Hitachi Virtual Storage Platform E1090 (VSP E1090). These LDEV port assignments provide multiple paths to the storage system from the host for high availability. This reference architecture uses two dual port Emulex HBAs for each HA820 G2 server.

The SAN architecture includes:

- 8 SAN switch connections for VSP E1090 Fibre Channel ports.
- 8 SAN switch connections for server HBA ports.
- 4 SAN switch connections for VSP E990 Fibre Channel ports.
- 4 SAN switch connections for management server HBA ports.

The following table lists the Fibre Channel switch connection configuration on the VSP E1090 and database servers.

Table 12 Fibre Channel Switch Configuration

Server	HBA Ports	Storage Host Group	Switch Zone	Storage System	Storage Port	Brocade G620 Switch
HA820 G2 Server 1	HBA1_1	HA820_G2_62_HBA1_1	HA820_G2_62_HBA1_1_VSP_E1090_33_3A	VSP E1090	3A	SAN-switch 1
	HBA1_2	HA820_G2_62_HBA1_2	HA820_G2_62_HBA1_2_VSP_E1090_33_4A		4A	SAN-switch 2
	HBA2_1	HA820_G2_62_HBA2_1	HA820_G2_62_HBA2_1_VSP_E1090_33_3B		3B	SAN-switch 1
	HBA2_2	HA820_G2_62_HBA2_2	HA820_G2_62_HBA2_2_VSP_E1090_33_4B		4B	SAN-switch 2
HA820 G2	HBA1_1	HA820_G2_64_HBA1_1	HA820_G2_64_HBA1_1_VSP_E1090_33_7A			7A

Server	HBA Ports	Storage Host Group	Switch Zone	Storage System	Storage Port	Brocade G620 Switch
Server 2	HBA1_2	HA820_G2_64_HBA1_2	HA820_G2_64_HBA1_2_VSP_E1090_33_8A		8A	SAN-switch 2
	HBA2_1	HA820_G2_64_HBA2_1	HA820_G2_64_HBA2_1_VSP_E1090_33_7B		7B	SAN-switch 1
	HBA2_2	HA820_G2_64_HBA2_2	HA820_G2_64_HBA2_2_VSP_E1090_33_8B		8B	SAN-switch 2
DS120 G2 Server 1	HBA1_1	DS120_68_HBA1_1	DS120_68_HBA1_1_AS E32_50_7A	VSP E990	7A	SAN-switch 1
	HBA1_2	DS120_68_HBA1_2	DS120_68_HBA1_2_AS E32_50_8A		8A	SAN-switch 2
DS120 G2 Server 2	HBA1_1	DS120_69_HBA1_1	DS120_69_HBA1_1_AS E32_50_7B		7B	SAN-switch 1
	HBA1_2	DS120_69_HBA1_2	DS120_69_HBA1_2_AS E32_50_8B		8B	SAN-switch 2



Note: In a production environment, separate storage ports are recommended for the management servers to avoid impacting database performance. Shared storage ports can be used; however, port utilization should be monitored to avoid performance issues in high-performance environments.

Network architecture

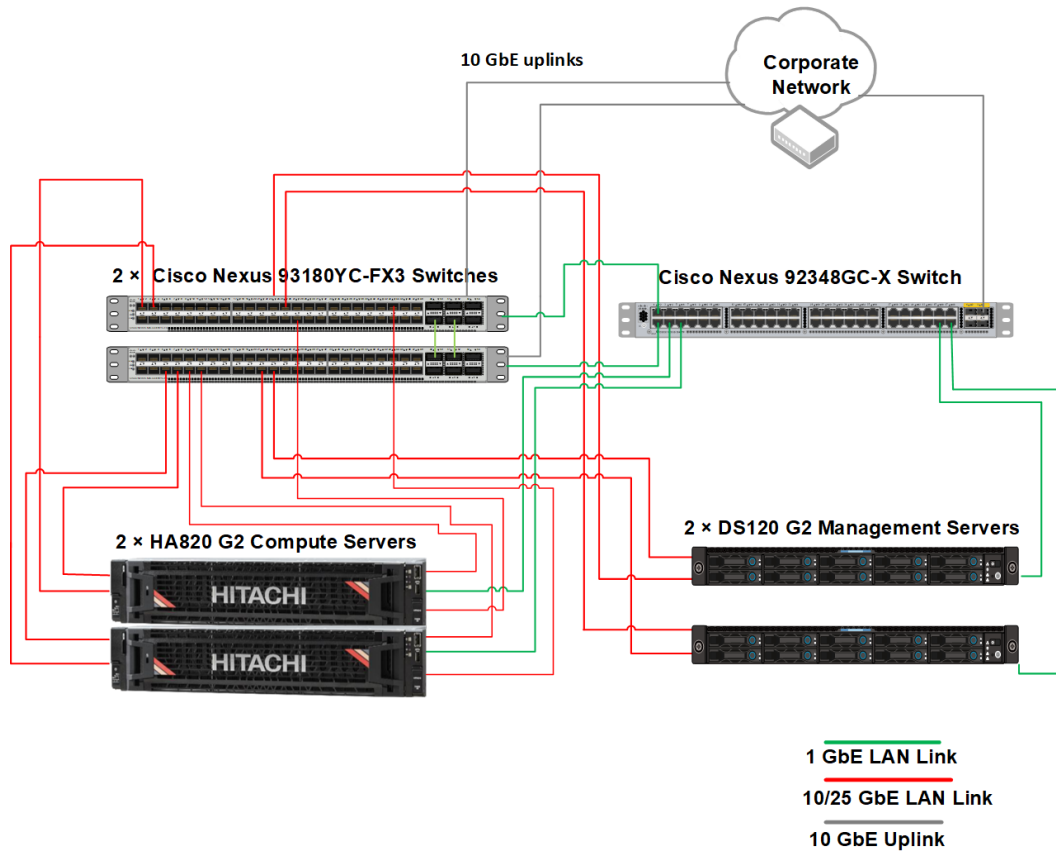
This architecture uses the following separate networks:

- Private Network (also called cluster interconnect) — This network must be scalable. In addition, it must meet the low latency needs of the network traffic generated by the cache synchronization of Oracle Real Application Clusters and inter-node communication among the nodes in the cluster.
- Public Oracle Network — This network provides client connections to Oracle Real Application Clusters and other applications.
- Management Network — This network is for hardware management console connections.

Note that Hitachi Vantara recommends using pairs of 25 Gbps NICs for the cluster interconnect network and public network. Observe these guidelines when configuring private and public networks in your environment:

- For each server in the clusterware configuration, use at least two identical, high-bandwidth, low-latency NICs for the interconnection.
- Use NIC bonding to provide failover and load balancing of interconnections within a server.
- Set all NICs to full duplex mode.
- Use at least two public NICs for client connections to the application and the database.
- Use at least two private NICs for the cluster interconnect.

The following figure shows the IP network switch connection.



The following table lists the test network configuration. Your values might be different.

When creating NIC bonding pairs, paired ports should be on different cards to eliminate a single point of failure (SPoF).

Table 13 Database Server Network Configuration

Server	NIC Port	VLAN/ Subnet	NIC Bond	IP Address	Network	Bandwidth (Gbps)	Cisco Nexus 93180YC-FX3 switch	
							Switch Number	Port
Oracle Database Server1	NIC 1 PORT 1	208	Bond0	192.168.208.91	Private	25	1	31
	NIC 2 PORT 1					25	2	
	NIC 1 PORT 2	242	Bond1	192.168.242.91	Public Oracle	25	1	32
	NIC 2 PORT 2					25	2	
	BMC- Dedicated NIC	242	-	192.168.242.161	Management	1	-	
Oracle Database Server2	NIC 1 PORT 1	208	Bond0	192.168.208.92	Private	25	1	34
	NIC 2 PORT 1					25	2	
	NIC 1 PORT 2	242	Bond1	192.168.242.92	Public Oracle	25	1	35
	NIC 2 PORT 2					25	2	
	BMC- Dedicated NIC	242	-	192.168.242.162	Management	1	-	
Management Server 1	BMC- Dedicated NIC	242	-	192.168.242.169	Management	1	-	
	NIC 1	244	-	192.168.244.101	Public Oracle	25	1	

Server	NIC Port	VLAN/ Subnet	NIC Bond	IP Address	Network	Bandwidth (Gbps)	Cisco Nexus 93180YC-FX3 switch	
							Switch Number	Port
	PORT 1							
Management Server 2	BMC- Dedicated NIC	242	-	192.168.242.170	Management	1	-	
	NIC 1 PORT 1	244	-	192.168.244.102	Public Oracle	25	1	

The following table lists the virtual IP address and SCAN name configuration that was used when testing the environment.

Table 14 Virtual IP Address and Scan Name Configuration

Server	Virtual IP Address	Scan Name pub-scan
Database Server 1	192.168.242.91	192.168.242.222
Database Server 2	192.168.242.92	192.168.242.223 192.168.242.224

The following table lists the virtual machine configurations running on the management server cluster. Virtual machine configurations listed in this table were required for the versions used for testing in the lab.

Table 15 Management Server Cluster Virtual Machine Configuration

Virtual Machine	vCPU	Virtual Memory	Disk Capacity	IP Address
vCenter	2	10 GB	300 GB	192.168.242.102
Hitachi Ops Center Administrator	4	16 GB	100 GB	192.168.242.81
Hitachi Ops Center Analyzer	4	32 GB	800 GB	192.168.242.194
Hitachi Ops Center detail view	4	10 GB	110 GB	192.168.242.197

Engineering validation

This section summarizes the key observations from the test results for the Hitachi Unified Compute Platform architecture for Oracle RAC deployment with Hitachi Virtual Storage Platform E1090.

Test methodology

Oracle Orion and the peakmarks 9.6 benchmark software tools were used to validate this solution.

Orion

Oracle Orion is a tool for predicting the performance of an Oracle database without having to install Oracle or create a database. Unlike other I/O calibration tools, Oracle Orion is expressly designed for simulating Oracle database I/O workloads using the same I/O software stack as Oracle. Orion can also simulate the effect of striping performed by Oracle Automatic Storage Management.

For more information about Orion, see “I/O Configuration and Design” in the Oracle Database Performance Tuning Guide at <https://docs.oracle.com/en/database/oracle/oracle-database/12.2/tgdba/IO-configuration-and-design.html#GUID-B89C41F4-B12A-49E1-BFB9-5BF978E2D6B3>.

peakmarks

Test results are demonstrated using peakmarks OLTP test cases.

peakmarks is benchmark software for Oracle platforms. It is used in our tests for the purposes of:

- Performance verification (quality assurance).
- Evaluation of different infrastructure products, technologies, and solutions (price/performance comparison).
- Performance optimization (efficiency)

This provides transparency and comparability in price versus performance considerations for Oracle infrastructure solutions.

Database configuration

The following table lists parameter details for a two-node Oracle Real Application Clusters ASM database.

Table 16 Two-node Oracle RAC ASM Database Parameters

Oracle Database Parameter	Value
Compatible	19.14.0.0.0
cluster_database	TRUE
cluster_database_instances	2
Oracle Database size	16 TB
Database storage type	ASM
Database fill factor	80%

Test environment

The following table lists the test environment details.

Table 17 Test Environment Details

Item	Description	Value
Operating system	-	OL 8.5
Workload type	-	OLTP/OLAP
Database size	-	16 TB
Number of physical cores	CPU cores	152
Memory	Server memory	768 GB per node
Network	Cluster interconnect	2 × 25 Gbps NIC bonding

Test results

The following tables list results of the Orion and peakmarks tests.

Table 18 ORION Test Results with VSP E1090 RAID 6 (6D+2P) Protection Type

Test Category	Test Case	Test Result	
		Throughput (IOPS or GBps)	RT (ms)
ORION	8KB Random Read	2,211,003	0.49
	8KB Random Write	184,798	0.75
	1MB Sequential Read	21.50 GBps	N/A
	1MB Sequential Write	9.78 GBps	N/A

Peakmarks Workload		VSP E1090 Compression Off		VSP E1090 Compression On	
		Throughput (IOPS or GBps)	RT (ms)	Throughput (IOPS or GBps)	RT (ms)
Server Performance	Buffer cache scan rate SRV-SCAN	316.39 GBps	N/A	281.01 GBps	N/A
Storage Performance	SQL sequential read STO-READ	20.59 GBps	N/A	20.82 GBps	N/A
	SQL random read 100% read (<1ms) STO-RANDOM	1,993,124	0.76	893,691	0.97
Log Writer Performance	Throughput REDO data LGWR-THR	2.75 GBps	N/A	2.27 GBps	N/A
DB Writer Performance	Throughput DB data DBWR-THR	6.05 GBps	N/A	5.47 GBps	N/A
Data Analytics Performance	Data scan storage system DA-STORAGE	19.64 GBps	N/A	15.53 GBps	N/A
	Data scan row store	283.20 GBps	N/A	232.07 GBps	N/A

Peakmarks Workload		VSP E1090 Compression Off		VSP E1090 Compression On	
		Throughput (IOPS or GBps)	RT (ms)	Throughput (IOPS or GBps)	RT (ms)
	DA-ROWSTORE				
Transaction Processing Performance	Light transaction 20% update TP-LIGHT	445,885	0.57	312,757	0.62
	Medium transaction 20% update TP-MEDIUM	19,593	5.87	13,198	4.85

peakmarks® test descriptions

The following table lists peakmarks® Key Performance Tests/Metrics for platform components in database operations.

Category	Key Performance Metric	peakmarks® Workload
Server System All accessed data is stored entirely in the database buffer cache. No I/O operations.	Query throughput and response time for simple queries	SRV-QUERY1
	Query throughput and response time for more complex queries	SRV-QUERY25
	Throughput logical reads for online reports	SRV-REPORT
	Scan throughput database buffer cache	SRV-SCAN
	Query throughput and response time for mixed queries and scans	SRV-MIXED
Storage System	SQL sequential I/O throughput	STO-READ
	SQL sequential I/O throughput - using smart scan (offload)	STO-OFFLOAD
	SQL random read throughput and service time - 100% read	STO-RANDOM
	SQL random read throughput and service time - 80% read	STO-RANDOM
	SQL random write throughput	STO-SCATTER

The following table lists peakmarks® Key Performance Metrics for critical database background processes.

Category	Key Performance Metric	peakmarks® Workload
Log Writer (LGWR)	Commit throughput and latency for small transactions	LGWR-LAT1
	Commit throughput and latency for medium-sized transactions	LGWR-LAT25
	Commit throughput and latency for large transactions	LGWR-LAT125
	Log Writer throughput	LGWR-THR
Database Writer (DBWR)	Database Writer throughput	DBWR-THR

The following table lists peakmarks® Key Performance Metrics for representative database operations.

Category	Key Performance Metric	peakmarks® Workload
Data Load	Throughput transactional data load - using the buffer cache	DL-BUFFER
	Throughput data warehouse data load - bypassing the buffer cache	DL-DIRECT
	Throughput IoT data load - using memory-optimized tables	DL-STREAM
Data Analytics	Throughput data scan - using the storage system	DA-STORAGE
	Throughput data scan - using smart scan	DA-OFFLOAD
	Throughput data scan - using row store	DA-ROWSTORE
	Throughput data scan - using column store	DA-COLSTORE
Transaction Processing	Transaction throughput and response time of light transactions	TP-LIGHT
	Transaction throughput and response time of medium transactions	TP-MEDIUM
	Transaction throughput and response time of heavy transactions	TP-HEAVY
	Transaction throughput and response time for mixed transactions	TP-MIXED

The following table lists peakmarks® Key Performance Metrics for PL/SQL application code.

Category	Key Performance Metric	peakmarks® Workload
PL/SQL	Throughput PL/SQL operations	PLS-MIXED
	Execution time in Fibonacci numbers (n = 42), SIMPLE-INTEGERS	PLS-FIBO (SI)

The following is a list of measurement units:

- [s] seconds
- [ms] milliseconds
- [μ s] microseconds
- [qps] queries per second
- [rps] rows per second
- [dbps] database blocks per second
- [tps] transactions per second
- [Mops] million operations per second
- [MBps] megabyte per second
- [IOPS] I/O operations per second

Product descriptions

The following products are used in this solution.

Hitachi Virtual Storage Platform E1090

The Hitachi Virtual Storage Platform E1090 (VSP E1090) storage system is a high-performance, large-capacity data storage system. The VSP E1090 all-flash arrays (AFAs) support NVMe and SAS solid-state drives (SSDs). The VSP E1090H hybrid models can be configured with both SSDs and hard disk drives (HDDs).

- The NVMe flash architecture delivers consistent, low-microsecond latency, which reduces the transaction costs of latency-critical applications and delivers predictable performance to optimize storage resources.
- The hybrid architecture allows for greater scalability and provides data-in-place migration support.

Hitachi Storage Virtualization Operating System RF

Hitachi Storage Virtualization Operating System RF powers the Hitachi Virtual Storage Platform (VSP) family. It integrates storage system software to provide system element management and advanced storage system functions. Used across multiple platforms, Storage Virtualization Operating System includes storage virtualization, thin provisioning, storage service level controls, dynamic provisioning, and performance instrumentation.

Flash performance is optimized with a patented flash-aware I/O stack, which accelerates data access. Adaptive inline data reduction increases storage efficiency while enabling a balance of data efficiency and application performance. Industry-leading storage virtualization allows SVOS RF to use third-party all-flash and hybrid arrays as storage capacity, consolidating resources for a higher ROI and providing a high-speed front end to slower, less-predictable arrays.

Hitachi Ops Center

Manage, optimize, orchestrate and protect your data with advanced IT analytics and automation using Hitachi Ops Center. Achieve new insights, accelerate resource delivery, eliminate risks, and speed innovation to modernize your data center operations.

Use the power of AI operations with the following:

- Administrator: Reduce storage management complexities for the Virtual Storage Platform. Intuitive graphical user interfaces (GUIs) and recommended configuration practices speed storage management operations so you spend more time on strategic efforts, not daily tasks.
- Analyzer: Improve IT operations with machine learning (ML) to drive resource service levels, utilization and automation at lower costs. Obtain operational visibility from virtual machines, servers, SAN switches to shared storage resources to optimize an application's full data path.
- Automator: Deliver resources up to 70% faster than manual processes. Free staff to focus on strategic initiatives.
- Protector: Meet tight service level requirements when protecting critical data and applications. Automatically support secondary business functions with data copies staff need to do their jobs. Make better use of backup data for activities, such as e-discovery and analysis. Simplify administration and replication management. Do it all with no disruption to production application availability and performance.

Hitachi Advanced Server HA820 G2

Hitachi Advanced Server HA820 G2 is a high-performance two-socket rackmount server designed for optimal performance and power efficiency. This allows owners to upgrade computing performance without overextending power consumption and offers non-latency support to virtualization environments that require maximum memory capacity. Hitachi Advanced Server HA820 G2 provides flexible I/O scalability for today's diverse data center application requirements.

Hitachi Advanced Server DS120 G2

With support for two Intel Xeon Scalable processors in just 1U of rack space, the Hitachi Advanced Server DS120 G2 delivers exceptional compute density. It provides flexible memory and storage options to meet the needs of converged and hyperconverged infrastructure solutions, as well as for dedicated application platforms such as internet of things (IoT) and data appliances.

The Intel Xeon Scalable processor family is optimized to address the growing demands on today's IT infrastructure. The server provides 32 slots for high-speed DDR4 memory, allowing up to 4 TB memory capacity with RDIMM population (128 GB × 32) or 8 TB (512 GB × 16) of Intel Optane Persistent Memory. DS120 G2 supports up to 12 hot-pluggable, front-side-accessible 2.5-inch non-volatile memory express (NVMe), serial-attached SCSI (SAS), serial-ATA (SATA) hard disk drive (HDD), or solid-state drives (SSD). The system also offers 2 onboard M.2 slots.

With these options, DS120 G2 can be flexibly configured to address both I/O performance and capacity requirements for a wide range of applications and solutions.

Oracle Linux

[Oracle Linux](#) (OL, formerly known as Oracle Enterprise Linux) is a Linux distribution packaged and freely distributed by Oracle, available partially under the GNU General Public License. It is compiled from Red Hat Enterprise Linux source code, replacing Red Hat branding with Oracle branding.

Oracle Database with Real Application Clusters Option

[Oracle Database](#) has a multi-tenant architecture used to consolidate many databases quickly and manage them as a cloud service. Oracle Database also includes in-memory data processing capabilities for analytical performance. Additional database innovations deliver efficiency, performance, security, and availability. Oracle Database comes in two editions: Enterprise Edition and Standard Edition 2.

[Oracle Real Application Clusters](#) (Oracle RAC) is a clustered version of Oracle Database. It is based on a comprehensive high-availability stack that can be used as the foundation of a database cloud system, as well as a shared infrastructure. This ensures high availability, scalability, and agility for any application.

[Oracle Automatic Storage Management](#) (Oracle ASM) is a volume manager and file system for Oracle database files. This supports both single-instance Oracle Database and Oracle Real Application Clusters configurations. Oracle ASM is the recommended storage management solution that provides an alternative to conventional volume managers, file systems, and raw devices.

VMware ESXi

[VMware ESXi](#) is a foundation for the virtual infrastructure used for the management applications in this architecture. This allows the environment to operate independently from any general-purpose operating system, offering security, reliability, and simplified management.

VMware vCenter Server Appliance

The [VMware vCenter Server Appliance](#) is a preconfigured Linux virtual machine, which is optimized for running VMware vCenter Server and the associated services on Linux.

vCenter Server Appliance is an Open Virtualization Format (OVF) template. The appliance is imported to an ESXi host and configured through the web-based interface. It comes pre-installed with all the components needed to run a vCenter Server. These include vCenter SSO (Single Sign-on), Inventory Service, vSphere Web Client, and the vCenter Server itself.

Brocade switches from Broadcom

Brocade and Hitachi Vantara have partnered to deliver storage networking and data center solutions. These solutions reduce complexity and cost, as well as enable virtualization and cloud computing to increase business agility.

Brocade Fibre Channel switches deliver industry-leading performance, simplifying scale-out network architectures. Get the high-performance, availability, and ease of management you need for a solid foundation to grow the storage network you want.

Cisco Nexus switches

The Cisco Nexus switch product line provides a series of solutions that make it easier to connect and manage disparate data center resources with software-defined networking (SDN). Leveraging the Cisco Unified Fabric, which unifies storage, data and networking (Ethernet/IP) services, the Nexus switches create an open, programmable network foundation built to support a virtualized data center environment.

Hitachi Vantara

Corporate Headquarters
2535 Augustine Drive
Santa Clara, CA 95054 USA



HitachiVantara.com/contact