Reference Architecture for Workloads using the Lenovo ThinkAgile HX Series Appliances

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Provides a technical overview of Lenovo ThinkAgile HX Series appliances and the Lenovo ThinkAgile SX for Nutanix solution

Contains performance data and sizing recommendations

Shows variety of workloads that can be used in a hyper-converged environment

Explains reliability and performance features of hyper-converged appliances

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1 Introduction

The intended audience for this document is technical IT architects, system administrators, and managers who are interested in executing workloads on the Lenovo ThinkAgile HX Series appliances and ThinkAgile SXN solutions.

HX Series appliances provide a hyper-converged infrastructure. Hyper-converged means incorporating multiple components like compute and storage into a single entity through software. A hyper-converged infrastructure seamlessly pools compute and storage to deliver high performance for the virtual workloads and provides flexibility to combine the local storage using a distributed file system to eliminate shared storage such as SAN or NAS. These factors make the solution cost effective without compromising the performance.

The SXN solution integrates HX appliances and network switches together with a rack and power distribution units (PDUs) into an integrated solution that provides easy deployment and manageability.

Chapter 2 provides a technical overview of the HX Series appliances together with the SXN solution and explains why the combination of Lenovo servers and Nutanix software provides best of breed system performance and reliability. Chapter 3 provides some deployment models for HX Series appliances and SXN solution.

Each of the subsequent chapters in the document describes a particular virtualized workload and provides recommendations on what appliance model to use and how to size the appliance to that workload. Some best practice recommendations are also listed. HX Series appliances are not limited to just the workloads described in this reference architecture and can execute any virtualized workload on the supported hypervisors.

This RA describes five workloads:

- Citrix XenDesktop
- Microsoft Exchange
- Microsoft SQL Server
- VMware Horizon
- VMware vCloud Suite

The final chapter provides references about the ThinkAgile HX Series appliances, ThinkAgile SX, and Nutanix software.

2 Technical overview of appliances

This chapter provides an overview of the ThinkAgile HX and ThinkAgile SX appliances including the associated software, systems management, and networking. The last section provides an overview of the performance and reliability features of the ThinkAgile HX appliances.

2.1 ThinkAgile HX appliances

Lenovo ThinkAgile HX Series appliances are designed to help you simplify IT infrastructure, reduce costs, and accelerate time to value. These hyper-converged appliances from Lenovo combine industry-leading hyper-convergence software from Nutanix with Lenovo enterprise platforms. Several common uses for the Lenovo ThinkAgile HX Series appliances that feature Intel Xeon Scalable processors:

- Enterprise workloads
- Private and hybrid clouds
- Remote office and branch office (ROBO)
- Server virtualization
- Virtual desktop infrastructure (VDI)
- Small-medium business (SMB) workloads

Starting with as few as three nodes to keep your acquisition costs down, the Lenovo ThinkAgile HX Series appliances are capable of immense scalability as your needs grow.

The Lenovo ThinkAgile HX Series appliances are available in five families that can be tailored to your needs:

- Lenovo ThinkAgile HX1000 Series: optimized for ROBO environments
- Lenovo ThinkAgile HX2000 Series: optimized for SMB environments
- Lenovo ThinkAgile HX3000 Series: optimized for compute-heavy environments
- Lenovo ThinkAgile HX5000 Series: optimized for storage-heavy workloads
- Lenovo ThinkAgile HX7000 Series: optimized for high-performance workloads

For more information about the system specifications and supported configurations, refer to the product guides for the Lenovo ThinkAgile HX Series appliances based on the Intel Xeon Scalable processor:

- Lenovo ThinkAgile HX1000 Series: lenovopress.com/lp0726
- Lenovo ThinkAgile HX2000 Series: lenovopress.com/lp0727
- Lenovo ThinkAgile HX3000 Series: lenovopress.com/lp0728
- Lenovo ThinkAgile HX5000 Series: lenovopress.com/lp0729
- Lenovo ThinkAgile HX7000 Series: lenovopress.com/lp0730

The diagrams below show the ten Intel Xeon Scalable processor-based HX appliances.

HX1320:

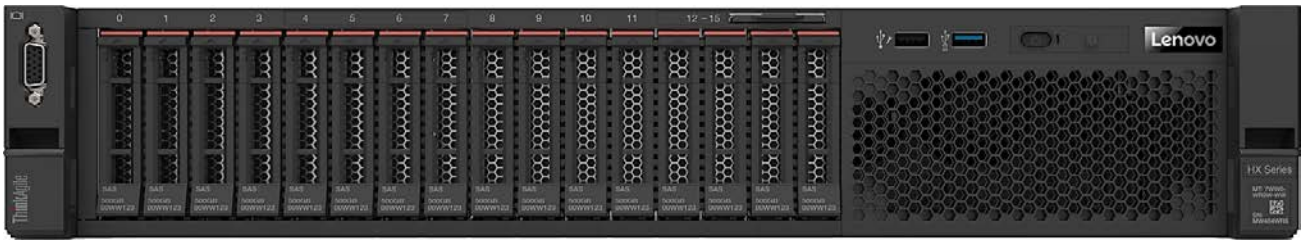
HX1520-R:

HX2320-E:

HX2720-E:

HX3320:

HX3520-G:



HX3720:

HX5510 and HX5510-C:

HX7520:

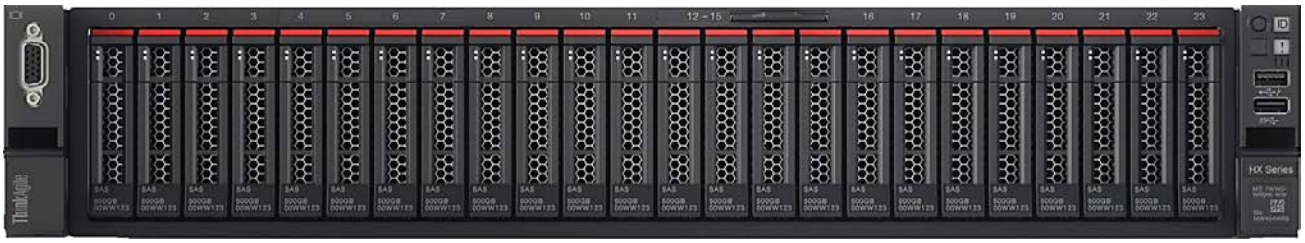


Table 1 provides a summary of the default configurations for the nine HX Series appliances (including all-flash variations).

Table 1: Default configurations for HX Series appliances

Model	Intel Xeon processor	Memory (RDIMMs)	Storage controller	SSDs	HDDs	NIC
HX1320	1x 4110 8C	96GB (6x 16GB)	1x 430-8i	3.84TB (2x 1.92TB)	8TB (2x 4TB)	2x 10GbE RJ-45
HX1520-R	1x 4114 10C	192GB (12x 16GB)	1x 430-16i	3.84TB (2x 1.92TB)	60TB (10x 6TB)	2x 10GbE RJ-45
HX2320-E	2x 4108 8C	192GB (12x 16GB)	1x 430-8i	1.92TB (1x 1.92TB)	6TB (6x 1TB)	2x 10GbE RJ-45
HX2720-E	1x 4108 8C	192GB (12x 16GB)	1x 430-8i	1.92TB (1x 1.92TB)	4TB (4x 1TB)	2x 10GbE SFP+
HX3320 Hybrid	2x 6136 12C	384GB (12x 32GB)	1x 430-16i	3.84TB (2x 1.92TB)	6TB (6x 1TB)	2x 10GbE SFP+
HX3320 All Flash	2x 6136 12C	384GB (12x 32GB)	1x 430-16i	11.52TB (6x 1.92TB)	N/A	2x 10GbE SFP+
HX3520-G Hybrid	2x 6126 12C	384GB (12x 32GB)	1x 430-16i	3.84TB (2x 1.92TB)	12TB (12x 1TB)	4x 10GbE SFP+
HX3520-G All Flash	2x 6126 12C	384GB (12x 32GB)	1x 430-16i	23.04TB (12x 1.92TB)	N/A	4x 10GbE SFP+
HX3720 Hybrid	2x 6126 12C	384GB (12x 32GB)	1x 430-8i	3.84TB (2x 1.92TB)	8TB (4x 2TB)	2x 10GbE SFP+
HX3720 All Flash	2x 6126 12C	384GB (12x 32GB)	1x 430-8i	7.68TB (4x 1.92TB)	N/A	2x 10GbE SFP+
HX5520	2x 6140 18C	384GB (12x 32GB)	1x 430-16i	3.84TB (2x 1.92TB)	60TB (10x 6TB)	2x 10GbE SFP+
HX5520-C	1x 4110 8C	64GB (4x 16GB)	1x 430-16i	3.84TB (2x 1.92TB)	60TB (10x 6TB)	2x 10GbE SFP+
HX7520 Hybrid	2x 8164 26C	768GB (24x 32GB)	3x 430-8i	7.68TB (4x 1.92TB)	32TB (16x 2TB)	4x 10GbE SFP+
HX7520 All Flash	2x 8164 26C	768GB (24x 32GB)	3x 430-8i	34.56TB (18x 1.92TB)	N/A	4x 10GbE SFP+

2.2 ThinkAgile SX for Nutanix

Designed for easy deployment and manageability, the Lenovo ThinkAgile SX for Nutanix (SXN) solution integrates state-of-the-art Lenovo ThinkAgile HX Series appliances, premier Lenovo networking and management infrastructure into a turnkey, virtualization-ready system. Lenovo ThinkAgile Advantage provides comprehensive lifecycle support and 24x7 end-to-end case management with a Lenovo Single Point of Support. Collaborating with Nutanix, Lenovo has created a best-of-breed hyperconverged rack-scale solution with innovative, first-to-market features, giving you the freedom to delight your customers.

The turnkey ThinkAgile SX for Nutanix systems ship from Lenovo factories to the customer site fully integrated, tested, and configured for breakthrough time-to-value and reduced business risk. Thanks to innovative Lenovo factory automation of the majority of onsite steps, ThinkAgile SXN helps customers realize significant time and cost savings for up to 80 percent faster deployment.

ThinkAgile SXN includes innovative, industry-first features through tight integration with the Nutanix Prism user interface (see section 2.3.3). Industry-unique Lenovo ThinkAgile Network Orchestrator on the Lenovo CNOS switches (see section 2.3.4) works with Prism management to reduce errors and remove scheduled maintenance windows by automatically configuring the switches in response to changes in the virtual environment. Lenovo XClarity Pro provides a simple, efficient tool for managing the hardware infrastructure. Rated #1 in reliability for the fourth year running, Lenovo platforms leverage advanced algorithms to send proactive platform alerts to XClarity, so that administrators can take action prior to component failures, reducing in increased uptime.

ThinkAgile SXN enables customers to deploy faster and have a lower total cost of ownership, while leveraging rack-level scalability, tight integration with Lenovo networking, an agile cloud-ready environment, and end-to-end Lenovo ThinkAgile Advantage services and support.

ThinkAgile SXN is offered in two models: ThinkAgile SXN3000 for a 42U rack and ThinkAgile SXN3000 for a 25U rack. The 25U model supports up to sixteen 1U and 2U HX appliances and the 42U model supports up to thirty-two 1U, 2U, or 2U4N appliances. Appliances can be combined providing a maximum of 16U is used in the 25U model and a maximum of 36U is used in the 42U model. The 2U4N HX3720 is restricted to the 42U model only. Both models can include the HX1000, HX3000, HX5000, and HX7000 series appliances but not the two HX2000 series appliances which are reserved for small SMB clusters.

See the ThinkAgile SXN product guide for more information: lenovopress.com/lp0731.

It is also possible to order more than one model and connect them together into a multi-rack configuration using spine switches such as the Lenovo RackSwitch G8332.

Figure 1 shows an example of the SXN3000 42U model with four 1U appliances, twelve 2U appliances, and 16 2U4N appliances.

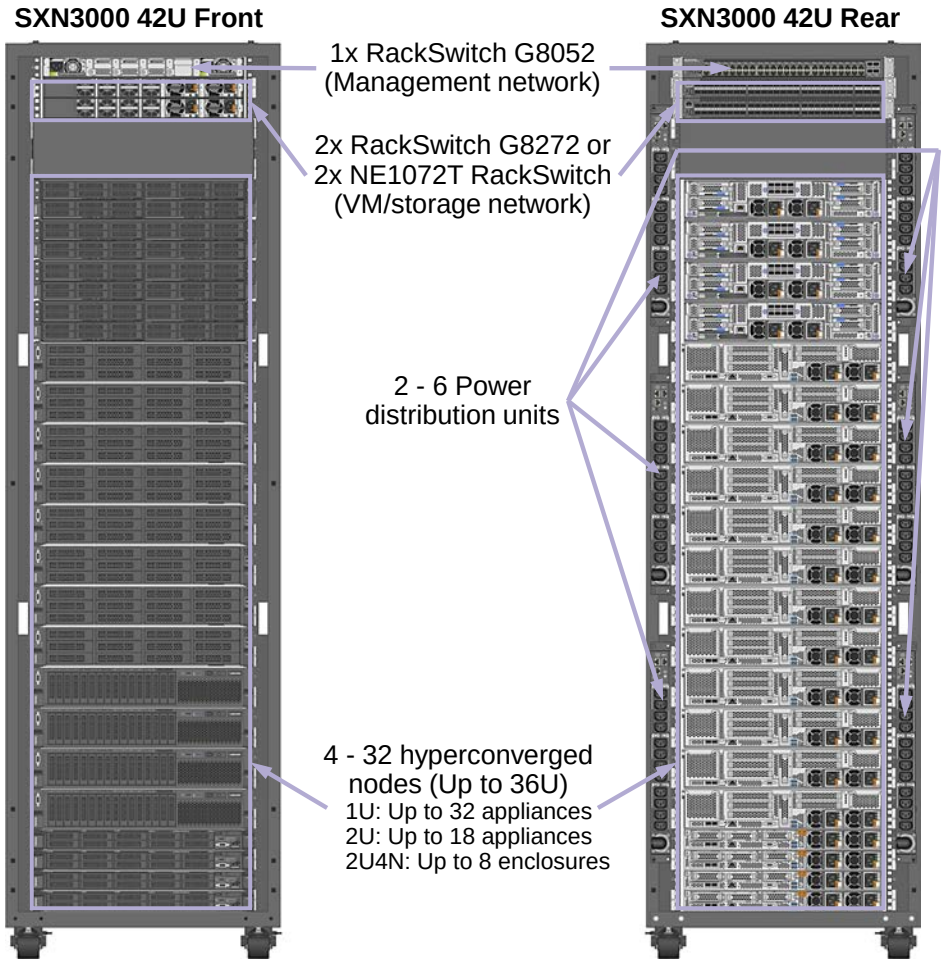


Figure 1: SXN3000 42U model

Figure 2 shows an example of the SXN3000 25U model with eight 1U appliances and four 2U appliances.

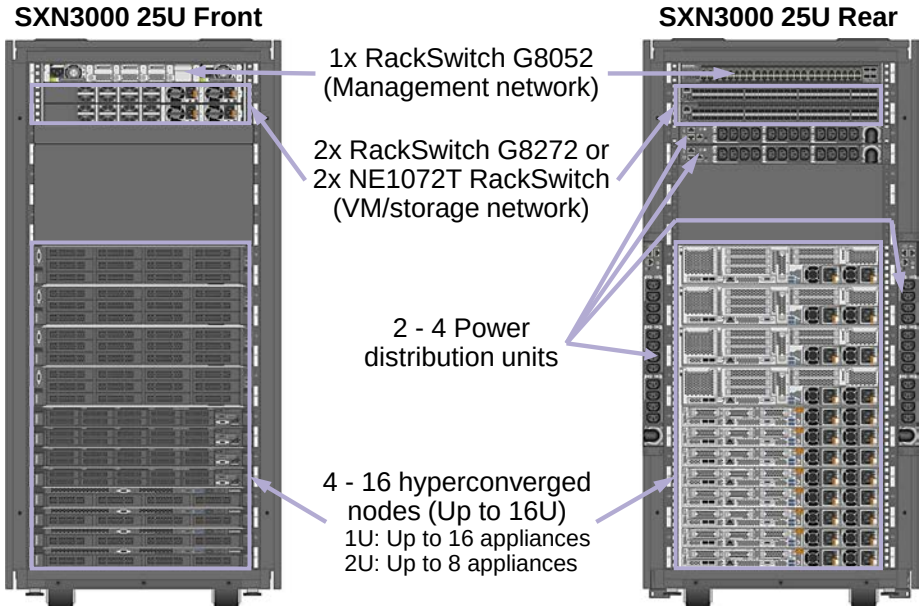


Figure 2: SXN3000 25U model

2.3 Software components

This section gives an overview of the software components used in the solution.

2.3.1 Hypervisor

The ThinkAgile HX Series appliances support the following hypervisors:

- Nutanix Acropolis Hypervisor based on KVM (AHV)
- VMware ESXi 6.0 U3
- VMware ESXi 6.5 U1

The HX Series appliances come standard with the Nutanix Acropolis Hypervisor (AHV) or VMware ESXi hypervisors preloaded in the factory.

With the ThinkAgile SXN models, it is optional to purchase up to 12 VMware vCenter licenses and VMware vSphere licenses. The number of vSphere licenses is based on the total number of ESXi nodes selected in the configurator.

2.3.2 Lenovo XClarity Administrator

Lenovo XClarity Administrator is a centralized systems management solution that helps administrators deliver infrastructure faster. This solution integrates easily with Lenovo servers, ThinkAgile HX Series appliances, and Flex System, providing automated agent-less discovery, monitoring, firmware updates, and configuration management.

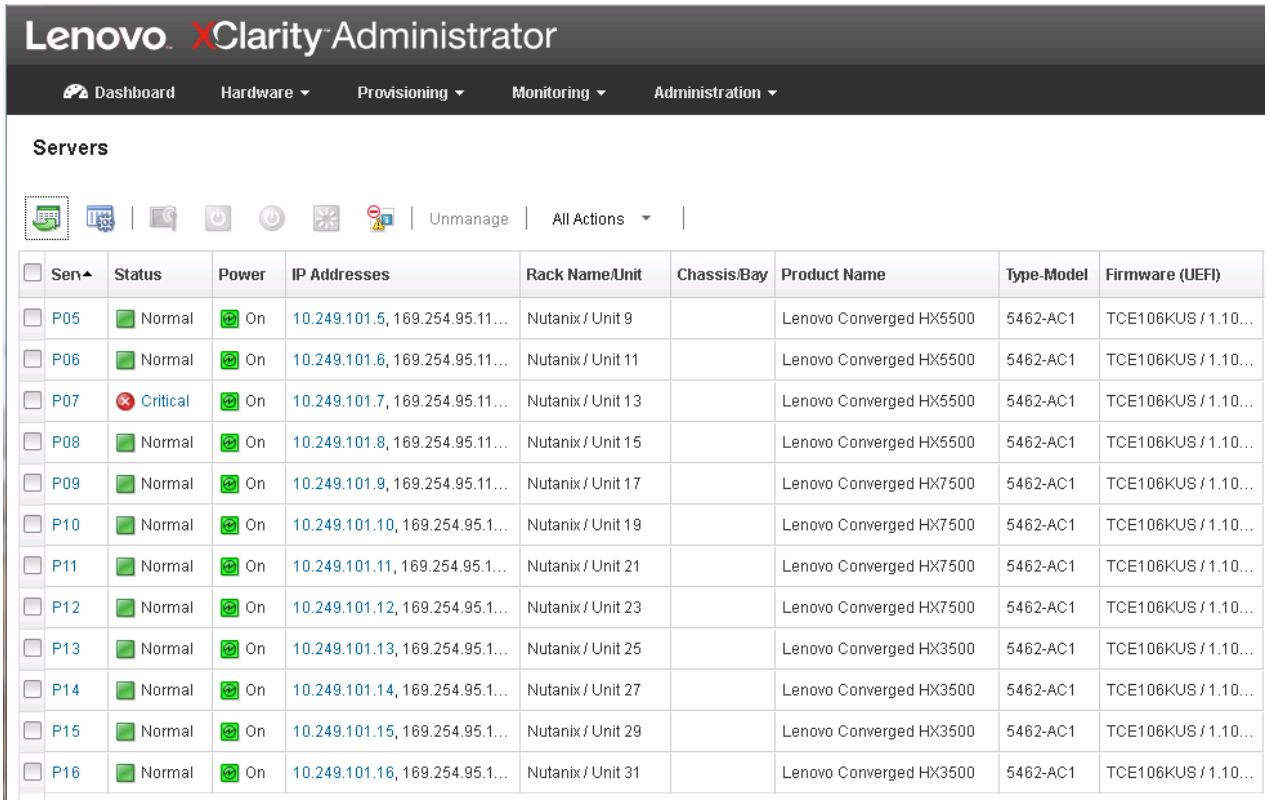
Lenovo XClarity Pro goes one step further and provides entitlement to additional functions such as XClarity Integrators for Microsoft System Center and VMware vCenter, XClarity Administrator Configuration Patterns and Service and Support.

Lenovo XClarity Administrator is an optional software component for the Lenovo ThinkAgile HX Series appliances but Lenovo XClarity Pro licenses are always provided with ThinkAgile XSN models.

Lenovo XClarity Administrator which can be used to manage firmware upgrades outside of the Nutanix Prism web console. Note that XClarity should not be used to install hypervisors and Nutanix Foundation should be used instead.

Lenovo XClarity Administrator is provided as a virtual appliance that can be quickly imported into a virtualized environment. XClarity can either be installed on a separate server or a server within a Nutanix cluster providing that the hardware management network with the server IMMs is routable from the server hosting the XClarity VM.

Figure 3 shows the Lenovo XClarity administrator interface with some HX Series appliances.



Sen	Status	Power	IP Addresses	Rack Name/Unit	Chassis/Bay	Product Name	Type-Model	Firmware (UEFI)
P05	Normal	On	10.249.101.5, 169.254.95.11...	Nutanix / Unit 9		Lenovo Converged HX5500	5462-AC1	TCE106KUS / 1.10...
P06	Normal	On	10.249.101.6, 169.254.95.11...	Nutanix / Unit 11		Lenovo Converged HX5500	5462-AC1	TCE106KUS / 1.10...
P07	Critical	On	10.249.101.7, 169.254.95.11...	Nutanix / Unit 13		Lenovo Converged HX5500	5462-AC1	TCE106KUS / 1.10...
P08	Normal	On	10.249.101.8, 169.254.95.11...	Nutanix / Unit 15		Lenovo Converged HX5500	5462-AC1	TCE106KUS / 1.10...
P09	Normal	On	10.249.101.9, 169.254.95.11...	Nutanix / Unit 17		Lenovo Converged HX7500	5462-AC1	TCE106KUS / 1.10...
P10	Normal	On	10.249.101.10, 169.254.95.1...	Nutanix / Unit 19		Lenovo Converged HX7500	5462-AC1	TCE106KUS / 1.10...
P11	Normal	On	10.249.101.11, 169.254.95.1...	Nutanix / Unit 21		Lenovo Converged HX7500	5462-AC1	TCE106KUS / 1.10...
P12	Normal	On	10.249.101.12, 169.254.95.1...	Nutanix / Unit 23		Lenovo Converged HX7500	5462-AC1	TCE106KUS / 1.10...
P13	Normal	On	10.249.101.13, 169.254.95.1...	Nutanix / Unit 25		Lenovo Converged HX3500	5462-AC1	TCE106KUS / 1.10...
P14	Normal	On	10.249.101.14, 169.254.95.1...	Nutanix / Unit 27		Lenovo Converged HX3500	5462-AC1	TCE106KUS / 1.10...
P15	Normal	On	10.249.101.15, 169.254.95.1...	Nutanix / Unit 29		Lenovo Converged HX3500	5462-AC1	TCE106KUS / 1.10...
P16	Normal	On	10.249.101.16, 169.254.95.1...	Nutanix / Unit 31		Lenovo Converged HX3500	5462-AC1	TCE106KUS / 1.10...

Figure 3: XClarity Administrator interface

2.3.3 Nutanix Prism

Nutanix Prism gives administrators a simple and elegant way to manage virtual environments. Powered by advanced data analytics and heuristics, Prism simplifies and streamlines common workflows within a data center.

Nutanix Prism is a part of the Nutanix software preloaded on the appliances and offers the following features:

- Single point of control
    - Accelerates enterprise-wide deployment
    - Manages capacity centrally
    - Adds nodes in minutes
    - Supports non-disruptive software upgrades with zero downtime
    - Integrates with REST APIs and PowerShell
- Monitoring and alerting
    - Tracks infrastructure utilization (storage, processor, memory)
    - Centrally monitors multiple clusters across multiple sites
    - Monitors per virtual machine (VM) performance and resource usage
    - Checks system health
    - Generates alerts and notifications

- Integrated data protection
    - Offers customizable RPO/RTO and retention policies
    - Supports configurable per-VM replication (1:1, 1:many and many:1)
    - Provides efficient VM recovery
    - Deploys affordable data recovery (DR) and backup to the cloud
- Diagnostics and troubleshooting
    - Provides time-based historical views of VM activity
    - Performs proactive alert analysis
    - Correlates alerts and events to quickly diagnose issues
    - Generates actionable alerts and reduces resolution times
    - Analyzes trending patterns for accurate capacity planning

2.3.4 ThinkAgile Network Orchestrator for Nutanix

The Lenovo® ThinkAgile™ Network Orchestrator is a unique feature of the Lenovo RackSwitch CNOS (Cloud Network OS) network switch firmware that automatically provisions the switches as needed, on-the-fly, to support changes in the virtual network, such as the creation, moving, and shutdown of virtual machines, as well as manipulation of guest virtual machines on VLANs. These tasks are performed dynamically in response to PRISM commands, with the switches configured to detect the changes and act upon them. This software capability simplifies the server administrator's tasks by reducing the need to provision the switches, reducing maintenance windows, reducing human error, and dramatically saving time and administrative costs. The switches learn of changes in the environment from PRISM and dynamically modify their configurations as needed.

The ThinkAgile Network Orchestrator capability is supported with the CNOS version 10.3.2.0 or higher and the Acropolis hypervisor AOS version 5.0.2 and higher. See the following paper for more details:

lenovopress.com/lp0604-thinkagile-network-orchestrator-for-nutanix

2.3.5 Nutanix Foundation

Nutanix Foundation is a separate utility that you use to orchestrate the installation of hypervisors and Nutanix software on one or more nodes. The maximum number of nodes that can be deployed at one time is 20.

Foundation is available both as a stand-alone VM and also integrated into the CVM. Because CVM is pre-installed in the factory, the CVM integration of Foundation simplifies the deployment and cluster creation of new servers delivered from the factory.

The dual M.2 boot drives must be configured as a RAID 1 mirrored array for installation to be successful.

2.3.6 Nutanix Controller VM

The Nutanix Controller VM (CVM) is the key to hyper-converged capability and each node in a cluster has its own instance. Figure 4 shows the main components of the CVM.

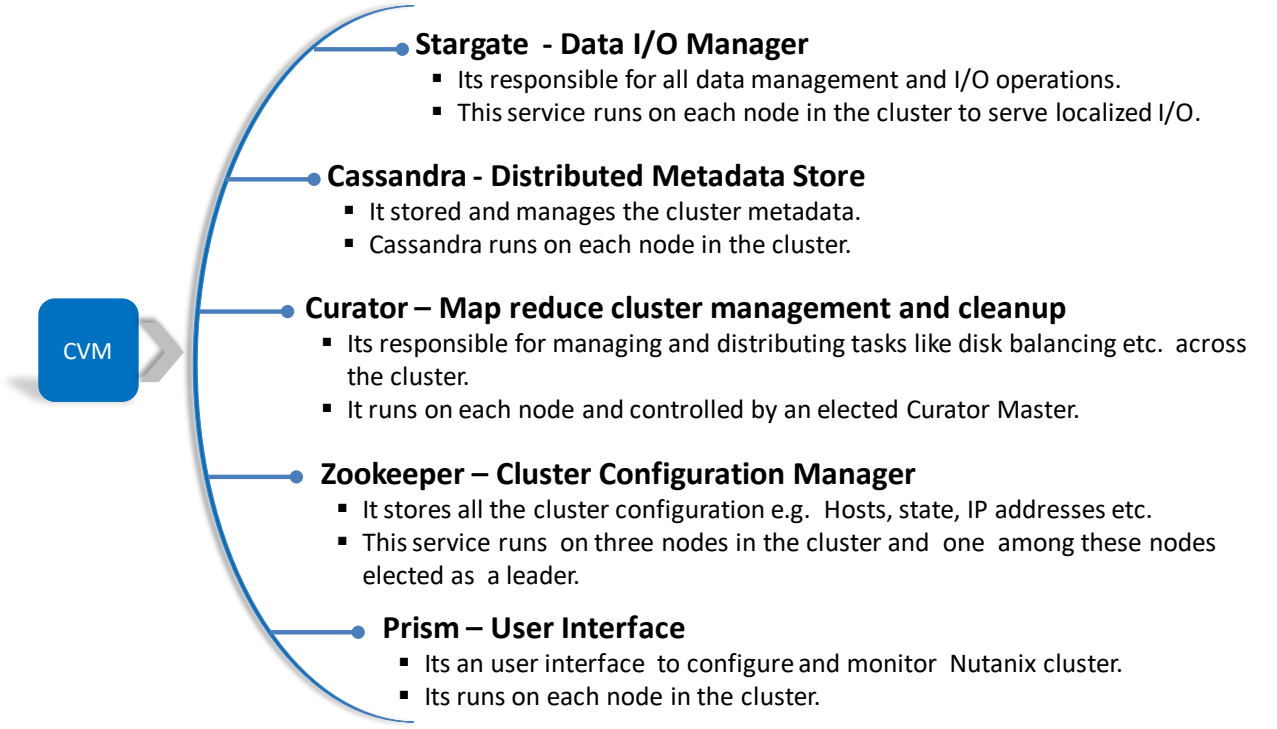


Figure 4: Controller VM components

The CVM works as interface between the storage and hypervisor to manage all I/O operations for the hypervisor and user VMs running on the nodes as shown in Figure 5.

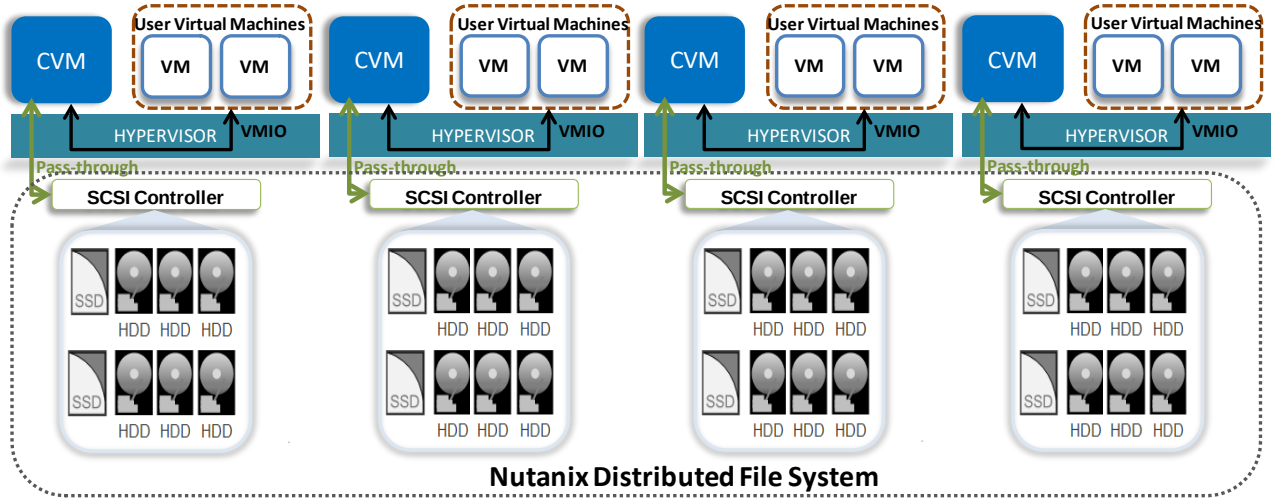


Figure 5: CVM interaction with Hypervisor and User VMs

CVM virtualizes all the local storage attached to each node in a cluster and presents it as centralized storage array using Nutanix Distributed File System (NDFS). All I/O operations are handled locally to provide the highest performance. See section 2.6 for more details on the performance features of NDFS.

2.4 Data network components

The data network is the fabric that carries all inter-node storage I/O traffic for the shared Lenovo HX distributed file system, in addition to the user data traffic via the virtual Network Interface Cards (NICs) exposed through the hypervisor to the virtual machines.

Each HX Series appliance contains between zero and two dual-port 10GbE network adapters as well as 4 on-board 1GbE ports. The hypervisors are configured by the Nutanix software so that the fastest network ports on the appliance are pooled for the data network. The hypervisor VM management network should use the same network. Because all of the network ports are pooled, each appliance only needs two network IP addresses; one for the hypervisor and one for the Nutanix CVM. These IP addresses should be all on the same subnet.

All storage I/O for virtual machines (VMs) running on a HX Series appliance node is handled by the hypervisor on a dedicated private network. The I/O request is handled by the hypervisor, which then forwards the request to the private IP on the local controller VM (CVM). The CVM then performs the remote data replication with other nodes in the cluster using its external IP address. In most cases, read request traffic is served locally and does not enter the data network. This means that the only traffic in the public data network is remote replication traffic and VM network I/O (i.e. user data). In some cases, the CVM will forward requests to other CVMs in the cluster, such as if a CVM is down or data is remote. Also, cluster-wide tasks, such as disk balancing, temporarily generate I/O traffic on the data network.

For more information on the network architecture see nutanixbible.com.

2.4.1 Data network switches

The following Lenovo 10GbE TOR switches are recommended for use in a HX Series cluster:

- Lenovo ThinkSystem NE1032 RackSwitch
- Lenovo RackSwitch G8272
- Lenovo ThinkSystem NE1072T RackSwitch
- Lenovo ThinkSystem NE2572 RackSwitch

Lenovo ThinkSystem NE1032 RackSwitch

The Lenovo ThinkSystem NE1032 RackSwitch (as shown in Figure 6) is a 1U rack-mount 10 Gb Ethernet switch that delivers lossless, low-latency performance with feature-rich design that supports virtualization, Converged Enhanced Ethernet (CEE), high availability, and enterprise class Layer 2 and Layer 3 functionality. The switch delivers line-rate, high-bandwidth switching, filtering, and traffic queuing without delaying data.

The NE1032 RackSwitch has 32x SFP+ ports that support 1 GbE and 10 GbE optical transceivers, active optical cables (AOCs), and direct attach copper (DAC) cables. The switch helps consolidate server and storage networks into a single fabric, and it is an ideal choice for virtualization, cloud, and enterprise workload solutions.

Figure 6: Lenovo ThinkSystem NE1032 RackSwitch

For more information, see this website: lenovopress.com/lp0605

Lenovo RackSwitch G8272

The Lenovo RackSwitch G8272 uses 10Gb SFP+ and 40Gb QSFP+ Ethernet technology and is specifically designed for the data center. It is an enterprise class Layer 2 and Layer 3 full featured switch that delivers line-rate, high-bandwidth switching, filtering, and traffic queuing without delaying data. Large data center-grade buffers help keep traffic moving, while the hot-swap redundant power supplies and fans (along with numerous high-availability features) help provide high availability for business sensitive traffic.

The RackSwitch G8272 (shown in Figure 7), is ideal for latency sensitive applications, such as high-performance computing clusters and financial applications. In addition to the 10 Gb Ethernet (GbE) and 40 GbE connections, the G8272 can use 1 GbE connections.

Figure 7: Lenovo RackSwitch G8272

For more information, see this website: lenovopress.com/tips1267

Lenovo ThinkSystem NE1072T RackSwitch

The Lenovo ThinkSystem NE1072T RackSwitch that uses 10GBASE-T and 40 Gb QSFP+ Ethernet technology is specifically designed for the data center. It is ideal for today's big data, cloud, and enterprise workload solutions. It is an enterprise class Layer 2 and Layer 3 full featured switch that delivers line-rate, high-bandwidth switching, filtering, and traffic queuing without delaying data. Large data center-grade buffers help keep traffic moving, while the hot-swap redundant power supplies and fans (along with numerous high-availability features) help provide high availability for business sensitive traffic.

The NE1072T RackSwitch (as shown in Figure 8) has 48x 1/10 Gb Ethernet (RJ-45) fixed ports and 6x QSFP+ ports that support 40 GbE optical transceivers, active optical cables (AOCs), and direct attach copper (DAC) cables. The QSFP+ ports can also be split out into four 10 GbE ports by using QSFP+ to 4x SFP+ DAC or active optical breakout cables.

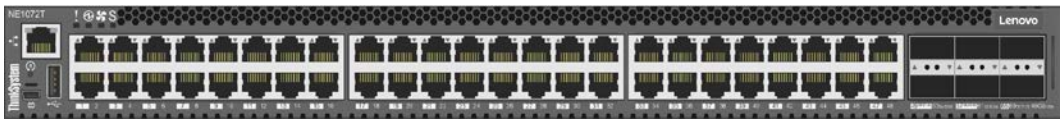


Figure 8: Lenovo ThinkSystem NE1072T RackSwitch

For more information, see this website: lenovopress.com/lp0607

Lenovo ThinkSystem NE2572 RackSwitch

The Lenovo ThinkSystem NE2572 RackSwitch is designed for the data center and provides 10 Gb/25 Gb Ethernet connectivity with 40 Gb/100 Gb Ethernet upstream links. It is ideal for big data, cloud, and enterprise workload solutions. It is an enterprise class Layer 2 and Layer 3 full featured switch that delivers line-rate,

high-bandwidth switching, filtering, and traffic queuing without delaying data. Large data center-grade buffers help keep traffic moving, while the hot-swap redundant power supplies and fans (along with numerous high-availability software features) help provide high availability for business sensitive traffic.

The NE2572 RackSwitch (as shown in Figure 9) has 48x SFP28/SFP+ ports that support 10 GbE SFP+ and 25 GbE SFP28 optical transceivers, active optical cables (AOCs), and direct attach copper (DAC) cables. The switch also offers 6x QSFP28/QSFP+ ports that support 40 GbE QSFP+ and 100 GbE QSFP28 optical transceivers, active optical cables (AOCs), and direct attach copper (DAC) cables. The QSFP28/QSFP+ ports can also be split out into four 10 GbE (for 40 GbE QSFP+) or 25 GbE (for 100 GbE QSFP28) connections by using breakout cables.

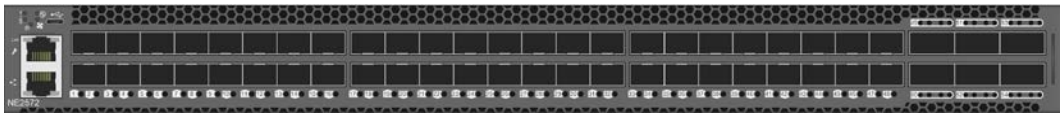


Figure 9: Lenovo ThinkSystem NE2572 RackSwitch

For more information, see this website: lenovopress.com/lp0608

2.4.2 VLANs

It is a networking best practice to use VLANs to logically separate different kinds of network traffic. The following standard VLANs are recommended:

- Management — Used for all management traffic for the hypervisor
- Storage network — Used for NDFS storage traffic

The following ESXi specific VLANs are recommended:

- vSphere vMotion — Used to move VMs from one server to another.
- Fault Tolerance — Used to support the fault tolerance (FT) feature of vSphere.

In addition, each workload application might require one or more VLANs for its logical networks. For larger networks with many workloads, it is easy to run out of unique VLANs. In this case, VXLANs could be used.

The procedure for configuring VLANs for HX Series appliances is outside of the scope of this document.

2.4.3 Redundancy

It is recommended that two top of rack (TOR) switches are used for redundancy in the data network. It is recommended to use two dual-port 10Gbps network adapters in the HX Series appliances for workloads that require high throughput on the network or scale-out cluster deployments. This will effectively provide two redundant, bonded links per host for 20Gbps of bandwidth per logical link. Note that by default, the bonding configuration in the HX appliances is active/passive, but this can be changed to active/active with the proper configuration on the hypervisor host and switch side.

In order to support the logical pairing of the network adapter ports and to provide automatic failover of the switches, the Lenovo ThinkSystem NE1032 RackSwitch and G8272 support virtual link aggregation groups (VLAGs). When VLAG is enabled over the inter-switch link (ISL) trunk, it enables logical grouping of these

switches. When one of the switches is lost, or the uplink from the host to the switch is lost, the connectivity is automatically maintained over the other switch.

Figure 10 shows the two scenarios of single port and dual-port connectivity using the Lenovo RackSwitch G8272. Note the connections into the customer switch and also the extra link between the data switches and the management switch that is required for initial setup only.

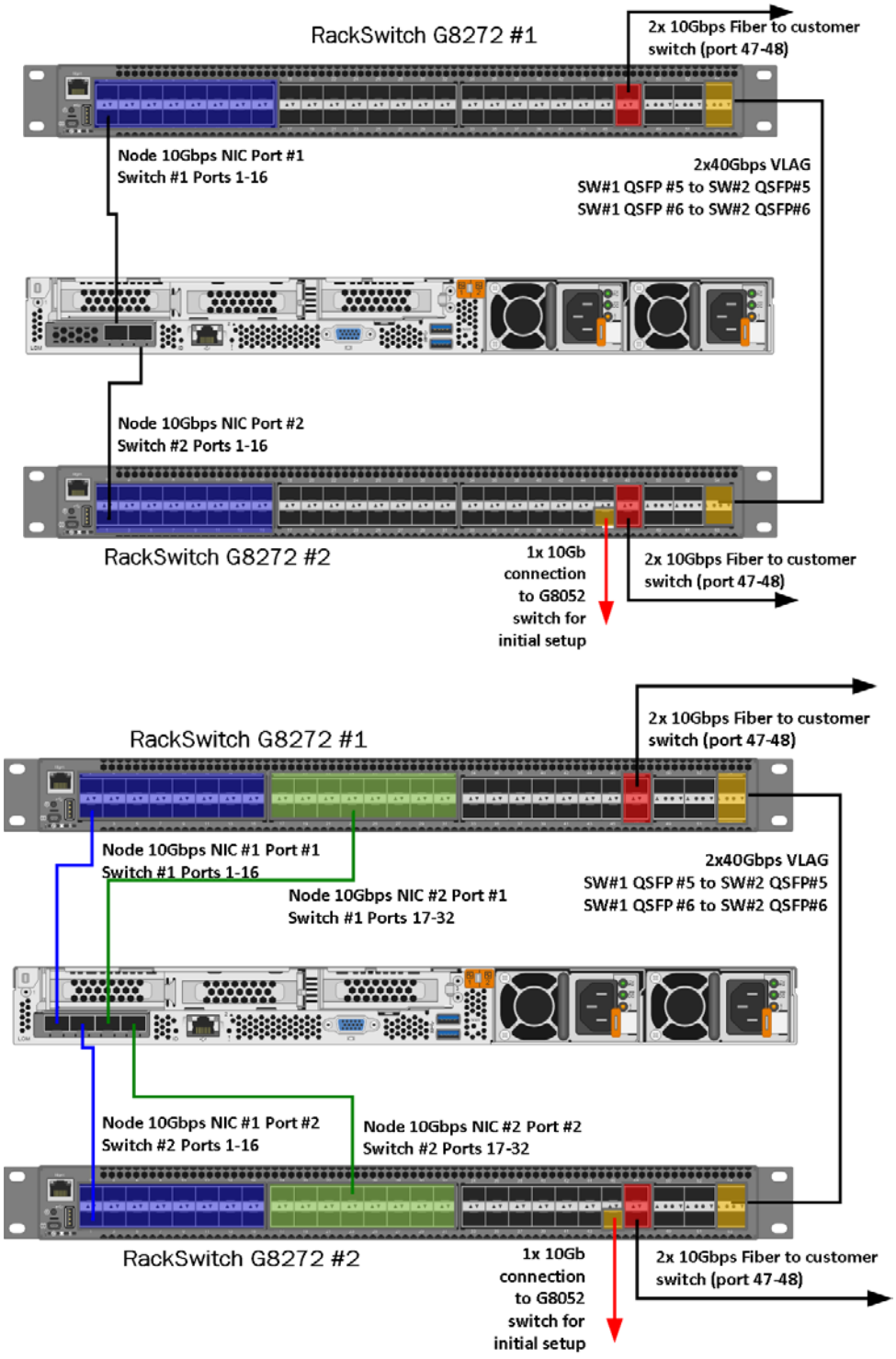


Figure 10: Data network with single and dual adapters

In addition, the Lenovo Cloud Network Operating System (CNOS) should be used on the G8272 switches. A detailed description of the CNOS operating system and its application to the HX Series deployments is provided in the following paper:

Networking Guide for Lenovo ThinkAgile HX Series Appliances (CNOS Switch Firmware)

lenovopress.com/lp0595-networking-guide-for-lenovo-converged-hx-series-nutanix-cnos.

2.5 Hardware management network components

The hardware management network is used for out-of-band access to the HX appliances via the optional Lenovo XClarity Administrator. It may also be needed to re-image an appliance. All systems management for HX appliances is handled in-band via Intelligent Platform Management Interface (IPMI) commands.

The dedicated Integrated Management Module (IMM) port on all of the Lenovo ThinkAgile HX series appliances needs to be connected to a 1GbE TOR switch as shown in Figure 11.

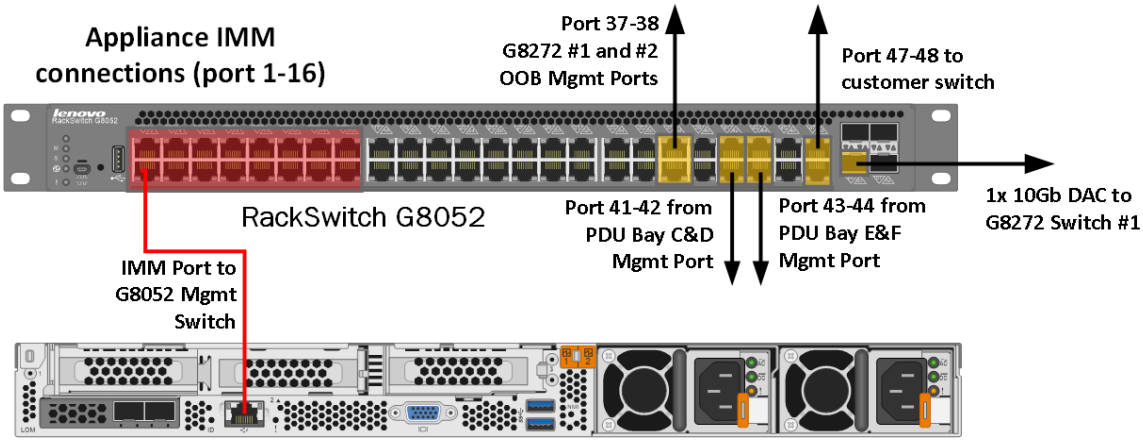


Figure 11: IMM 1GbE management network

2.5.1 Hardware management switches

The following Lenovo 1GbE TOR switches are recommended for use in a HX Series cluster:

- Lenovo RackSwitch G7028
- Lenovo RackSwitch G8052

Lenovo RackSwitch G7028

The Lenovo RackSwitch G7028 (as shown in Figure 12) is a 1 Gb top-of-rack switch that delivers line-rate Layer 2 performance at an attractive price. G7028 has 24 10/100/1000BASE-T RJ45 ports and four 10 Gb Ethernet SFP+ ports. It typically uses only 45 W of power, which helps improve energy efficiency.

Figure 12. Lenovo RackSwitch G7028

For more information, see this website: lenovopress.com/tips1268.

Lenovo RackSwitch G8052

The Lenovo System Networking RackSwitch G8052 (as shown in Figure 13) is an Ethernet switch that is designed for the data center and provides a virtualized, cooler, and simpler network solution. The Lenovo RackSwitch G8052 offers up to 48 1 GbE ports and up to four 10 GbE ports in a 1U footprint. The G8052 switch is always available for business-sensitive traffic by using redundant power supplies, fans, and numerous high-availability features.

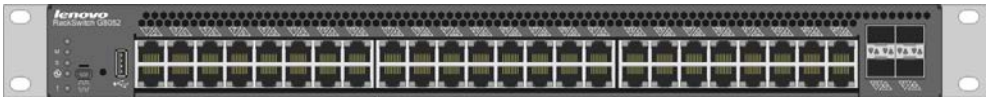


Figure 13: Lenovo RackSwitch G8052

For more information, see this website: lenovopress.com/tips0813.

2.6 Reliability and performance features

Reliability and excellent performance are important for any workload but particularly for hyper-converged infrastructures like the HX Series appliances. These requirements are met through the following design features of Nutanix software combined with Lenovo Servers.

Hardware reliability

Lenovo uses the highest quality hardware components combined with firmware that is thoroughly tested. As a consequence Lenovo servers have been rated #1 in hardware reliability for the last 3 years. This is important as it lowers the frequency of a server failure which in turn lowers OPEX.

A HX appliance has redundant hardware components by including two power supplies, multiple chassis fans, two Intel CPUs, multiple memory DIMMs, multiple SSDs and HDDs, and optionally up to two dual-port network interface cards.

Hardware performance

The HX Series appliances have been carefully designed for performance. In addition to all of the usual attributes like processors and memory, the 24 drive HX7520 uses three HBA controllers instead of the one. As a consequence the latency is halved for some workloads that heavily utilize the cold tier. This allows a higher throughput and improved transaction rates.

Distributed file system

The Nutanix Distributed file system (NDFS) is an intelligent file system which virtualizes the local attached storage (SSD/HDD) on all the nodes in a cluster and presents it as single storage entity to cluster. Figure 14 shows the high level structure of NDFS:

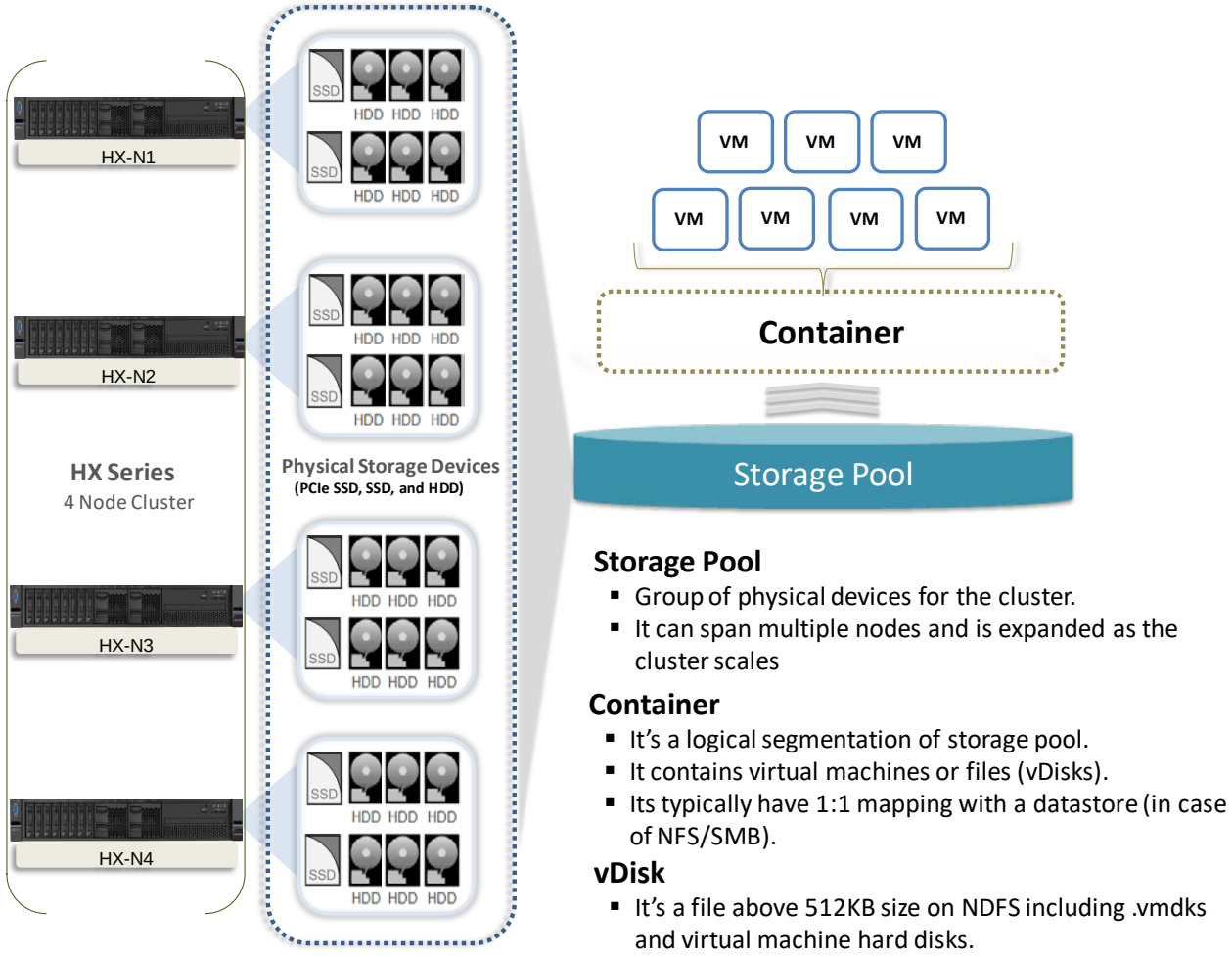


Figure 14: Nutanix Distributed File System

Data protection via replication

The Nutanix platform replication factor (RF) and checksum is used to ensure data redundancy and accessibility in the event of a node or disk failure or corruption. It uses an OpLog which acts as a staging area for incoming writes on low latency SSDs which are then replicated to the OpLogs for one or two other Controller VMs before acknowledging a successful write. This approach ensures that data available in at least two to three different locations and is fault tolerant. While the data is being written a checksum is calculated and stored as part of its metadata.

In the case of a drive or node failure, that data is replicated out to more nodes to maintain the replication factor. A checksum is computed every time the data is read to ensure the data validity. If the checksum and data mismatch, then the data replica is read to replace the invalid copy.

Performance with data tiering

Nutanix uses a disk tiering concept in which disk resources (SSD and HDD) are pooled together to form a cluster wide storage tier. This tier can be accessed by any node within the cluster for data placement and can leverage the full tier capacity. The following data tiering functions are provided:

- The SSD on a local node always has the highest tier priority for write I/O.
- If the local node's SSD is full then the other SSDs in the cluster are used for I/O.
- The NDFS Information Lifecycle Management (ILM) component migrates cold data from the local SSD to HDD to free up SSD space. It also moves heavily accessed data to the local SSD to provide high performance.

Performance by data locality

Data locality is a crucial factor for cluster and VM performance. In order to minimize latency the CVM will work to ensure that all I/O happens locally. This ensures optimal performance and provides very low latencies and high data transfer speeds that cannot be achieved easily with shared storage arrays, even if all-flash.

The following occurs in case of a VM migration or high availability event that moves a VM from Node-A to Node-B:

- The VM's data is provided by the CVM running on Node-B.
- All write I/O requests occur locally i.e. to the local storage of Node-B.
- When a request comes for reading old data, the I/O request is forwarded by Node-B to Node-A. NDFS detects that the I/O request originated from different node and migrates the data locally in the background i.e. from Node-A to Node-B so that all subsequent read I/O operations are served locally. This approach (migration only on a read) helps to avoid network flooding.

Performance of snapshots and clones

NDFS provides support for offloaded snapshots and clones using a redirect-on-write algorithm. When a snapshot or clone is created, the base vDisk is marked as read only and another vDisk is created with read/write permissions as shown in Figure 15 and Figure 16 below.

At this point both vDisks have the same block map - a metadata mapping of the vDisk to its corresponding extents. This approach reduces the overhead of creating snapshots and allows snapshots to be taken very quickly with little performance impact.

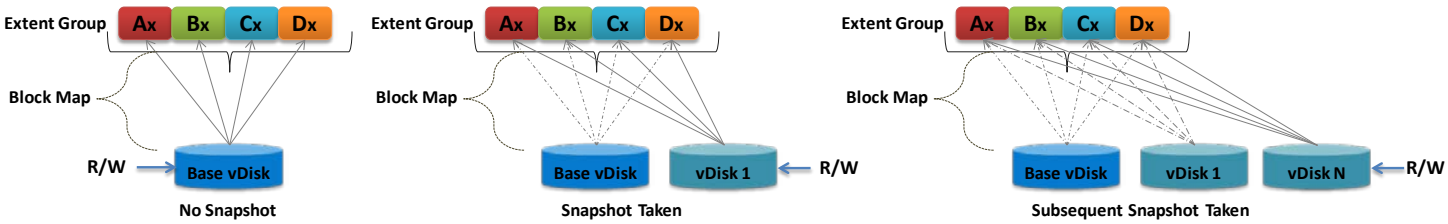


Figure 15: VM snapshots

When a VM is cloned the current block map is locked and then clones are created. These updates are metadata only so again no actual I/O takes place. The logic applies for clones of clones as well where a previously cloned VM acts as a base vDisk. All the clones inherit the prior block map and any new writes take place on the individual block maps.

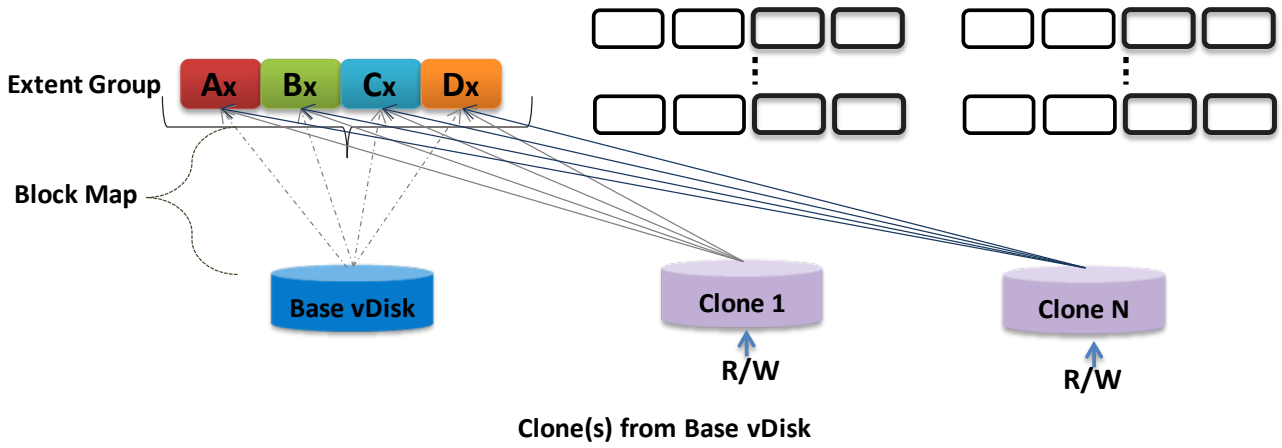


Figure 16: VM clones

Storage reduction via De-duplication and Compression

The Nutanix elastic de-duplication engine increases the effective capacity of a disk, as well as the RAM and cache of the system by removing duplicate data. It's an intelligent technology which performs following actions to increase storage efficiency:

- Sequential streams of data fingerprinted at 4K granularity
- Single instance of the shared VM data is loaded into the cache upon read
- Each node in a cluster performs its own fingerprinting and deduplication

The Nutanix capacity optimization engine is responsible for performing data transformations and compression to achieve data optimization. NDFS provides following compression methods:

- In-line compression sequential streams of data or large I/O sizes are compressed in memory before written to the disk
- Post-process compression whereby data is written in an uncompressed state and the curator framework is used to compress the data in a cluster wide manner

The Nutanix capacity optimization engine uses the Google snappy compression library to deliver good compression ratios with minimal compute overhead and very fast compression or decompression rates.

Elimination of "split-brain" errors

In a distributed system it is possible for one participant to become disconnected which will cause differences in the stored data. NDFS uses the proven "Paxos" algorithm to eliminate these "split-brain" issues by reaching a consensus (quorum) among the participants in a distributed system before the writes are made.

Drive reliability via active monitoring

The CVM actively monitors the performance of every drive in a node. The deterioration of a drive's performance may indicate that the drive is about to fail. The CVM proactively moves data off the drive before it fails and marks the drive offline and in need to replacement. The idea is to avoid the expensive data transfers to maintain data redundancy and possible loss of data.

3 Deployment models

This chapter provides recommended deployment models for different examples of using a HX Series cluster.

3.1 SMB deployment model

There are two specific models of HX Series appliances targeted for the small-medium business (SMB) environment. These are the HX2320-E in a 1U form factor and HX2720-E in a 2U4N form factor.

As described in the product guide for the HX2000 Series appliances, the cluster size is limited to 4 nodes. This example deployment for a SMB customer with low performance requirements includes 4 HX2720-E nodes in a 2U chassis and a Lenovo RackSwitch G7028 1GbE switch. Figure 17 shows the front view.

Figure 17: Front view of SMB Deployment

Figure 18 shows the rear view and the cabling for both the data (blue, red) and hardware management (green) networks into the same switch. It is also typical in these environments that the data network and management network IP addresses are in the same subnet.

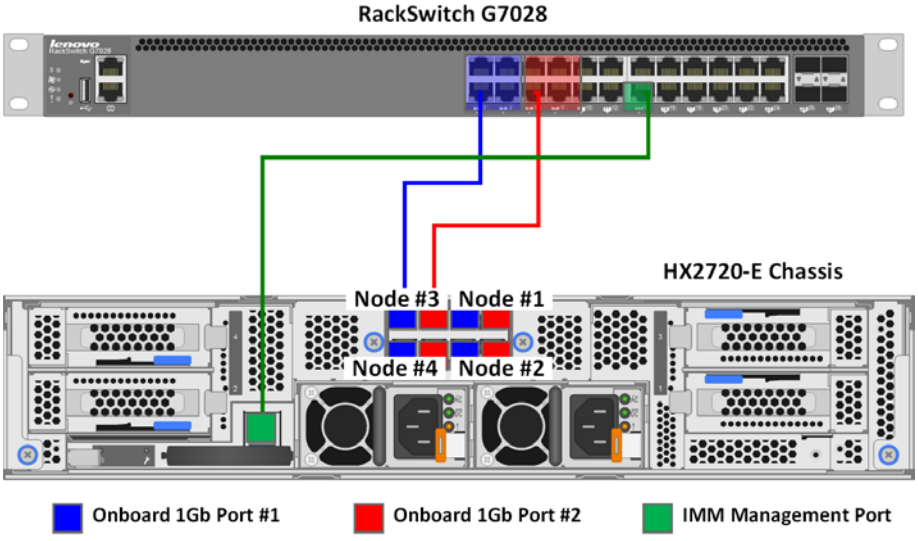


Figure 18: Rear view of SMB Deployment

3.2 Rack-scale deployment models

It is recommended to use one of the two ThinkAgile SXN3000 models as the rack-scale deployment model for HX Series appliances. See section 2.2 on page 5 for more details. This section gives some example deployment models using the SXN3000 42U.

3.2.1 VDI deployment model

This deployment model applies equally for either Citrix XenDesktop (see chapter 4) or VMware Horizon (see chapter 7). In this example the requirement is to support 5000 stateless virtual desktops. Each Windows 10 desktop virtual machine (VM) requires 3GB of RAM and 1 vCPU (similar to Office worker profile).

In order to promote reusability, the management nodes are configured the same as the compute nodes running the virtual desktops. Because of the low requirement for storage, the HX3720 appliance is used and configured as follows:

- 2x Intel Xeon Scalable 6130 processors with 768 GB of system memory
- 2x 1.92TB SSD for cache
- 4x 2TB SATA HDD

Using the sizing tables presented in chapter 4 and chapter 7, it is recommended to have on average 180 virtual desktops per node. This translates to twenty-eight HX3720 appliances. In this configuration up to 5 nodes could be out of service (which is very unlikely) and that would leave twenty-three nodes to service the 5000 virtual desktops. This gives a 1:6 ratio for redundancy of the nodes.

In addition three nodes are needed for the VDI management VMs and to provide adequate failover characteristics. A fourth node could be used as a quick deploy spare.

Figure 19 shows the deployment for 5000 VDI users using a SXN3000 42U model with thirty-two HX3720 appliances (8 chassis) and the TOR switches. Each of the compute nodes is numbered C1 to C28 and each of the management nodes is numbered M1 to M3.

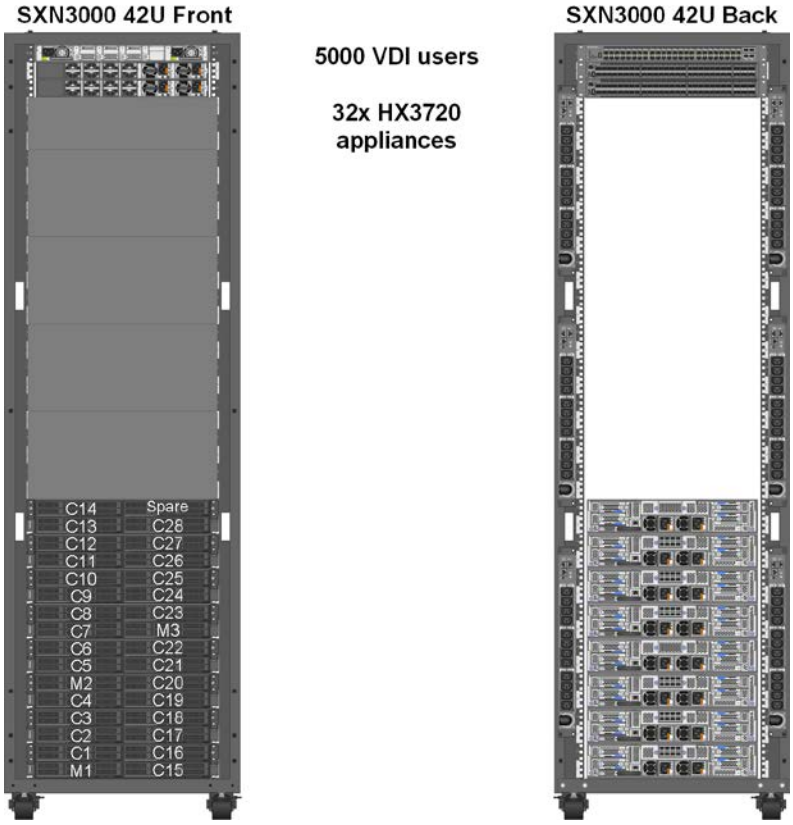


Figure 19: Example deployment model for 5000 VDI users

3.2.2 Microsoft Exchange and SQL Server deployment model

In this example deployment model, the requirement is to support 70,000 mailboxes of 1GB each and 8 applications that use Microsoft SQL Server for the database.

The 70,000 mailboxes are supported using 8 HX7520 appliances. An additional 4 HX7520 appliances are used for sixteen Microsoft SQL Server VMs which use Microsoft AlwaysOn availability groups (AAGs) for database redundancy. The VMs for the web front-ends are redundantly deployed on 4 HX3320 appliances.

The HX7520 appliance is configured as follows:

- 2x Intel Xeon Scalable 8170 processors with 768 GB of system memory
- 4x 1.92TB SSD for cache
- 20x 2TB SATA HDD

The HX3320 appliance is configured as follows:

- 2x Intel Xeon Scalable 6130 processors with 768 GB of system memory
- 2x 1.92TB SSD for cache
- 8x 2TB SATA HDD

Figure 20 shows the deployment of the 12 HX7520 appliances, 4 HX3320 appliances, and the TOR switches.

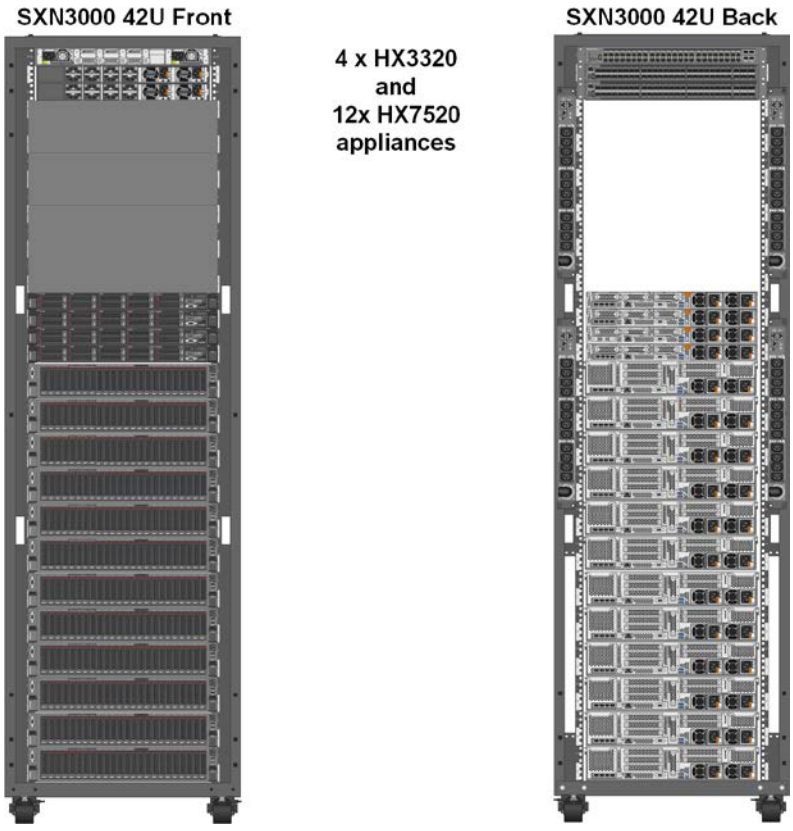


Figure 20: Example deployment model for Microsoft Exchange and SQL Server

3.2.3 VMware vCloud Suite deployment model

In this example deployment model, the requirement is to support VDI users with graphics acceleration using a VMware vCloud Suite. For more details see section 8.7 on page 92.

The vCloud edge-compute cluster uses 12 HX3520-G appliances configured as follows:

- 2x Intel Xeon Scalable 6130 processors with 384 GB of system memory
- 2x 1.92TB SSD for cache
- 6x 2TB SATA HDD
- 2x M60 GPU adapter

The vCloud management cluster uses four HX3320 appliances configured as follows:

- 2x Intel Xeon Scalable 6130 processors with 384 GB of system memory
- 2x 1.92TB SSD for cache
- 8x 2TB SATA HDD

Figure 21 shows the deployment of the 12 HX3520-G appliances, 4 HX3320 appliances, and the TOR switches.

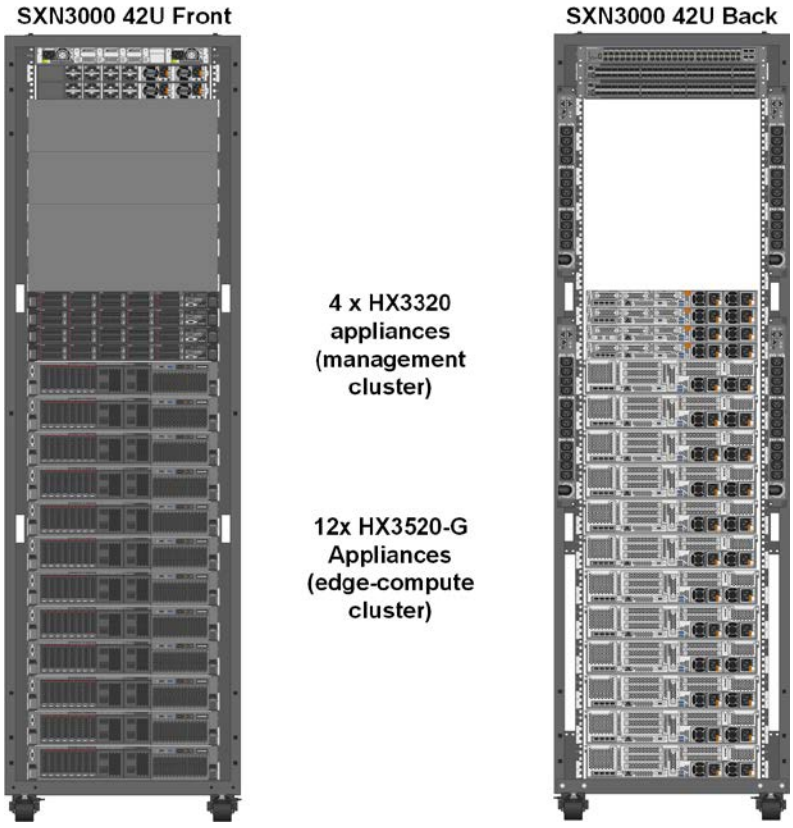


Figure 21: Example deployment model for VMware vCloud

4 Citrix XenDesktop

Citrix XenDesktop is a suite of virtualization software which delivers Windows virtual desktops as well as virtual applications to meet the demands of any use case. It is based on the unified FlexCast Management Architecture (FMA) platform. See this website for more details: citrix.com/products/xendesktop.

4.1 Solution overview

Figure 22 provides an architecture overview of Lenovo hyper-converged Nutanix solution's reference architecture with Citrix XenDesktop 7.15 on VMware ESXi 6.5 U1 hypervisor. This chapter does not address the general issues of multi-site deployment and network management and limits the description to the components that are inside the customer's intranet.

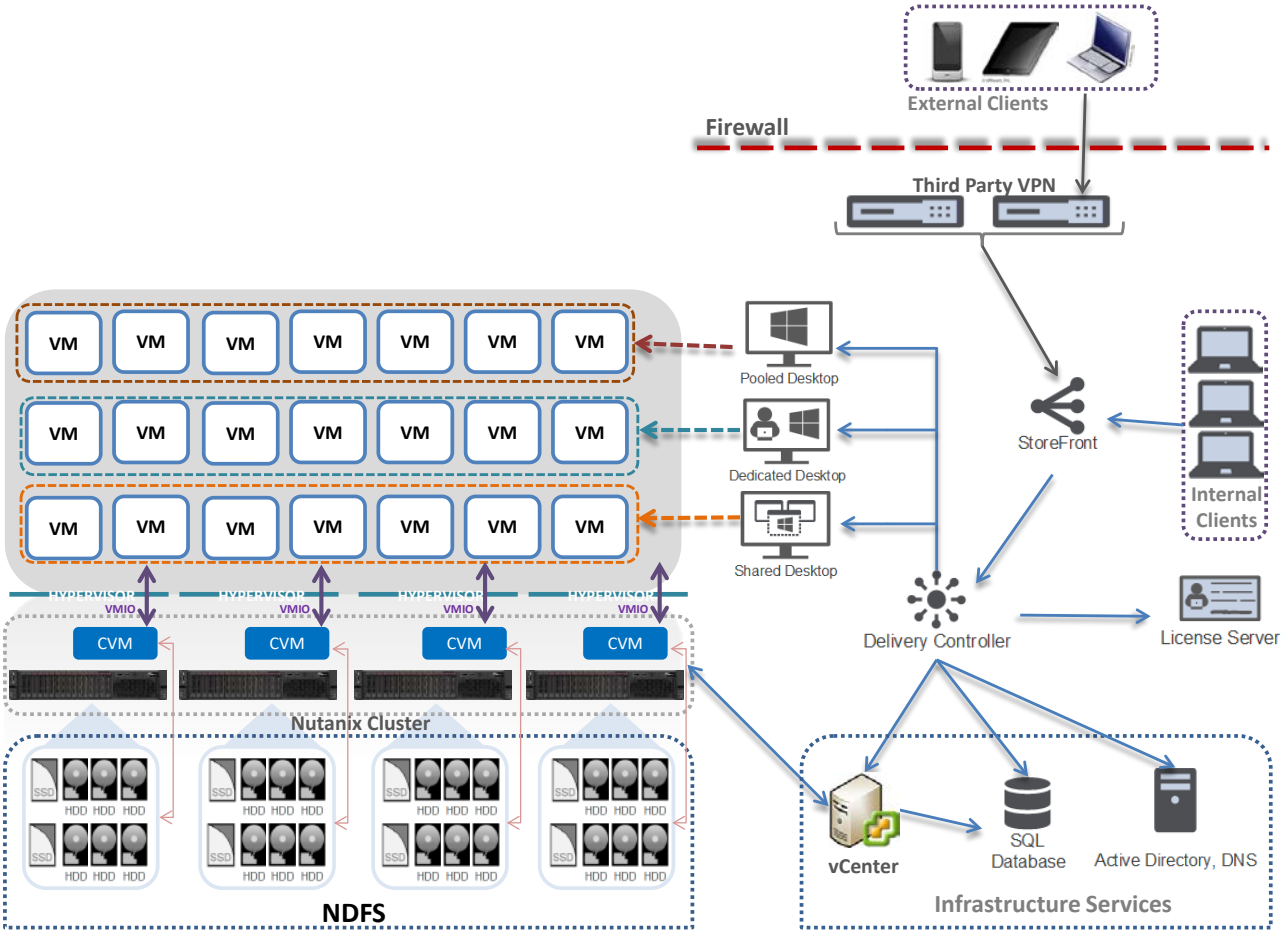


Figure 22: Lenovo ThinkAgile HX Series solution with Citrix XenDesktop

Pooled desktops are stateless (non-persistent) virtual desktops and dedicated desktops are persistent. Shared desktops are used for hosted shared desktops or hosted shared applications.

4.2 Component model

Figure 23 is a layered component view for the Citrix XenDesktop virtualization infrastructure.

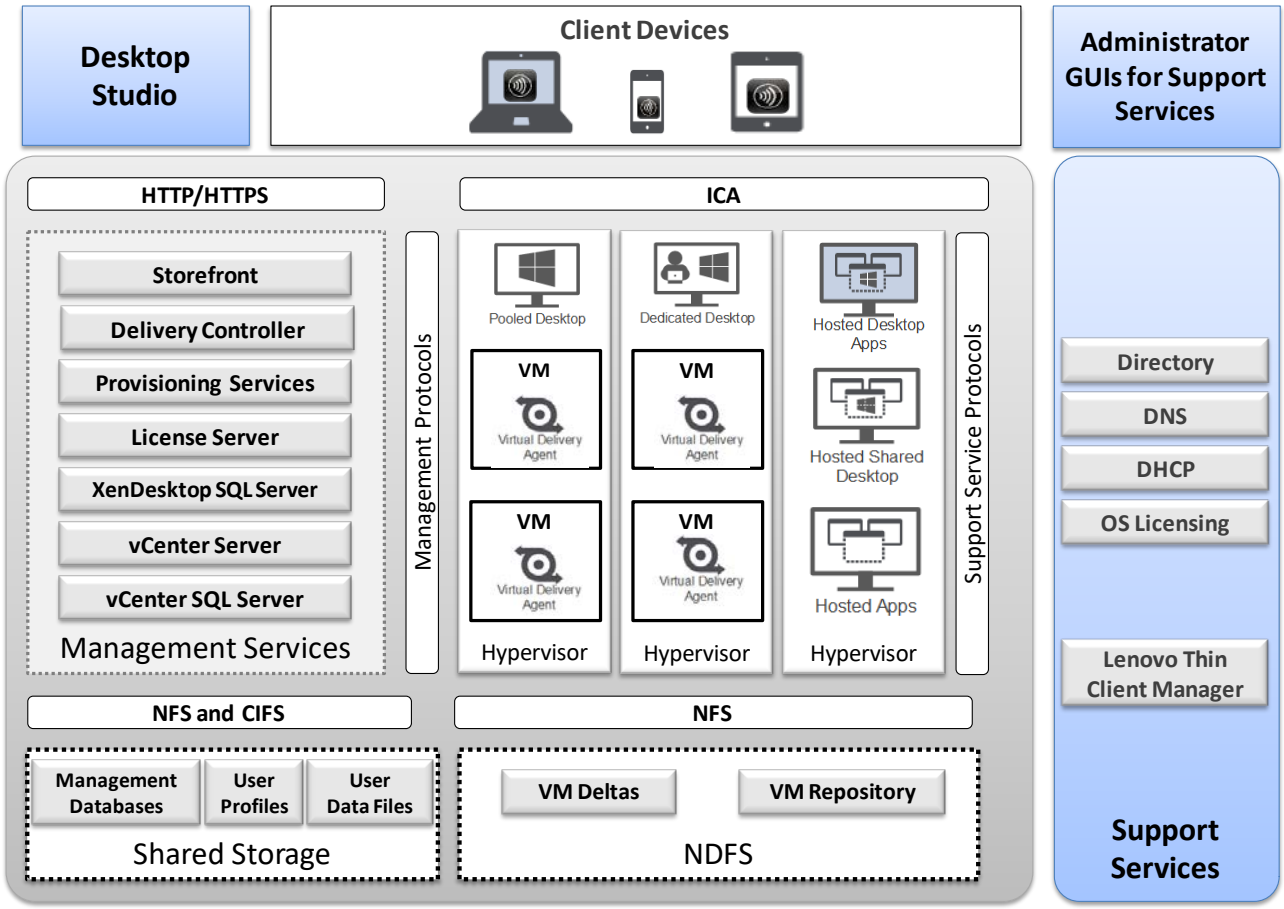


Figure 23: Component model with Citrix XenDesktop

Citrix XenDesktop features the following main components:

Desktop Studio Desktop Studio is the main administrator GUI for Citrix XenDesktop. It is used to configure and manage all of the main entities, including servers, desktop pools and provisioning, policy, and licensing.

Storefront Storefront provides the user interface to the XenDesktop environment. The Web Interface brokers user authentication, enumerates the available desktops and, upon start, delivers a .ica file to the Citrix Receiver on the user's local device to start a connection. The Independent Computing Architecture (ICA) file contains configuration information for the Citrix receiver to communicate with the virtual desktop. Because the Web Interface is a critical component, redundant servers must be available to provide fault tolerance.

Delivery controller	The Delivery controller is responsible for maintaining the proper level of idle desktops to allow for instantaneous connections, monitoring the state of online and connected desktops, and shutting down desktops as needed. A XenDesktop farm is a larger grouping of virtual machine servers. Each delivery controller in the XenDesktop acts as an XML server that is responsible for brokering user authentication, resource enumeration, and desktop starting. Because a failure in the XML service results in users being unable to start their desktops, it is recommended that you configure multiple controllers per farm.
PVS and MCS	Provisioning Services (PVS) is used to provision stateless desktops at a large scale. Machine Creation Services (MCS) is used to provision dedicated or stateless desktops in a quick and integrated manner. For more information, see “Citrix XenDesktop provisioning” section on page 27.
License Server	The Citrix License Server is responsible for managing the licenses for all XenDesktop components. XenDesktop has a 30-day grace period that allows the system to function normally for 30 days if the license server becomes unavailable. This grace period offsets the complexity of otherwise building redundancy into the license server.
XenDesktop SQL Server	Each Citrix XenDesktop site requires an SQL Server database that is called the data store, which used to centralize farm configuration information and transaction logs. The data store maintains all static and dynamic information about the XenDesktop environment. Because the XenDesktop SQL server is a critical component, redundant servers must be available to provide fault tolerance.
vCenter Server	By using a single console, vCenter Server provides centralized management of the virtual machines (VMs) for the VMware ESXi hypervisor. VMware vCenter can be used to perform live migration (called VMware vMotion), which allows a running VM to be moved from one physical server to another without downtime. Redundancy for vCenter Server is achieved through VMware high availability (HA). The vCenter Server also contains a licensing server for VMware ESXi.
vCenter SQL Server	vCenter Server for VMware ESXi hypervisor requires an SQL database. The vCenter SQL server might be Microsoft® Data Engine (MSDE), Oracle, or SQL Server. Because the vCenter SQL server is a critical component, redundant servers must be available to provide fault tolerance. Customer SQL databases (including respective redundancy) can be used.

Client devices	Citrix XenDesktop supports a broad set of devices and all major device operating platforms, including Apple iOS, Google Android, and Google ChromeOS. XenDesktop enables a rich, native experience on each device, including support for gestures and multi-touch features, which customizes the experience based on the type of device. Each client device has a Citrix Receiver, which acts as the agent to communicate with the virtual desktop by using the ICA/HDX protocol.
Thin-client Manager	The Lenovo Thin-client Manager (LTM) is used to manage and support Lenovo thin-client devices individually or in groups.
VDA	Each VM needs a Citrix Virtual Desktop Agent (VDA) to capture desktop data and send it to the Citrix Receiver in the client device. The VDA also emulates keyboard and gestures sent from the receiver. ICA is the Citrix remote display protocol for VDI.
Citrix Receiver	Citrix Receiver is the client software that provides access to applications, desktops and data easily and securely from any device, including smartphones, tablets, PCs and Macs

For more information, see the Lenovo Client Virtualization base reference architecture document that is available at this website: lenovopress.com/lp0756.

4.3 Citrix XenDesktop provisioning

Citrix XenDesktop features the following primary provisioning components for desktops and applications:

- Provisioning Services (PVS)
- Machine Creation Services (MCS)

4.3.1 Provisioning services

Hosted VDI desktops can be deployed with or without Citrix PVS. The advantage of PVS is that you can stream a single desktop image to create multiple virtual desktops on one or more servers in a data center. Figure 24 shows the sequence of operations that are executed by XenDesktop to deliver a hosted VDI virtual desktop.

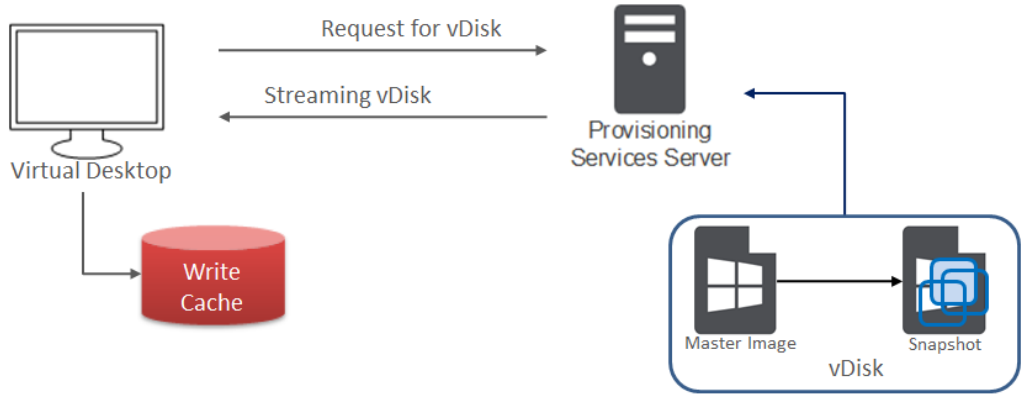


Figure 24: Using PVS for a stateless model

When the virtual disk (vDisk) master image is available from the network, the VM on a target device no longer needs its local hard disk drive (HDD) to operate; it boots directly from the network and behaves as if it were running from a local drive on the target device, which is why PVS is recommended for stateless virtual desktops. PVS often is not used for dedicated virtual desktops because the write cache is not stored on shared storage.

PVS is also used with Microsoft Roaming Profiles (MSRPs) so that the user's profile information can be separated out and reused. Profile data is available from CIFS based shared storage.

It is a best practice to use snapshots for changes to the master VM images and also keep copies as a backup.

4.3.2 Machine creation services

Unlike PVS, MCS does not require more servers. Instead, it uses integrated functionality that is built into the hypervisor and communicates through the APIs. Each desktop has one difference disk and one identity disk (as shown in Figure 25). The difference disk is used to capture any changes that are made to the master image. The identity disk is used to store information, such as device name and password.

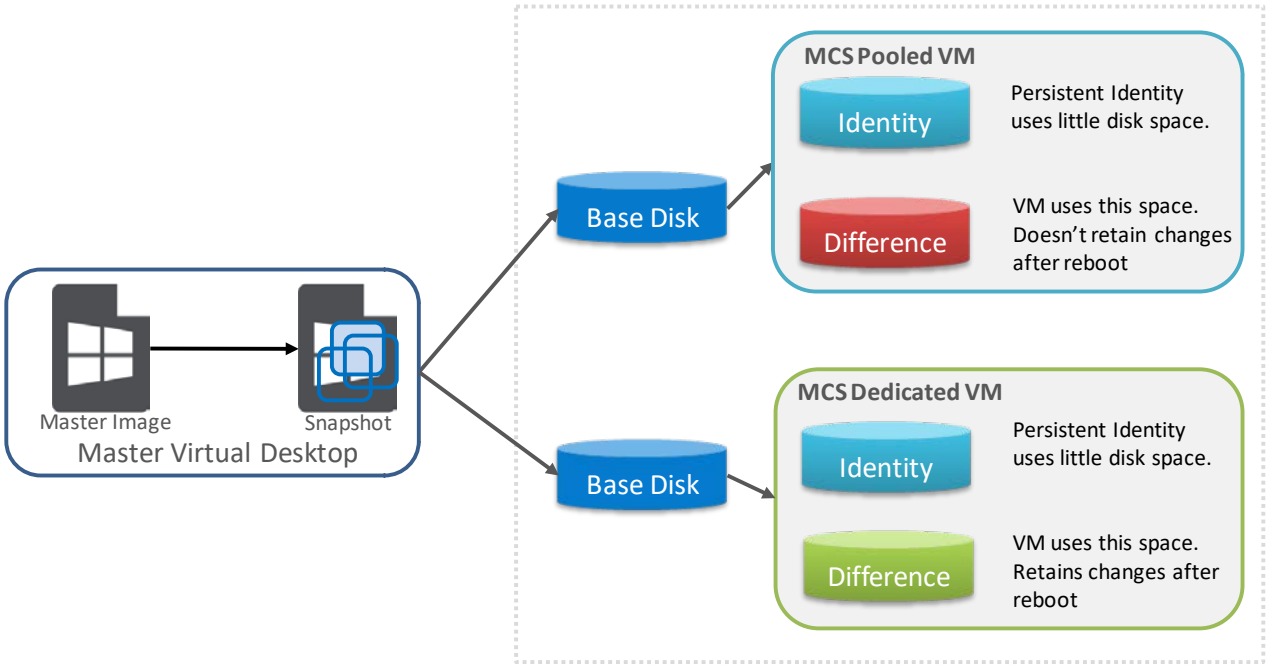


Figure 25: MCS image and difference/identity disk storage model

The following types of image assignment models for MCS are available:

- Pooled-random: Desktops are assigned randomly. When they log off, the desktop is free for another user. When rebooted, any changes that were made are destroyed.
- Pooled-static: Desktops are permanently assigned to a single user. When a user logs off, only that user can use the desktop, regardless if the desktop is rebooted. During reboots, any changes that are made are destroyed.
- Dedicated: Desktops are permanently assigned to a single user. When a user logs off, only that user can use the desktop, regardless if the desktop is rebooted. During reboots, any changes that are made persist across subsequent restarts.

MCS thin provisions each desktop from a master image by using built-in technology to provide each desktop with a unique identity. Only changes that are made to the desktop use more disk space.

There is a new caching option in Citrix XenDesktop 7.9 for Pooled and Hosted Shared desktops. Figure 26 shows a screenshot of the option.

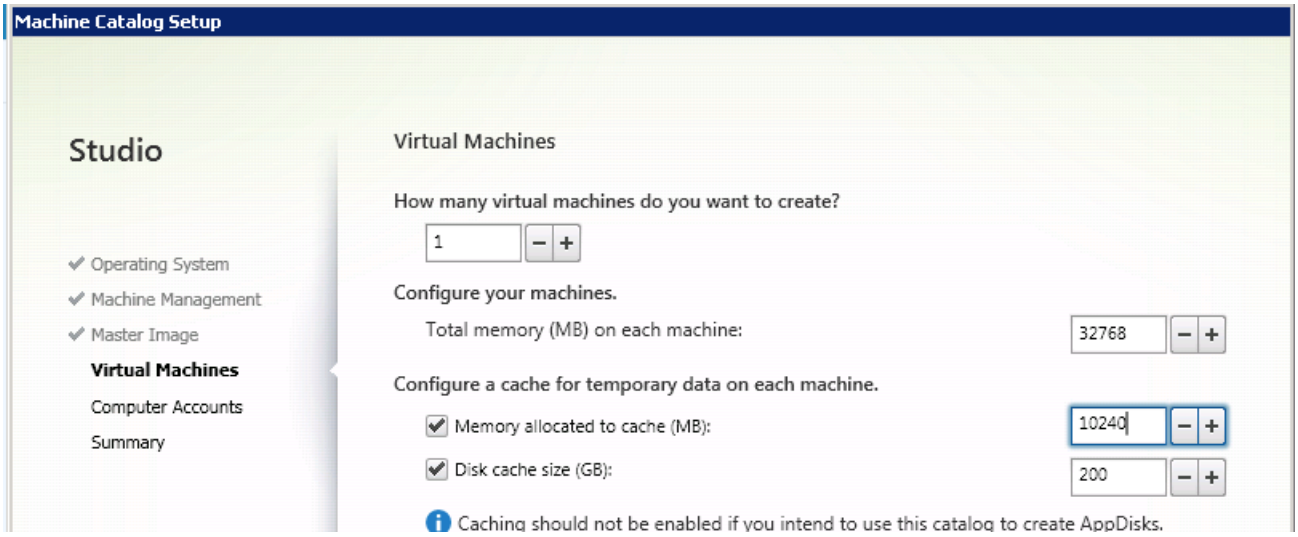


Figure 26: Caching option for Pooled and Hosted Shared desktops

4.4 Management VMs

A key part of the Citrix XenDesktop environment is the various management VMs used to manage the VDI infrastructure and user VMs. Table 2 lists the VM requirements and performance characteristics of each management service for Citrix XenDesktop.

Table 2: Characteristics of XenDesktop and ESXi management services

Management service VM	Virtual processors	System memory	Storage	Windows OS	HA needed	Performance characteristic
Delivery controller	4	8 GB	60 GB	2012 R2	Yes	5000 user connections
Storefront	4	4 GB	60 GB	2012 R2	Yes	30,000 connections per hour
Citrix licensing server	2	4 GB	60 GB	2012 R2	No	170 licenses per second
XenDesktop SQL server	2	8 GB	60 GB	2012 R2	Yes	5000 users
PVS servers	4	32 GB	60 GB (depends on number of images)	2012 R2	Yes	Up to 1000 desktops, memory should be a minimum of 2 GB plus 1.5 GB per image served

Management service VM	Virtual processors	System memory	Storage	Windows OS	HA needed	Performance characteristic
vCenter server	8	16 GB	60 GB	2012 R2	No	Up to 2000 desktops
vCenter SQL server	4	8 GB	200 GB	2012 R2	Yes	Double the virtual processors and memory for more than 2500 users

Table 3 lists the number of management VMs for each size of users following the recommendations for high availability and performance. The number of vCenter servers is half of the number of vCenter clusters because each vCenter server can handle two clusters of up to 1000 desktops.

Table 3: Management VMs needed

XenDesktop management service VM	300 users	600 users	1200 users	3000 users
Delivery Controllers Includes Citrix Licensing server Includes Web server	2 (1+1) Y Y	2 (1+1) Y Y	2 (1+1) N N	2 (1+1) N N
Web Interface	N/A	N/A	2 (1+1)	2 (1+1)
Citrix licensing servers	N/A	N/A	1	1
XenDesktop SQL servers	2 (1+1)	2 (1+1)	2 (1+1)	2 (1+1)
PVS servers for stateless case only	2 (1+1)	2 (1+1)	2 (1+1)	2 (1+1)
ESXi management service VM	**300 users**	**600 users**	**1200 users**	**3000 users**
vCenter servers	1	1	2	2
vCenter SQL servers	2 (1+1)	2 (1+1)	2 (1+1)	2 (1+1)

It is assumed that common services, such as Microsoft Active Directory, Dynamic Host Configuration Protocol (DHCP), domain name server (DNS), and Microsoft licensing servers exist in the customer environment.

There are 3 ways to deploy the management VMs for Citrix XenDesktop:

- Separate servers outside HX cluster
- Servers within the HX cluster
- In the Citrix Cloud using the Citrix Workspace Appliance (see section 4.4.1)

These management VMs can be run on separate servers from the HX series cluster or within the cluster itself. Separating out the VMs means that the management VMs can be separately managed and sized to the requirements and dedicated servers used for the user VMs. Putting all of the VMs together in one cluster means that the compute servers will execute less user VMs and additional resources are needed for the much larger and more granular management VMs. Lenovo recommends that the management and user VMs are separated for all but the smallest deployments (i.e. less than 600 users).

4.4.1 Citrix Workspace Appliance

Citrix Workspace Appliance (CWA) hosts the management VMs for XenDesktop in the Citrix Cloud; for a service fee. This significantly reduces the skills, effort, and hardware needed to manage a XenDesktop environment. The customer only needs to configure a cluster of servers to host user VMs for dedicated or stateless desktops.

For Nutanix, there are connectors to the Citrix Cloud for both AHV and XenServer hypervisors. The cloud connector advertises resources available in the Nutanix cluster and manages requests from the Citrix Cloud for those resources. For more information on configuring the Nutanix AHV Cloud Connector, see docs.citrix.com/en-us/citrix-app-layering/4/nutanix-ahv/configure/connector-essentials/mcs-for-nutanix-ahv-connector-configuration.html.

Users simply connect to a Citrix StoreFront in the Citrix Cloud, which allocates an available desktop VM, and connects the user directly to that desktop.

For more information on CWA and the Citrix Cloud, see docs.citrix.com/en-us/citrix-cloud.html.

4.5 Graphics acceleration

This section is specific to the Lenovo ThinkAgile HX3520-G that supports GPU acceleration. The VMware ESXi hypervisor supports the following options for graphics acceleration:

- Dedicated GPU with one GPU per user, which is called virtual dedicated graphics acceleration (vDGA) mode.
- GPU hardware virtualization (vGPU) that partitions each GPU.
- Shared GPU with users sharing a GPU, which is called virtual shared graphics acceleration (vSGA) mode and is not recommended because of user contention for shared use of the GPU.

The vDGA (or pass-through) option has a low user density as it restricts a single user to access each very powerful GPU. This option is not flexible and is no longer cost effective even for high-end power users. Therefore vDGA is no longer recommended especially given that the performance of the equivalent vGPU mode is similar.

When using the vGPU option with ESXi 6.5 and the latest drivers from NVidia, it is necessary to change the default GPU mode from “Shared” (vSGA) to “Shared Direct” (vGPU) for each GPU using VMware vCenter. This enables the correct GPU support for the VMs which would otherwise result in the VM not powering on correctly and the standard “graphics resources not available” error message. The host needs to be rebooted for the changes to take effect.

The performance of graphics acceleration was tested using the Lenovo ThinkSystem SR650 servers. Each server supports up to two GPU adapters. The Heaven benchmark is used to measure the per user frame rate for different GPUs, resolutions, and image quality. This benchmark is graphics-heavy and is fairly realistic for designers and engineers. Power users or knowledge workers usually have less intense graphics workloads and can achieve higher frame rates. Table 4 lists the results of the Heaven benchmark as FPS that are available to each user with the GRID 2,0 M60 adapter by using vGPU mode with DirectX 11.

Table 4: Performance of GRID 2.0 M60 vGPU modes with DirectX 11

Quality	Tessellation	Anti-Aliasing	Resolution	M60-8Q	M60-4Q	M60-2Q	M60-4A	M60-2A
High	Normal	0	1280x1024	Untested	Untested	32.07	59.94	33.12
High	Normal	0	1680x1050	Untested	50.43	25.68	N/A	N/A
High	Normal	0	1920x1200	Untested	41.82	21.72	N/A	N/A
Ultra	Extreme	8	1280x1024	Untested	Untested	18.24	36.91	18.76
Ultra	Extreme	8	1680x1050	57.61	29.79	14.40	N/A	N/A
Ultra	Extreme	8	1920x1080	50.50	26.18	12.63	N/A	N/A
Ultra	Extreme	8	1920x1200	46.17	23.01	Untested	N/A	N/A
Ultra	Extreme	8hai	2560x1600	27.46	14.19	Untested	N/A	N/A

Lenovo recommends that a medium to high powered CPU, such as the Xeon Scalable 6130, is used for accelerated graphics applications tend to also require extra load on the processor. For vGPU mode, Lenovo recommends at least 384GB of server memory. Because there are many variables when graphics acceleration is used, Lenovo recommends that testing is done in the customer environment to verify the performance for the required user workloads.

4.6 Performance testing

This section describes the performance benchmarking tool and the results obtained for different configurations of a cluster of 4 Lenovo ThinkAgile HX3320 appliances.

4.6.1 Login VSI benchmarking tool

Login VSI is a vendor-independent benchmarking tool that is used to objectively test and measure the performance and scalability of server-based Windows desktop environments. Leading IT analysts recognize and recommend Login VSI as an industry-standard benchmarking tool for client virtualization and can be used by user organizations, system integrators, hosting providers, and testing companies.

Login VSI provides multiple workloads to simulate real user work and suitable in performing load test, benchmarking and capacity planning for VDI environments. Table 5 lists the characteristics of the Login VSI 4.1 workloads that are used in the Lenovo testing.

Table 5. Login VSI Workload Comparison

Workload Name	Login VSI Version	Apps Open	CPU Usage	Disk Reads	Disk Writes	IOPS	Memory	vCPU
Office worker	4.1	5-8	82%	90%	101%	8.1	2GB	1vCPU
Knowledge worker	4.1	5-9	100%	100%	100%	8.5	2GB	2vCPU
Power worker	4.1	8-12	119%	133%	123%	10.8	3GB	3vCPU

The VSImax score parameter (the number indicates user density) is used to determine the performance of a particular system configuration. The following parameters and rules are used for Login VSI tests:

- User login interval: 30 seconds per node
- Workload: Office Worker, Knowledge Worker, or Power User
- All virtual desktops were pre-booted before the tests
- The number of powered-on VMs was adjusted to stay within a 10% margin of VSImax to avoid unreasonable overhead by "idling" virtual machines
- VSImax score is derived using the "classic model" calculation

4.6.2 Performance results for virtual desktops

This section shows the virtual desktop performance results for Lenovo ThinkAgile HX3320 appliances each configured with dual Xeon Scalable 6130 processors, 768 GB of memory, two 1.92 TB SATA SSDs, and six 2 TB SATA disk drives.

The recommended configuration of the Nutanix CVM is as follows:

- vCPU 12
- CPU Reservation 10000 MHz
- Memory 24GB
- Memory Reservation 24GB
- NUMA No Affinity
- Advance CPU – Scheduling Affinity No Affinity

Table 6 lists the Login VSI performance results of a HX Series appliance 4 node cluster using VMware ESXi 6.5 U1 and Windows 10.

Table 6: Login VSI Performance with VMware ESXI 6.5 U1

Processor	Workload	Stateless	Dedicated
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Office worker	1006 users	1011 users
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Knowledge worker	844 users	827 users
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Power worker	732 users	734 users

Table 7 lists the Login VSI performance results of a HX Series appliance 4 node cluster using Nutanix AHV 5.1.3 and Windows 10.

Table 7: Login VSI Performance with Nutanix AHV 5.1.3

Processor	Workload	Stateless	Dedicated
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Office worker	870 users	909 users
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Knowledge worker	622 users	649 users
Two Scalable 8176 processors 2.10 GHz, 28C 165W	Knowledge worker	1132 users	1175 users
Two Scalable 8176 processors 2.10 GHz, 28C 165W	Power worker	829 users	836 users

The results with AHV are 10% to 20% less than VMware ESXi using the Xeon Scalable 6130 processor. Using the Xeon Scalable 8176 processor provides an 80% boost in performance and based on other testing similar results can be expected from VMware ESXi.

4.6.3 Performance results from boot storm testing

A boot storm occurs when a substantial number of VMs are all booted within a short period of time. Booting a large number of VMs simultaneously requires large IOPS otherwise the VMs become slow and unresponsive.

Different numbers of VMs were booted on a cluster of 4 HX3320 hybrid appliances. The VMs were unpowered in vCenter and the boot storm created by powering on all of the VMs simultaneously. The time for all of the VMs to become visible in Citrix XenDesktop was measured.

Figure 27 shows a comparison of the boot times for a variety of VMs using VMware ESXi 6.5 U1. With an even spread of VMs on each node, the boot time for the VMs on each node was similar to the overall cluster boot time.

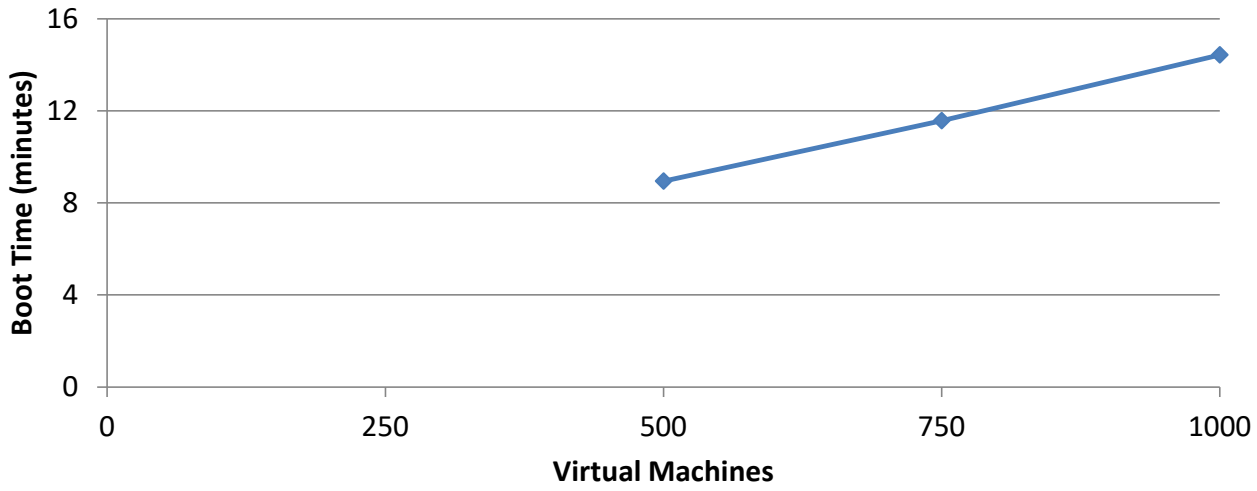


Figure 27: Boot storm comparison

4.7 Performance recommendations

This section provides performance recommendations for both sizing of ThinkAgile HX Series appliances and for best practices. These appliances can be configured into a complete ThinkAgile SXN solution delivered from the factory.

4.7.1 Sizing recommendations for virtual desktops

The default recommendation is two Xeon Scalable 6130 processors and 768 GB of system memory because this configuration provides the best coverage and density for a range of users. Assuming there is enough storage configured for the VMs, this configuration is recommended for any of the HX 3000 Series appliances.

For an office worker, Lenovo testing shows that 180 users per server is a good baseline and has an average of 80% usage of the processors in the server. If a server goes down, users on that server must be transferred to the remaining servers. For this degraded failover case, Lenovo testing shows that 216 users per server have an average of 88% usage of the processors. It is important to keep this 25% headroom on servers to cope with possible failover scenarios. Lenovo recommends a general failover ratio of 5:1. By using a target of 180 users per server, the maximum number of office workers is 11,520 in a 64 node cluster.

For a knowledge worker, Lenovo testing shows that 155 users per server is a good baseline and has an average of 80% usage of the processors in the server. For the degraded failover case, Lenovo testing shows

that 186 users per server have an average of 91% usage of the processors. By using a target of 155 users per server, the maximum number of knowledge workers is 9,920 in a 64 node cluster.

For a power, Lenovo testing shows that 125 users per server is a good baseline and has an average of 74% usage of the processors in the server. For the degraded failover case, Lenovo testing shows that 150 users per server have an average of 82% usage of the processors. By using a target of 125 users per server, the maximum number of knowledge workers is 8,000 in a 64 node cluster.

Table 8 summarizes the processor usage with ESXi for the recommended user counts for normal mode and failover mode.

Table 8: Processor usage

Processor	Workload	Users per Server	CPU Utilization
Two 6130	Office worker	180 users – Normal Mode	80%
Two 6130	Office worker	216 users – Failover Mode	88%
Two 6130	Knowledge worker	155 users – Normal Mode	80%
Two 6130	Knowledge worker	186 users – Failover Mode	91%
Two 6130	Power worker	125 users – Normal Mode	74%
Two 6130	Power worker	150 users – Failover Mode	82%

Table 9 lists the recommended number of virtual desktops per server for different workload types and VM memory sizes. The number of users is reduced in some cases to fit within the available memory and still maintain a reasonably balanced system of compute and memory.

Table 9: Recommended number of virtual desktops per server

Workload	Office worker	Knowledge worker	Power worker
Processor	Two 6130	Two 6130	Two 6130
VM memory size	3 GB	4 GB	5 GB
System memory	768 GB	768 GB	768 GB
Memory overhead of CVM	24 GB	24 GB	24 GB
Desktops per server (normal mode)	180	155	125
Desktops per server (failover mode)	216	186	150

Table 10 lists the approximate number of compute servers that are needed for different numbers of users and Office worker workloads.

Table 10: Compute servers needed for Office workers and different numbers of users

Office workers	300 users	600 users	1200 users	3000 users
Compute servers @180 users (normal)	3	4	7	17
Compute servers @210 users (failover)	2	3	6	15

Table 11 lists the approximate number of compute servers that are needed for different numbers of users and Knowledge worker workloads.

Table 11: Compute servers needed for Knowledge workers and different numbers of users

Knowledge workers	300 users	600 users	1200 users	3000 users
Compute servers @155 users (normal)	3	5	8	20
Compute servers @186 users (failover)	2	4	7	16

Table 12 lists the approximate number of compute servers that are needed for different numbers of users and Power worker workloads.

Table 12: Compute servers needed for Power workers and different numbers of users

Power workers	300 users	600 users	1200 users	3000 users
Compute servers @125 users (normal)	3	5	10	24
Compute servers @150 users (failover)	2	4	8	20

4.7.2 Best practices

The number of desktops that can be run on a specific server depends upon the available system memory, compute power of the processors, and number of logons per second during a logon storm. For a cost-effective solution, the maximum number of users should be put on each server to balance processor, memory, storage I/O, and networking. Lenovo recommends using all flash appliances for situations where the user logon rate is high or time to reboot all the VMs on a node must be less than 10 minutes.

Another important consideration for compute servers is system memory. For stateless users, the typical range of memory that is required for each desktop is 2 GB - 4 GB. For dedicated users, the range of memory for each desktop is 2 GB - 6 GB. In general, power users that require larger memory sizes also require more virtual processors. This reference architecture standardizes on 2 GB per desktop as the minimum requirement of a Windows 10 desktop. The virtual desktop memory should be large enough so that swapping is not needed and vSwap can be disabled.

It is a best practice not to overcommit on memory as swapping to disk can have a severe effect on performance; a better strategy is to give each desktop more memory. Alternatively, a monitoring tool can be run to gather information about existing desktops. The desktop memory size that is required does not necessarily have to match the memory supplied in a desktop machine; it can be larger or smaller.

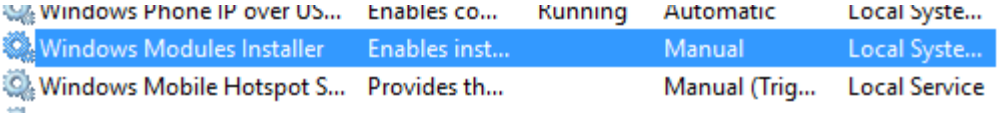
Lenovo recommends the use of VLANs to partition the network traffic. The following VLANs should be used:

- User (for web protocols, display protocols, and support service protocols)
- Management (for management protocols)
- Storage (for NDFS)

Lenovo recommends to always perform user virtualization, even if users have dedicated desktops. This separation of user-specific data makes it much easier to manage and perform upgrades.

Windows 10 was used for all of the performance testing. In general Windows 10 requires 10% to 20% more compute power than Windows 7. The following optimizations are recommended for the Windows 10 base image:

- Applied #VDILIKEAPRO Tuning Template(developed by loginVSI) – see the following for more details:
  loginvsi.com/blog/520-the-ultimate-windows-10-tuning-template-for-any-vdi-environment
- Set Adobe acrobat as a default app for PDF files using steps in following webpage:
  adobe.com/devnet-docs/acrobatetk/tools/AdminGuide/pdfviewer.html
- Disabled **Windows Modules installer** service on the base image because the CPU utilization can remain high after rebooting all the VMs. By default this service is set to manual rather than disabled.



Please refer to the websites below for best practices and optimizations recommended by Citrix:

- Windows 10 Optimization Guide:
  support.citrix.com/article/CTX216252
- Citrix Virtual Desktop Handbook 7.x:
  support.citrix.com/article/CTX139331

5 Microsoft Exchange

Microsoft Exchange Server 2016 is the market leader in enterprise messaging and collaboration. With increasing processor performance, the primary design goal for Exchange 2016 is simplicity of scale, hardware utilization, and failure isolation. With Exchange 2016, the number of server roles is reduced to two: Edge Transport server and the Mailbox server which includes client access and mailbox services. This chapter shows the performance of two scenarios using a 4 node cluster of Lenovo ThinkAgile HX7520 appliances: 30,000 mailboxes with hybrid storage and 60,000 mailboxes with all flash storage.

5.1 Solution overview

Figure 28 shows the architectural overview of the Microsoft Exchange solution. This chapter does not address integrating Exchange with unified messaging solutions and handling edge transport routing and distribution.

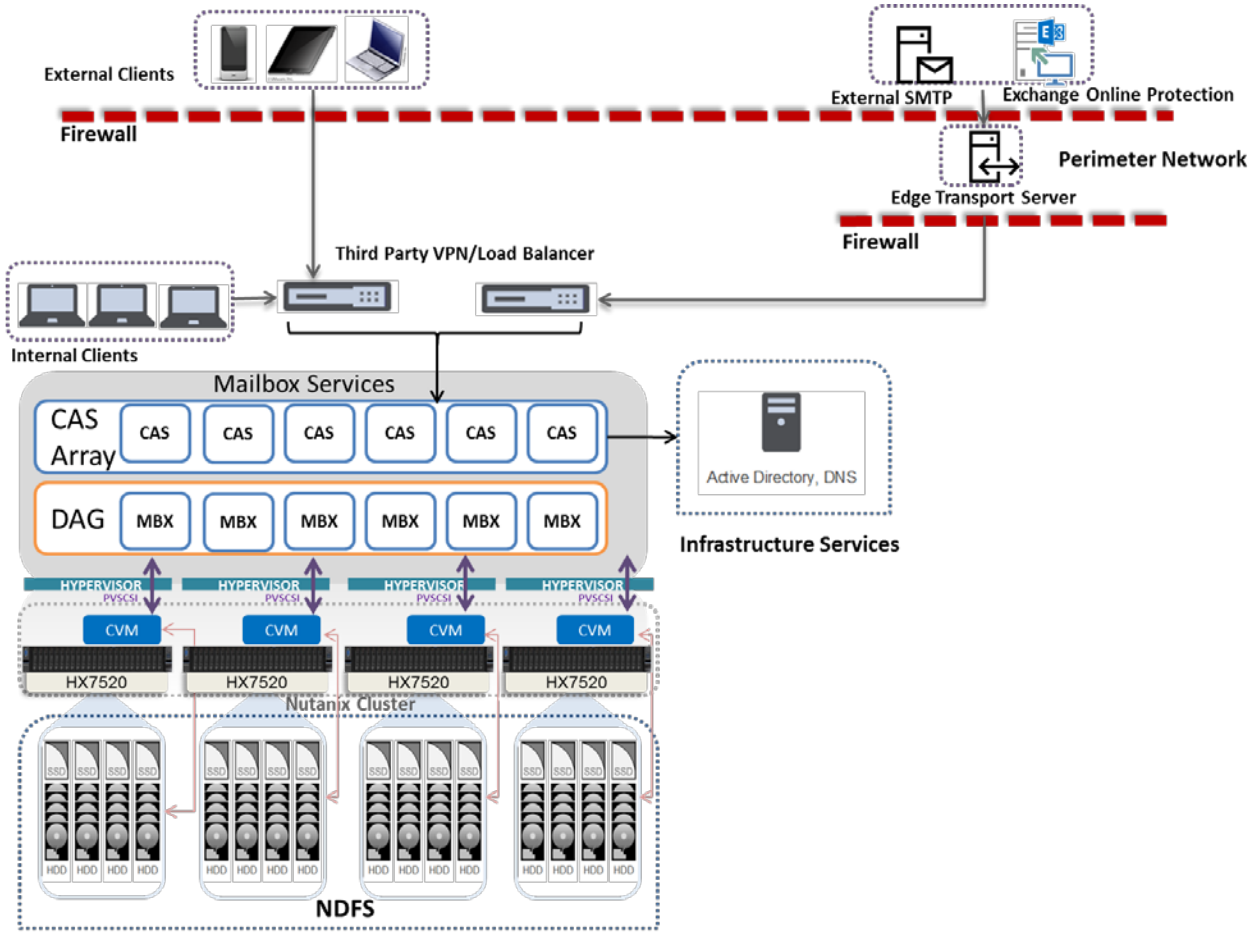


Figure 28. Lenovo ThinkAgile HX Series solution with Microsoft Exchange

The Client Access Server (CAS) role which is no longer a separate entity and is automatically installed with the Mailbox Server role still provides client protocols and unified messaging support. The Mailbox Server (MBX) role provides all of the data processing services. All external mail through SMTP is now handled via a separately installed Edge Transport Server, which usually resides within the perimeter network.

For load balancing into the CAS layer either a network load balancer can be used with a CAS array object or a layer 4 or layer 7 load balancer can be used without the need for configuring a CAS array.

5.2 Component model

This section describes the logical component view of the Exchange Server environment. Figure 29 shows a high-level component model.

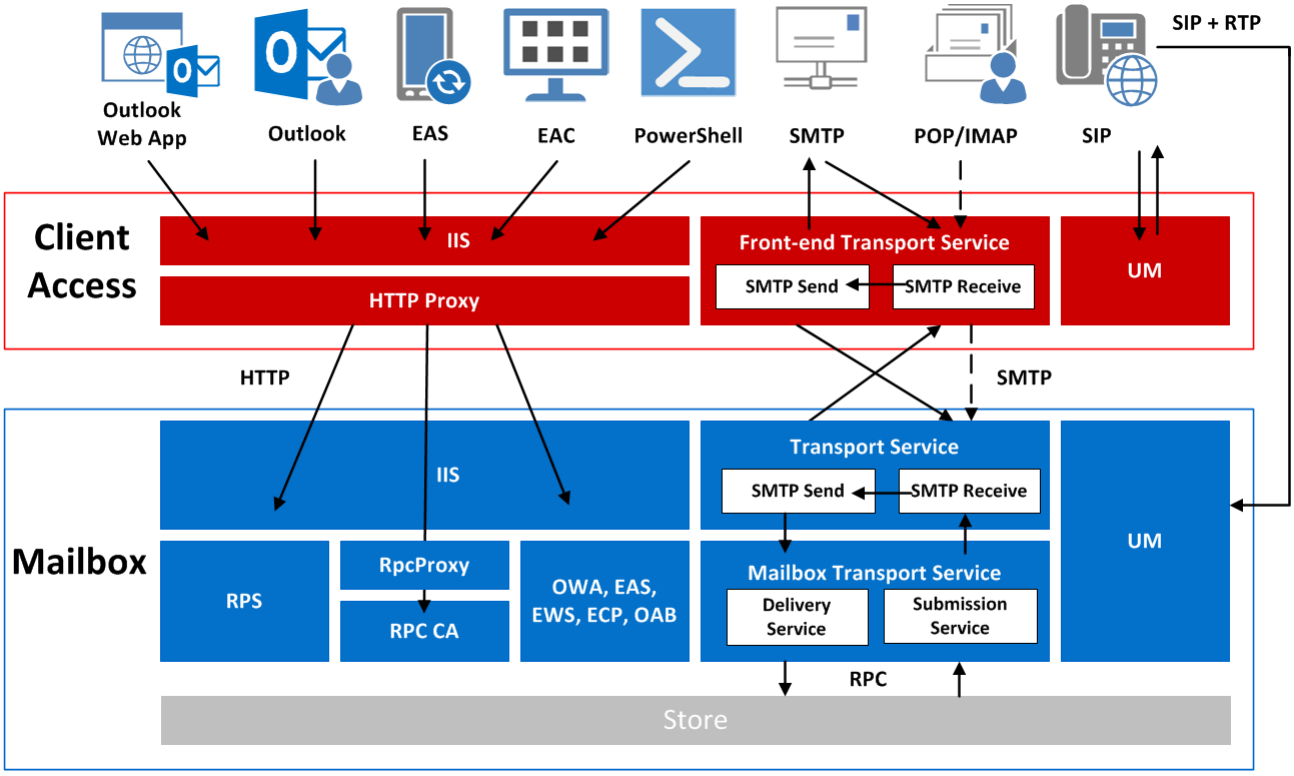


Figure 29. Exchange Server logical component view

The following basic concepts and terminology are used throughout this section:

Exchange Admin Center (EAC) – The EAC is the web-based management console in Microsoft Exchange Server that is optimized for on-premises, online, and hybrid Exchange deployments. The EAC replaces the Exchange Management Console (EMC) and the Exchange Control Panel (ECP), which were the two interfaces used to manage Exchange Server 2010.

Exchange Control Panel (ECP) – The ECP is a web application that runs on a Client Access Server and provides services for the Exchange organization.

Exchange Web Services (EWS) – EWS provides the functionality to enable client applications to communicate with the Exchange server.

Internet Information Services (IIS) – IIS is an extensible web server that was created by Microsoft for use with Windows NT family.

Internet Message Access Protocol (IMAP) – IMAP is a communications protocol for email retrieval and storage developed as an alternative to POP.

Microsoft Exchange ActiveSync (EAS) – EAS is a communications protocol that is designed for the synchronization of email, contacts, calendar, tasks, and notes from a messaging server to a smartphone or other mobile device.

Microsoft Outlook® Web App (OWA) – OWA (formerly Outlook Web Access) is a browser-based email client with which users can access their Microsoft Exchange Server mailbox from almost any web browser.

Offline Address Book (OAB) – The OAB is a copy of an address list collection that was downloaded so a Microsoft Outlook user can access the address book while disconnected from the server. Microsoft Exchange generates the new OAB files and then compresses the files and places them on a local share.

Outlook Anywhere – Outlook Anywhere is a service that provides RPC/MAPI connectivity for Outlook clients over HTTP or HTTPS by using the Windows RPC over HTTP component.

Post Office Protocol (POP) – The POP is an application-layer Internet standard protocol that is used by local email clients to retrieve email from a remote server over a TCP/IP connection

Real-time Transport Protocol (RTP) – RTP is a network protocol for delivering audio and video over IP networks.

Remote PowerShell (RPS) – RPS allows you to use Windows PowerShell on your local computer to create a remote Shell session to an Exchange server if you do not have the Exchange management tools installed.

RPC Client Access (RPC) – In Microsoft Exchange Server 2007, the Client Access server role was introduced to handle incoming client connections to Exchange mailboxes. Although most types of client connections were made to the Client Access server, Microsoft Office Outlook still connected directly to the Mailbox server when it was running internally with the MAPI protocol.

A new service was introduced with Exchange Server 2010 to allow these MAPI connections to be handled by the Client Access server. The RPC Client Access service provides data access through a single, common path of the Client Access server, with the exception of public folder requests (which are still made directly to the Mailbox server). This change applies business logic to clients more consistently and provides a better client experience when failover occurs.

Remote Procedure Call over HTTP – In Exchange 2016 this feature has been replaced by **MAPI over HTTP** offering improvements over the traditional Outlook anywhere (RPC over HTTP). In Exchange 2016 the MAPI over HTTP feature is enabled by default because Exchange 2016 which does not allow direct RPC connectivity.

Session Initiation Protocol (SIP) – SIP is a protocol that is used for starting, modifying, and ending an interactive user session that involves multimedia elements, such as video, voice, and instant messaging.

Simple Mail Transfer Protocol (SMTP) – SMTP is an Internet standard for email transmission.

Unified Messaging (UM) – UM allows an Exchange Server mailbox account that was enabled for UM to receive email, voice, and fax messages in the Inbox.

5.3 30,000 Mailbox Exchange Performance with Hybrid Storage

This section describes the deployment configuration and performance of a 4 node cluster using Lenovo ThinkAgile HX7520 appliances with hybrid storage to support 30,000 mailboxes.

5.3.1 DAG architecture overview

The following section illustrates the Lenovo ThinkAgile HX7520 based Exchange 2016 mailbox resiliency solution Lenovo implemented for ESRP testing.

Compute per node: 2 x Intel(R) Xeon(R) Platinum 8170 CPU @ 2.10GHz Processors

RAM per node: 768GB

Raw storage per node: SSD: 4 x 1.92TB SATA SSDs – 7.68TB
HDD: 20 x 2TB SATA HDDs – 40TB

Raw storage per cluster: SSD: 16 x 1.92 TB SATA SSDs – 31TB
HDD: 80 x 2TB SATA HDDs – 160 TB

Figure 30 describes the high level DAG architecture of the 30,000 mailbox virtualized Exchange 2016 mailbox resiliency solution. This solution comprises of two Lenovo ThinkAgile HX7520 clusters with 4 nodes per cluster. Each node uses the Nutanix Acropolis Hypervisor (AHV).

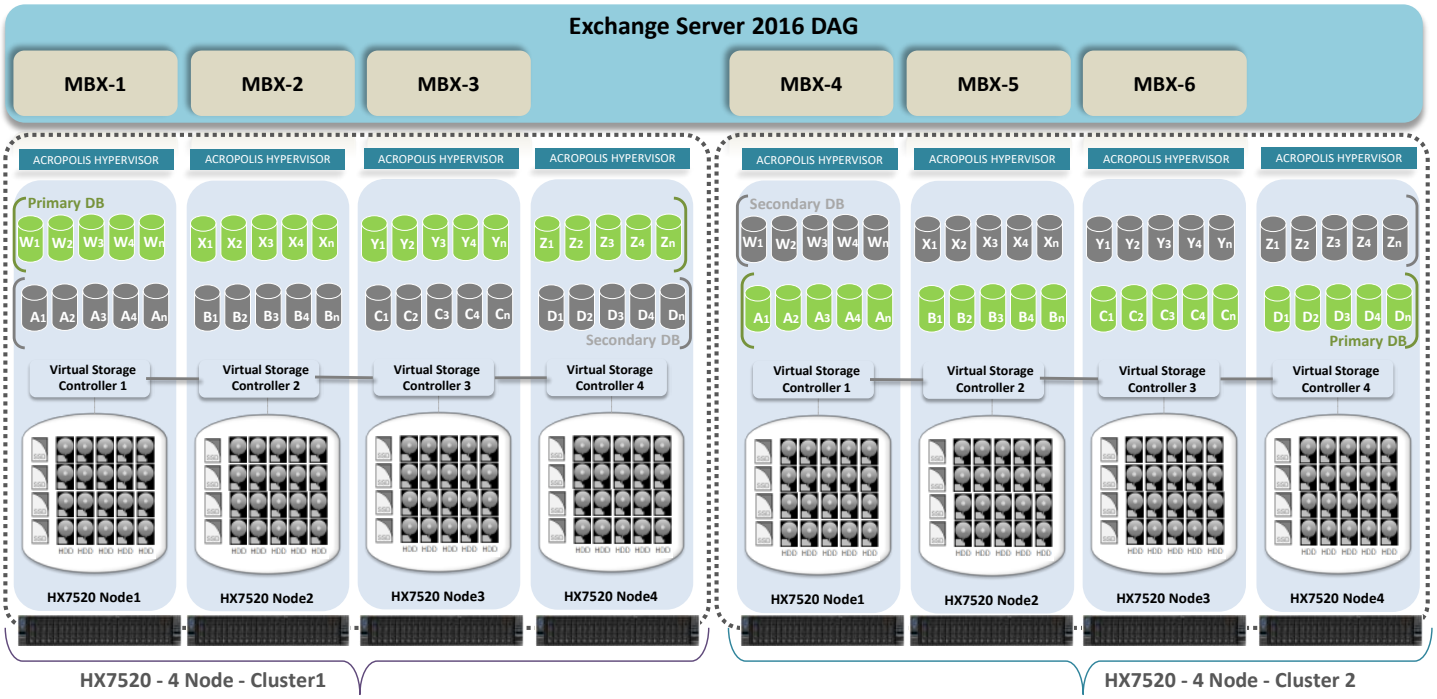


Figure 30. DAG Architecture using Exchange 2016 and Lenovo ThinkAgile HX7520 (30,000 Mailboxes)

The DAG has six Exchange 2016 mailbox servers and two database copies. The two database copies were placed on two physically isolated clusters. On both Cluster1 and Cluster2, the Mailbox server (MBX) VMs were created on three nodes. All the Database/Logs volumes were connected to Mailbox servers using the iSCSI protocol. The primary database copy and secondary database copy are stored on two physically

separated and isolated clusters. The two clusters can be located at the same datacentre or two different datacenters.

Each Mailbox Server VM is configured as follows:

- 40 vCPUs
- 96 GB RAM
- Windows Server 2016
- Microsoft Exchange 2016 with 10,000 mailboxes

The ESRP-Storage program focuses on storage solution testing to address performance and reliability issues with storage design. However, storage is not the only factor to take into consideration when designing a scale up Exchange solution. Other factors which affect the server scalability are: server processor utilization, server physical and virtual memory limitations, resource requirements for other applications, directory and network service latencies, network infrastructure limitations, replication and recovery requirements, and client usage profiles. All these factors are beyond the scope for ESRP-Storage. Therefore, the number of mailboxes hosted per server as part of the tested configuration may not necessarily be viable for some customer deployment.

For more information on identifying and addressing performance bottlenecks in an Exchange system, please refer to Microsoft's Troubleshooting Microsoft Exchange Server Performance, available at http://technet.microsoft.com/en-us/library/dd335215.aspx.

5.3.2 Targeted customer profile

The target customer profile for a medium enterprise Microsoft Exchange 2016 environment is as follows:

- 30,000 mailboxes of 1GB
- 6x Exchange 2016 servers (3x Tested)
- 0.06 IOPS per mailbox
- 24/7 background database maintenance
- Mailbox resiliency factor of 2
- 10 databases per host

5.3.3 Tested deployment environment

The section describes the tested deployment environment.

Simulated exchange configuration

The following table summarizes the simulated Exchange configuration.

Number of Exchange mailboxes simulated	30,000
Number of Database Availability Groups (DAGs)	1
Number of servers/DAG	6 (3 tested)
Number of active mailboxes/server	5,000 (5,000 active and 5,000 passive mailboxes per server and tested 10,000 active mailboxes per server)

Number of databases/host	10
Number of copies/database	2
Number of mailboxes/database	1000
Simulated profile: I/O's per second per mailbox (IOPS, include 20% headroom)	0.06 IOPs / Mailbox
Database/LUN size	1.5 TB
Total database size for performance testing	30 TB
% storage capacity used by Exchange database[1]	38.3%

Storage hardware

The following table summarizes the storage hardware.

Storage Connectivity (Fiber Channel, SAS, SATA, iSCSI)	iSCSI
Storage model and OS/firmware revision	HX7520 running Acropolis 5.1.3
Storage cache	47.69 GB per node
Number of storage controllers	4x virtual controller virtual machines
Number of storage ports	4 x 10 Gbe Port
Maximum bandwidth of storage connectivity to host	40 Gbps per node
Switch type/model/firmware revision	Lenovo RackSwitch G8272 (10GbE) Firmware version: 7.7.5
HBA model and firmware	Lenovo ThinkSystem 430-8i HBA
Number of HBA's/host	3
Host server type	3x Lenovo ThinkAgile HX7520 (2 x Intel(R) Xeon(R) Platinum 8170 CPU @ 2.10GHz) 768 GB RAM
Total number of disks tested in solution	96 (4 node cluster)
Maximum number of spindles can be hosted in the storage	96 (cluster can be scaled to 40+ nodes)

[1] Storage performance characteristics change based on the percentage utilization of the individual disks. Tests that use a small percentage of the storage (~25%) may exhibit reduced throughput if the storage capacity utilization is significantly increased beyond what is tested in this paper.

Storage software

The following table summarizes the storage software.

HBA driver	Nutanix Virt I/O SCSI Pass-thru Driver 62.62.101.5800
HBA QueueTarget Setting	N/A
HBA QueueDepth Setting	N/A
Hypervisor	Nutanix Acropolis Hypervisor (AHV)
Exchange VM guest OS	Windows Server 2016
ESE.dll file version	15.00.0847.030
Replication solution name/version	N/A

Storage disk configuration (mailbox store disks)

The following table summarizes the storage disk configuration.

Disk type, speed and firmware revision	Per Node: 4x Intel 1.92TB 6Gbps SATA G3HS 2.5" SSD 20x 2 TB 7.2K 6Gbps NL SATA 2.5" G3HS 512e HDD
Raw capacity per disk (GB)	2048 GB (2 TB)
Number of physical disks in test	96 (16x 1.92 TB + 80x 2 TB)
Total raw storage capacity (GB)	195,297GB
Disk slice size (GB)	N/A
Number of slices or disks per LUN	N/A
Raid level	Nutanix Replication Factor 2 (RAID 1)
Total formatted capacity	78.33 TB
Storage capacity utilization	41%
Database capacity utilization	15.7%

5.3.4 Performance test results

This section provides a high-level summary of the results of executing the Microsoft ESRP storage test version 4.0 on the configuration of 4 Lenovo ThinkAgile HX7520 appliances as described in the previous section. ESRP storage test results include reliability, storage performance, and database backup/restore.

Note that the ESRP program is not designed to be a benchmarking program and tests are not designed to get the maximum throughput for a giving solution. Rather, the program is focused on producing recommendations from vendors for the Exchange application. Therefore, the data presented in this document should not be

used for direct comparisons among the solutions and customers should not quote the data directly for their pre-deployment verifications. It is recommended that a proof of concept is carried out to validate the storage design for a specific customer environment.

The results in this section were developed by Lenovo and reviewed by the Microsoft Exchange Product team.

Reliability

Several of the tests in the ESP test framework are used to check reliability and run for 24 hours. The test objective is to verify that the storage can handle high I/O workloads for extensive periods. Log and database files are analyzed for integrity after the stress test to ensure there is no database or log corruption.

Executing this test on the Lenovo ThinkAgile HX7520 appliances showed:

- No errors reported in the saved event log file.
- No errors reported during the database and log checksum process.

Storage performance results

The primary storage performance test in the ESP test framework is designed to exercise the storage with a maximum sustainable Exchange I/O pattern for 2 hours. The purpose is to reveal how long it takes for the storage to respond to I/O operations under a load.

Table 13 shows the sum of I/O's and the average latency across all storage groups on a per server basis.

Table 13: Individual Server Performance

	Node 1	**Node 2**	**Node 3**
Database I/O			
Database Disks Transfers/sec	1564.80	1460.86	1464.32
Database Disks Reads/sec	1061.10	991.52	993.425
Database Disks Write/sec	503.66	469.34	470.90
Average Database Disk Read Latency (ms)	6.90	7.55	7.56
Average Database Disk Write Latency (ms)	3.90	4.56	4.66
Transaction Log I/O			
Log Disks Writes/sec	11.8	11.03	11.05
Average Log Disk Write Latency(ms)	0.98	0.91	0.91

Table 14 shows the sum of I/O's and the average latency across the 3 primary servers in the solution.

Table 14: Aggregate Server Performance

Database I/O	
Database Disks Transfers/sec	4489.98
Database Disks Reads/sec	3046.05
Database Disks Writes/sec	1443.89
Average Database Disk Read Latency (ms)	7.35
Average Database Disk Write Latency (ms)	4.39
Transaction Log I/O	
Log Disks Writes/sec	33.89
Average Log Disk Write Latency (ms)	1.70

Database backup/recovery performance

Several of the tests in the ESP test framework are used to measure the sequential read rate of the database files and the recovery/replay performance (playing transaction logs into the database).

The database read-only performance test measures the maximum rate at which databases could be backed up using Microsoft Volume Shadow Copy Service (VSS). Table 15 shows the average read performance for a backing up a single database file and all ten database files on a single node.

Table 15: Database backup read-only performance results

MB read/sec per database	67.07
MB read/sec total per node (10 databases)	670.70

Transaction log recovery/replay performance

The test is to measure the maximum rate at which the log files can be played against the databases. Table 16 shows the average rate for 500 log files played in a single storage group. Each log file is 1 MB in size.

Table 16: Transaction Log Recovery/Replay Performance

Average time to play one Log file (sec)	0.42

5.4 60,000 Mailbox Exchange Performance with AF Storage

This section describes the deployment configuration and performance of a 4 node cluster using Lenovo ThinkAgile HX7520 appliances with all flash storage to support 60,000 mailboxes.

5.4.1 DAG architecture overview

The following section illustrates the Lenovo ThinkAgile HX7520 based Exchange 2016 mailbox resiliency solution Lenovo implemented for ESRP testing.

Compute per node: 2 x Intel(R) Xeon(R) Platinum 8170 CPU @ 2.10GHz Processors

RAM per node: 768GB

Raw storage per node: SSD: 24 x 1.92TB SATA SSDs – 46.08TB

Raw storage per cluster: SSD: 96 x 1.92 TB SATA SSDs – 184.32TB

Figure 30 describes the high level DAG architecture of the 60,000 mailbox virtualized Exchange 2016 mailbox resiliency solution. This solution comprises of two Lenovo ThinkAgile HX7520 clusters with 4 nodes per cluster. Each node uses the Nutanix Acropolis Hypervisor (AHV).

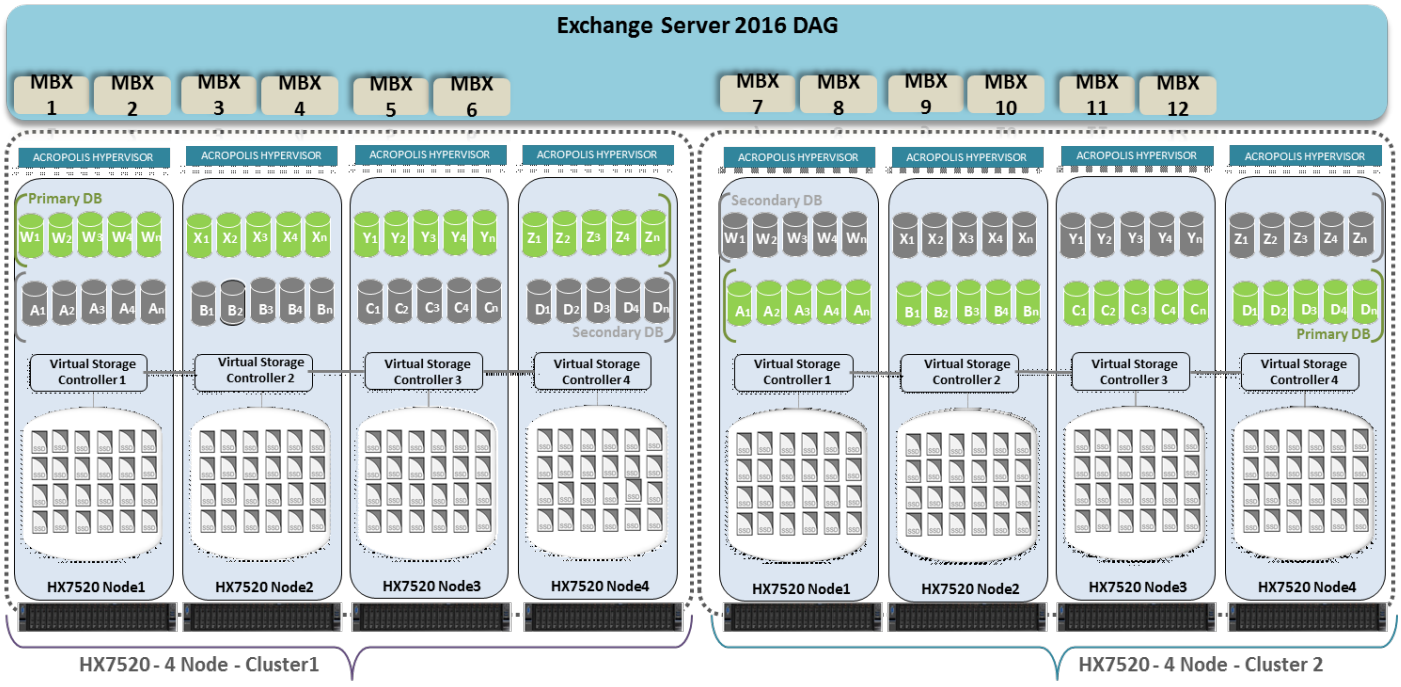


Figure 31. DAG Architecture using Exchange 2016 and Lenovo ThinkAgile HX7520 (60,000 Mailboxes)

The DAG has twelve Exchange 2016 mailbox servers and two database copies. The two database copies were placed on two physically isolated clusters. On both Cluster1 and Cluster2, the Mailbox server (MBX) VMs were created on three nodes. All the Database/Logs volumes were connected to Mailbox servers using the iSCSI protocol. The primary database copy and secondary database copy are stored on two physically separated and isolated clusters. The two clusters can be located at the same datacentre or two different datacenters.

Each Mailbox Server VM is configured as follows:

- 40 vCPUs
- 96 GB RAM
- Windows Server 2016
- Microsoft Exchange 2016 with 10,000 mailboxes

The ESRP-Storage program focuses on storage solution testing to address performance and reliability issues with storage design. However, storage is not the only factor to take into consideration when designing a scale up Exchange solution. Other factors which affect the server scalability are: server processor utilization, server physical and virtual memory limitations, resource requirements for other applications, directory and network service latencies, network infrastructure limitations, replication and recovery requirements, and client usage profiles. All these factors are beyond the scope for ESRP-Storage. Therefore, the number of mailboxes hosted per server as part of the tested configuration may not necessarily be viable for some customer deployment.

For more information on identifying and addressing performance bottlenecks in an Exchange system, please refer to Microsoft's Troubleshooting Microsoft Exchange Server Performance, available at http://technet.microsoft.com/en-us/library/dd335215.aspx.

5.4.2 Targeted customer profile

The target customer profile for a medium enterprise Microsoft Exchange 2016 environment is as follows:

- 60,000 mailboxes of 0.75GB
- 12x Exchange 2016 servers (6x Tested)
- 0.06 IOPS per mailbox
- 24/7 background database maintenance
- Mailbox resiliency factor of 2
- 10 databases per host

5.4.3 Tested deployment environment

The section describes the tested deployment environment.

Simulated exchange configuration

The following table summarizes the simulated Exchange configuration.

Number of Exchange mailboxes simulated	60,000
Number of Database Availability Groups (DAGs)	1
Number of servers/DAG	12 (6 tested)
Number of active mailboxes/server	10,000 (10,000 active and 10,000 passive mailboxes per server and tested 20,000 active mailboxes per server)
Number of databases/host	10

Number of copies/database	2
Number of mailboxes/database	1000
Simulated profile: I/O's per second per mailbox (IOPS, include 20% headroom)	0.06 IOPs / Mailbox
Database/LUN size	800 GB
Total database size for performance testing	32 TB
% storage capacity used by Exchange database[2]	44.8%

Storage hardware

The following table summarizes the storage hardware.

Storage Connectivity (Fiber Channel, SAS, SATA, iSCSI)	iSCSI
Storage model and OS/firmware revision	HX7520 running Acropolis 5.1.3
Storage cache	N/A
Number of storage controllers	4x virtual controller virtual machines
Number of storage ports	4 x 10 Gbe Port
Maximum bandwidth of storage connectivity to host	40 Gbps per node
Switch type/model/firmware revision	Lenovo RackSwitch G8272 (10GbE) Firmware version: 7.7.5
HBA model and firmware	Lenovo ThinkSystem 430-8i HBA
Number of HBA's/host	3
Host server type	3x Lenovo ThinkAgile HX7520 (2 x Intel(R) Xeon(R) Platinum 8170 CPU @ 2.10GHz) 768 GB RAM
Total number of disks tested in solution	96 (4 node cluster)
Maximum number of spindles can be hosted in the storage	96 (cluster can be scaled to 40+ nodes)

[2] Storage performance characteristics change based on the percentage utilization of the individual disks. Tests that use a small percentage of the storage (~25%) may exhibit reduced throughput if the storage capacity utilization is significantly increased beyond what is tested in this paper.

Storage software

The following table summarizes the storage software.

HBA driver	Nutanix Virt I/O SCSI Pass-thru Driver 62.62.101.5800
HBA QueueTarget Setting	N/A
HBA QueueDepth Setting	N/A
Hypervisor	Nutanix Acropolis Hypervisor (AHV)
Exchange VM guest OS	Windows Server 2016
ESE.dll file version	15.00.0847.030
Replication solution name/version	N/A

Storage disk configuration (mailbox store disks)

The following table summarizes the storage disk configuration.

Disk type, speed and firmware revision	Per Node: 24 x Intel 1.92TB 6Gbps SATA G3HS 2.5" SSD
Raw capacity per disk (GB)	1966 GB (1.92 TB)
Number of physical disks in test	96 x 1.92 TB
Total raw storage capacity (GB)	188,736 GB
Disk slice size (GB)	N/A
Number of slices or disks per LUN	N/A
Raid level	Nutanix Replication Factor 2 (RAID 1)
Total formatted capacity	71.33 TB
Storage capacity utilization	39%
Database capacity utilization	17.6%

5.4.4 Performance test results

This section provides a high-level summary of the results of executing the Microsoft ESRP storage test version 4.0 on the configuration of 4 Lenovo ThinkAgile HX7520 appliances as described in the previous section. ESRP storage test results include reliability, storage performance, and database backup/restore.

Note that the ESRP program is not designed to be a benchmarking program and tests are not designed to get the maximum throughput for a giving solution. Rather, the program is focused on producing recommendations from vendors for the Exchange application. Therefore, the data presented in this document should not be used for direct comparisons among the solutions and customers should not quote the data directly for their

pre-deployment verifications. It is recommended that a proof of concept is carried out to validate the storage design for a specific customer environment.

The results in this section were developed by Lenovo and reviewed by the Microsoft Exchange Product team.

Reliability

Several of the tests in the ESP test framework are used to check reliability and run for 24 hours. The test objective is to verify that the storage can handle high I/O workloads for extensive periods. Log and database files are analyzed for integrity after the stress test to ensure there is no database or log corruption.

Executing this test on the Lenovo ThinkAgile HX7520 appliances showed:

- No errors reported in the saved event log file.
- No errors reported during the database and log checksum process.

Storage performance results

The primary storage performance test in the ESP test framework is designed to exercise the storage with a maximum sustainable Exchange I/O pattern for 2 hours. The purpose is to reveal how long it takes for the storage to respond to I/O operations under a load.

Table 17 shows the sum of I/O's and the average latency across all storage groups on a per server basis.

Table 17: Individual Server Performance

	Node 1	**Node 2**	**Node 3**
Database I/O			
Database Disks Transfers/sec	3559.83	3441.53	3684.05
Database Disks Reads/sec	2530.87	2445.83	2514.00
Database Disks Write/sec	1210.10	1171.54	1260.44
Average Database Disk Read Latency (ms)	6.44	7.56	6.40
Average Database Disk Write Latency (ms)	8.14	10.24	8.26
Transaction Log I/O			
Log Disks Writes/sec	15.65	15.12	15.97
Average Log Disk Write Latency(ms)	2.58	2.31	2.63

Table 18 shows the sum of I/O's and the average latency across the 3 primary servers in the solution.

Table 18: Aggregate Server Performance

Database I/O	
Database Disks Transfers/sec	10685.41
Database Disks Reads/sec	7490.70
Database Disks Writes/sec	3642.08
Average Database Disk Read Latency (ms)	6.8
Average Database Disk Write Latency (ms)	8.88
Transaction Log I/O	
Log Disks Writes/sec	46.74
Average Log Disk Write Latency (ms)	2.51

Database backup/recovery performance

Several of the tests in the ESP test framework are used to measure the sequential read rate of the database files and the recovery/replay performance (playing transaction logs into the database).

The database read-only performance test measures the maximum rate at which databases could be backed up using Microsoft Volume Shadow Copy Service (VSS). Table 19 shows the average read performance for a backing up a single database file and all 20 database files on a single node.

Table 19: Database backup read-only performance results

MB read/sec per database	133.32
MB read/sec total per node (10 databases)	1330.05

Transaction log recovery/replay performance

The test is to measure the maximum rate at which the log files can be played against the databases. Table 20 shows the average rate for 500 log files played in a single storage group. Each log file is 1 MB in size.

Table 20: Transaction Log Recovery/Replay Performance

Average time to play one Log file (sec)	3.25

5.5 Exchange deployment best practices

This section describes recommended best practices for Microsoft Exchange mailboxes. See also this website for Nutanix Best Practices Guide: Virtualizing Microsoft Exchange: go.nutanix.com/virtualizing-microsoft-exchange-converged-infrastructure.html.

5.5.1 Data optimization

By default all Nutanix storage containers are thin provisioned which reduces unused capacity and automatically provisions additional storage capacity when needed. It is also very easy to add additional storage capacity for mailboxes by simply adding nodes to the cluster. It is also possible to set a storage reservation to guarantee a minimum amount of storage capacity.

Data compression can be used to further increase data capacity especially for data that is less frequently accessed. Lenovo recommends enabling compression with a delay of 1440 minutes (1 day) which minimizes the performance impact on I/O writes.

Data de-duplication is not recommended and should be disabled for active Exchange mailboxes because of the frequency of changes. Note that de-duplication may be beneficial for backup volumes which are not changed very often.

A resiliency factor of 2 is the default. This provides a minimum level of data redundancy but a resiliency factor of 3 might be important in some environments. Using erasure coding saves significant storage capacity but it is only recommended for archive data.

5.5.2 Cluster high availability

The minimum number of nodes in each cluster is 3 and should be at least 4 to provide failover. The following high availability features are recommended for an AHV-based cluster:

A database availability group (DAG) is the base component of the high availability and site resilience framework that is built into Microsoft Exchange Server. A DAG is a group of up to 16 mailbox servers that hosts a set of mailbox databases and provides automatic database-level recovery from failures that affect individual servers or databases.

A DAG is a boundary for mailbox database replication, database and server switchovers, failovers, and an internal component called Active Manager. Active Manager, which runs on every server in a DAG, manages switchovers and failovers.

Any server in a DAG can host a copy of a mailbox database from any other server in the DAG. When a server is added to a DAG, it works with the other servers in the DAG to provide automatic recovery from failures that affect mailbox databases (such as a disk failure or server failure).

Lenovo recommends a DAG configuration of 2 database copies and optionally one lagged copy. With a data resiliency factor of 2, the effective number of copies of each mailbox is 4 and this allows two disk failures without losing data.

DR across datacenters can also be done using DAGs assuming there is sufficient band-width between the sites. The scenarios for active-active and active-passive DR sites using DAGs are outside the scope of this document.

5.5.3 Other best practices

Consider the following points regarding virtualizing Exchange:

- All Exchange server roles should be supported in a single VM.
- Some hypervisors include features for taking snapshots of VMs. However, VM snapshots are not application aware, and the use of snapshots can have unintended and unexpected consequences for a server application that maintains state data, such as Exchange. Therefore, making VM snapshots of an Exchange guest VM is not supported.

5.6 Summary

This chapter shows the performance of two scenarios using a 4 node cluster of Lenovo ThinkAgile HX7520 appliances: 30,000 mailboxes with hybrid storage and 60,000 mailboxes with all flash storage. The performance advantage of an all flash configuration is clearly shown as it easily supports twice as many mailboxes as the hybrid drive configuration by using two VMs per node instead of one. Testing with Exchange 2013 shows very similar performance results to Exchange 2016.

The cluster of 4 Lenovo Converged HX7520 appliances proved more than capable of handling the high IOPs generated by both scenarios. Part of the reason for this is because the Lenovo Converged HX7520 appliances use 3 HBAs for the 24 drives. For best performance, it is recommended to use the Nutanix Windows drivers instead of the default Windows drivers for iSCSI. See download.nutanix.com/mobility/1.1.1/Nutanix-VirtIO-1.1.1.msi.

For more details, see the following ESRP reports published by Lenovo and approved by Microsoft:

- 60,000 Mailbox Resiliency Solution for Microsoft Exchange 2016 using all flash Lenovo ThinkAgile HX7520 Appliances and AHV: lenovopress.com/lp0838
- 30,000 Mailbox Resiliency Solution for Microsoft Exchange 2016 using Lenovo ThinkAgile HX7520 Appliances and AHV: lenovopress.com/lp0820
- 30,000 Mailbox Resiliency Solution for Microsoft Exchange 2013 using Lenovo ThinkAgile HX7520 Appliances and AHV: lenovopress.com/lp0819

6 Microsoft SQL Server

Microsoft SQL Server is a database platform for large-scale online transaction processing (OLTP), data warehousing, and a business intelligence platform for data integration, analysis, and reporting solutions. It uses a common set of tools to deploy and manage databases for in-house and cloud environments.

6.1 Solution overview

Figure 32 shows high level architecture of Microsoft SQL Server on Lenovo Converged HX7520 appliances.

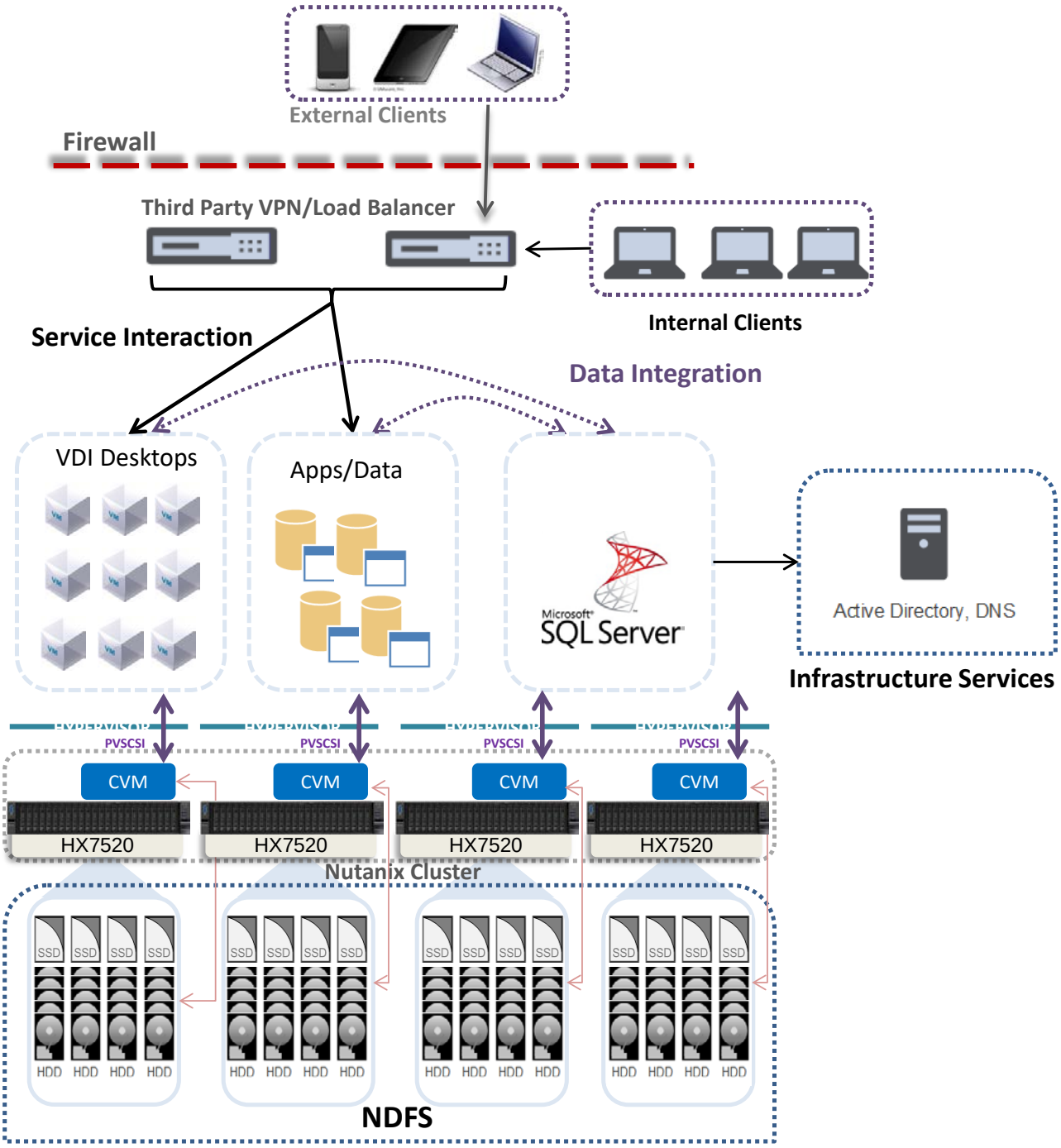


Figure 32: Lenovo Converged HX Series solution with Microsoft SQL Server

Microsoft SQL Server 2016 can be deployed and can operate in combination with other hosted applications and provides a single scalable platform for all deployments.

6.2 Component model

Figure 33 is a layered component view for Microsoft SQL Server.

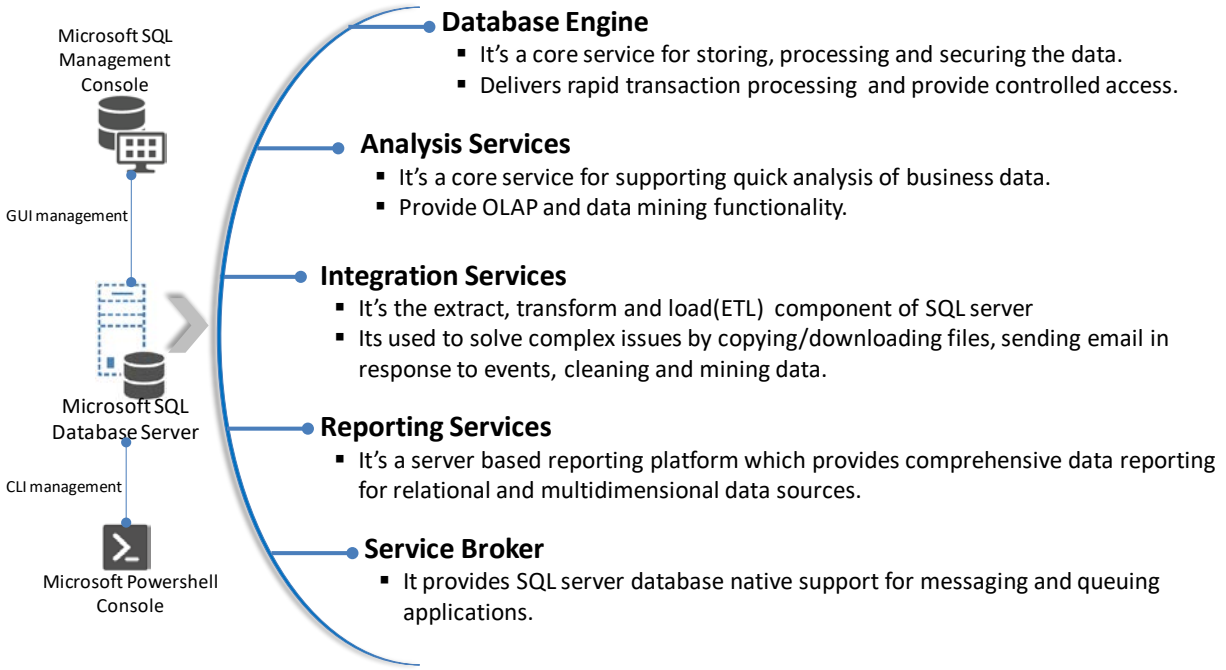


Figure 33: Component model with Microsoft SQL Server

Microsoft SQL Server features the following main components:

Database Engine	This part of SQL Server actually creates and drives relational databases.
Analysis Services	SQL Server Analysis Services (SSAS) is the data analysis component of SQL Server. It can create OLAP (OnLine Analytical Processing) cubes — sophisticated programming objects for organizing data inside a relational database — and do data mining (pulling relevant data out of a database in response to an ad-hoc question).
Integration Services	SQL Server Integration Services (SSIS) performs the extract-transform-load (ETL) process that cleans up and formats raw data from source systems for inclusion in the database as ready-to-use information.
Reporting Services	SQL Server Reporting Services (SSRS) provides reporting regardless of a database's operating system.
Service Broker	SQL Server Service Broker provides native support for messaging and queuing applications which makes it easier to build distributed and reliable applications that use the Database Engine components.

6.3 SQL Server deployment best practices

This section describes recommended best practices to provide data optimization and high availability of Microsoft SQL Server. See also this website for Nutanix Best Practices: Microsoft SQL server 2016: go.nutanix.com/microsoft-sql-server-converged-infrastructure.html.

6.3.1 Data optimization

By default all Nutanix storage containers are thin provisioned which reduces unused capacity and automatically provisions additional storage capacity when needed. It is also very easy to add additional storage capacity for databases by simply adding nodes to the cluster. It is also possible to set a storage reservation amount to guarantee a minimum amount of storage capacity.

Data compression can be used to further increase data capacity especially for data that is less frequently accessed. Lenovo recommends enabling compression with a delay of 1440 minutes (1 day) which minimizes the performance impact on I/O writes.

Data de-duplication is not recommended and should be disabled for SQL Server because of the frequency of changes. Note that de-duplication may be beneficial for backup volumes which are not changed very often.

A resiliency factor of 2 is the default. This provides a minimum level of data redundancy but a resiliency factor of 3 might be important in some environments. Using erasure coding saves significant storage capacity but it only recommended for archive data.

6.3.2 Cluster high availability

The minimum number of nodes in each cluster is 3 and should be at least 4 to provide failover. The following high availability features are recommended for an ESXi-based cluster:

- VMware vSphere high availability (HA) for failover
- VMware vSphere distributed resource scheduler (DRS) for load balancing
- Microsoft AlwaysOn availability groups (AAGs) for data redundancy

VMware vSphere HA pools VMs into a cluster to increase data resiliency. If a host fails, VMware HA moves the VMs to other hosts with spare capacity. Lenovo recommends enabling the “Admission Control Setting” and using the “Admission Control Policy” to set the percentage of cluster resources reserved as failover spare capacity.

VMware vSphere DRS can be used to group ESXi hosts into resource clusters to provide highly available resources and balance workloads. In order to keep the active working set for each SQL Server VM local to the node, Lenovo recommends creating a host group for each node and a “should” rule that keeps each SQL Server VM on a 1 to 1 ratio with the ESXi host. The hosts should be configured with a minimum of N+1 availability.

The Microsoft AlwaysOn availability groups (AAGs) is a recommended high availability mechanism. It uses a shared-nothing approach where transactions are replicated to other nodes so each node has a full copy of the database and transaction logs. This provides a very fast failover mechanism. The DRS anti-affinity rules need to be used to ensure that the SQL Server VMs are placed on different physical hosts.

DR across datacenters can also be done using AAGs assuming there is sufficient band-width between the sites. The scenarios for active-active and active-passive DR sites using AAGs are outside the scope of this document.

6.3.3 Virtual Disk Configuration

Multiple virtual disks should be used to keep SQL binaries, database, and database logs files and achieve optimal SQL performance. All four SCSI controllers should be utilized and virtual disks should be distributed evenly across controllers as shown in Table 21.

Table 21: Mapping of virtual disks for ESXi and cluster size

Virtual Disk	vSCSI Controller Type	Controller #	Cluster size
Operating System	LSI Logic SAS	0	4 KB
SQL Binaries	LSI Logic SAS	0	4 KB
Backup/Restore	LSI Logic SAS	0	64 KB
SQL Database - 1	VMware Paravirtual	1	64 KB
SQL Database - 2	VMware Paravirtual	1	64 KB
TempDB - 1	VMware Paravirtual	2	64 KB
TempDB - 2	VMware Paravirtual	2	64 KB
TempDB log files	VMware Paravirtual	3	64 KB
Database log files	VMware Paravirtual	3	64 KB

All SQL database and log drives should be formatted with 64KB NTFS cluster size as it enhances the I/O performance without adding any overhead. The OS and SQL binary drives should be formatted with the standard 4KB NTFS cluster size. Drives space utilization should not be above 80% to achieve optimal performance.

To maximize the storage performance of SQL Server VMs, Lenovo recommends using the ESXi Paravirtual SCSI (PVSCSI) adapters. Each PVSCSI adapter can support up to 15 VMDKs.

6.3.4 SQL Server Files

To achieve high performance, the database should be split into multiple files across multiple virtual disks. In general, one database file per vCPU is ideal. For example a VM with 4 vCPUs hosting 400GB database could be split into four 100GB database files and should spread evenly across the two virtual disks.

For write intensive databases, it is recommended to distribute the database files over four or more virtual disks as it improves the write performance on the back-end and delivers consistent performance.

SQL log files (DB and TempDB) are written sequentially, so using multiple log files wouldn't improve the performance. Using single log file per database is recommended.

TempDB is used as scratch space by the applications and is one of the most important factors of SQL performance. The number of TempDB files to be used is based on the vCPU count. If the vCPUs are less than 8, then configure the same number of TempDB files. If the number of vCPUs is higher than 8, then start with 8

TempDB files and monitor the contention for in-memory allocation (PAGELATCH_XX). The number of TempDB file should be increased in increments of four until contention is eliminated.

It is recommended to create all TempDBs with the same size and not allow for autogrowth. The TempDB file sizing should be done based on required application and is usually 1-10% of the database size.

6.4 Performance test configuration

This section describes the test configuration for Microsoft SQL Server 2016 using a cluster of 4 Lenovo Converged HX7520 appliances. Each appliance has the following configuration:

- 2 x Intel Xeon Scalable 8170 (26 cores @ 2.1 GHz) processors
- 768GB RAM
- 4 x 1.92TB SATA SSDs
- 20 x 2TB SATA HDDs
- ESXi 6.5 U1
- Set UEFI to “Performance Bias” – for more information, see lenovopress.com/lp0780

Each host has ESXi 6.5 U1 and is configured with HA and DRS. The cluster has 8 SQL Server VMs, each configured as follows:

- 28 vCPUs
- 192 GB RAM
- Windows Server 2012 R2
- Microsoft SQL 2016 Enterprise

The Nutanix CVM is configured as follows:

- 10 vCPUs
- 96 GB RAM
- CPU affinity 0-51

See also the optimization recommendation in the HammerDB optimization document: hammerdb.com/hammerdb_mssql_oltp_best_practice.pdf.

6.5 Performance test results

This section provides a high-level summary of the results of executing the HammerDB test suite. HammerDB is a graphical open source database load testing and benchmarking tool for Linux and Windows to test databases running on any operating system. HammerDB is automated, multi-threaded and extensible with dynamic scripting support. See this website for more details: hammerdb.com.

This test concentrated on executing 8 VMs on a four node cluster of Lenovo Converged HX7520 appliances with two VMs per node. Each cluster has a raw storage of 61TB of SSDs and 160TB of HDDs.

A 5,000 scale OLTP database was used for each VM, which equates to about 1.4TB of database records on the cluster per VM and a total storage of 11.2TB in the cluster.

Separate load servers were used to simulate the user load. Each OLTP database workload was simulated by running 500 users simultaneously for a total of 4,000 users across the 8 VMs. Each test run had a 5 minute ramp up phase and executed for 15 minutes to simulate 55,000 transactions per user.

Table 22 shows the results of the HammerDB test.

Table 22: Microsoft SQL Server results with cluster of four HX7520 appliances

Node	VM Name	HammerDB TPM	HammerDB NOPM
Node 1	SQL Instance - 1	1,717,934	374,350
	SQL Instance - 2	1,837,770	400,809
Node 2	SQL Instance - 3	1,790,723	389,993
	SQL Instance - 4	1,800,382	392,138
Node 3	SQL Instance - 5	1,756,975	383,838
	SQL Instance - 6	1,816,443	395,974
Node 4	SQL Instance - 7	1,782,125	388,232
	SQL Instance - 8	1,704,873	371,750
	Total	14,207,225	3,097,084

The 4 node cluster can execute over 14 million transactions per minute and over 3 million new orders per minute. The CPU utilization is 90-95%.

The HX7520 appliances can be configured into a complete ThinkAgile SXN solution delivered from the factory.

7 VMware Horizon

Horizon View is a desktop virtualization product developed by VMware Inc. It provides remote desktop capabilities by using VMware virtualization technology and can deliver a consistent user experience across devices and locations while keeping corporate data secure and compliant. See this website for more details: vmware.com/products/horizon-view.

7.1 Solution overview

Figure 34 shows all of the main features of the Lenovo Hyper-converged Nutanix solution's reference architecture with VMware Horizon 7.2 on VMware ESXi 6.5 U1 hypervisor. This chapter does not address the general issues of multi-site deployment and network management and limits the description to the components that are inside the customer's intranet.

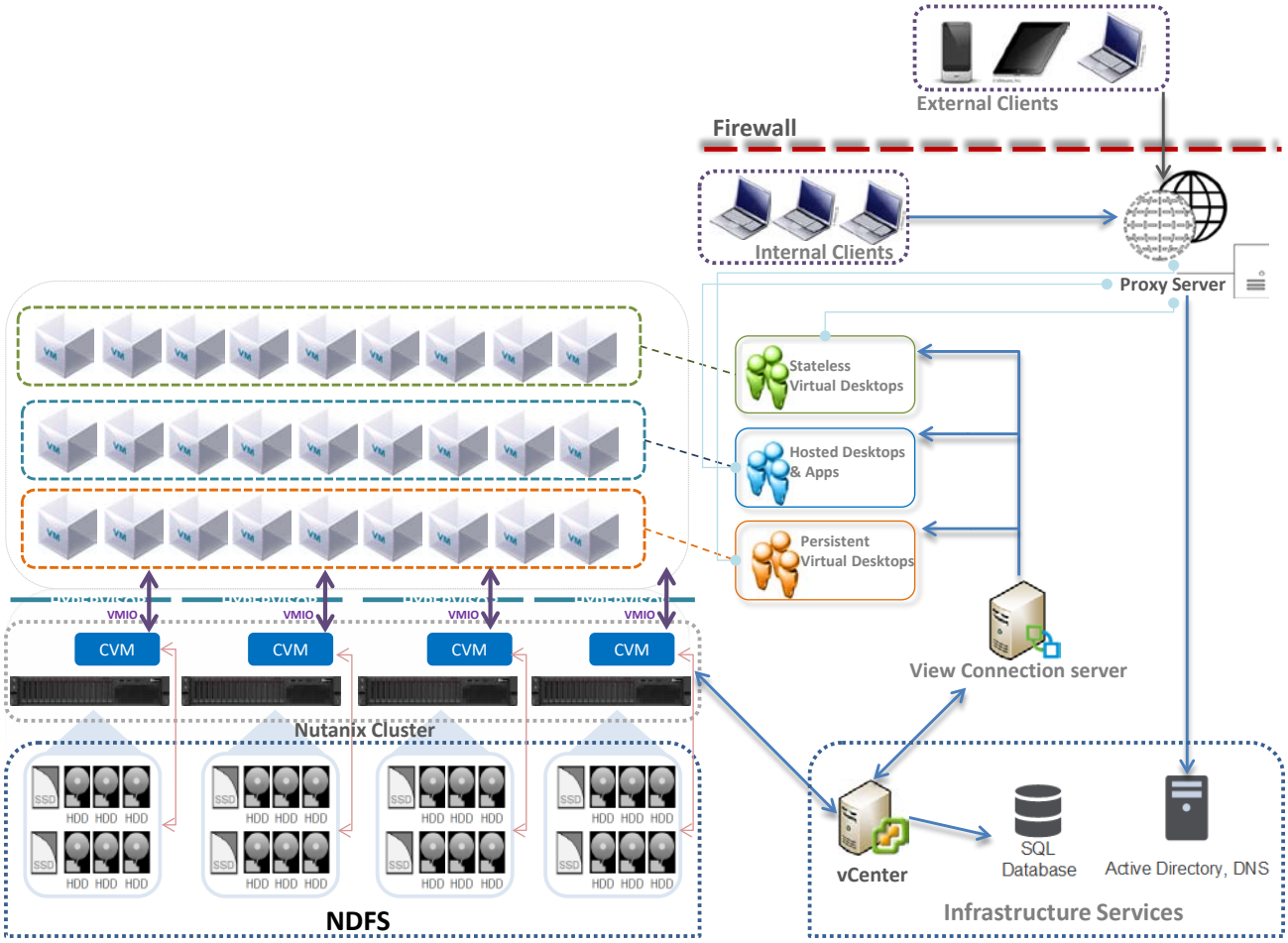


Figure 34: Lenovo ThinkAgile HX Series solution with VMware Horizon

7.2 Component model

Figure 35 is a layered component view for the VMware Horizon virtualization infrastructure.

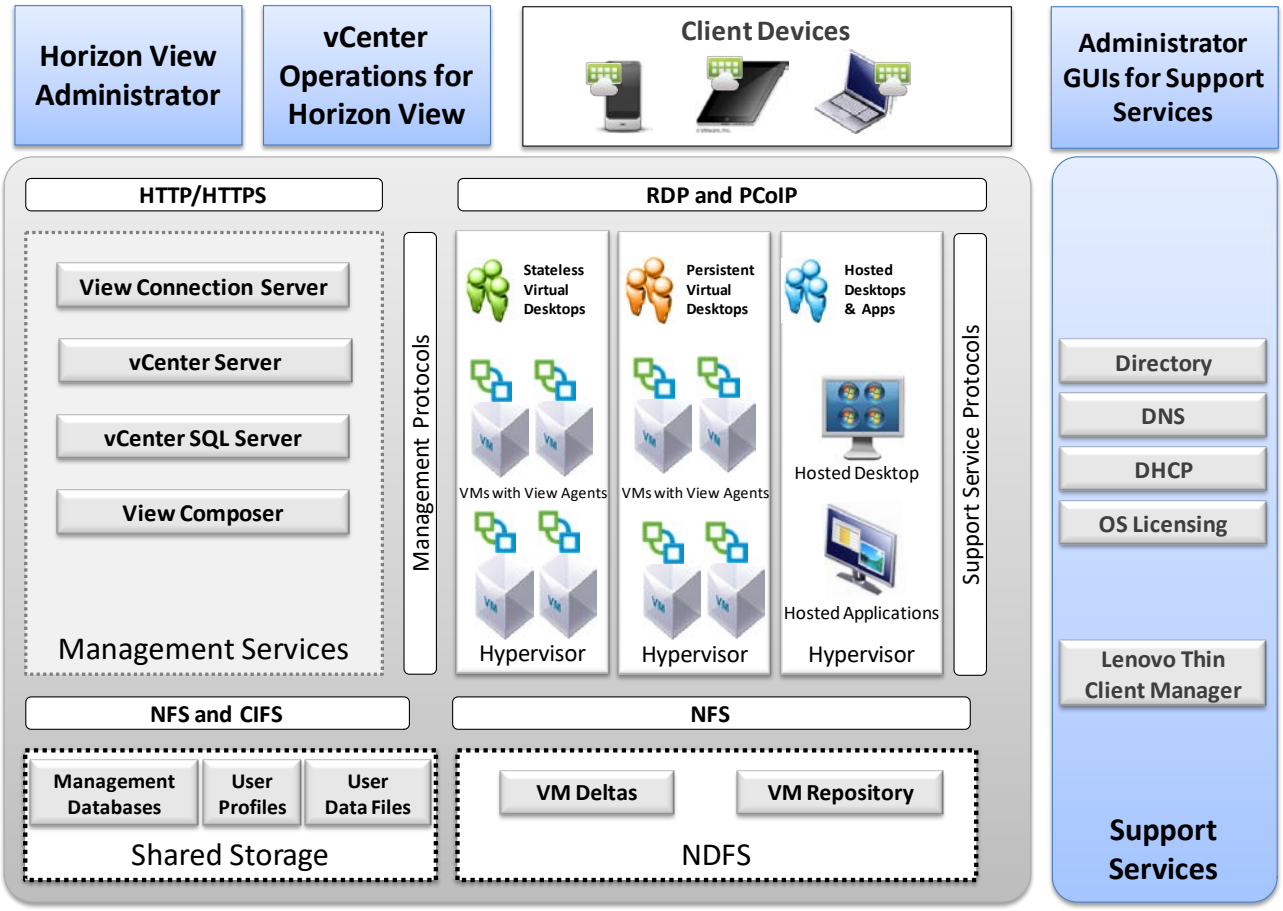


Figure 35: Component model with VMware Horizon

VMware Horizon with the VMware ESXi hypervisor features the following main components:

Horizon View Administrator

By using this web-based application, administrators can configure ViewConnection Server, deploy and manage View desktops, control user authentication, and troubleshoot user issues. It is installed during the installation of ViewConnection Server instances and is not required to be installed on local (administrator) devices.

vCenter Operations for Horizon View

This tool provides end-to-end visibility into the health, performance, and efficiency of the virtual desktop infrastructure (VDI) configuration. It enables administrators to proactively ensure the best user experience possible, avert incidents, and eliminate bottlenecks before they become larger issues.

View Connection Server

The VMware Horizon Connection Server is the point of contact for client devices that are requesting virtual desktops. It authenticates users and directs the virtual desktop request to the appropriate virtual machine (VM) or desktop, which ensures that only valid users are allowed access. After the authentication is complete, users are directed to their assigned VM or desktop.

If a virtual desktop is unavailable, the View Connection Server works with the management and the provisioning layer to have the VM ready and available.

View Composer	In a VMware vCenter Server instance, View Composer is installed. View Composer is required when linked clones are created from a parent VM.
vCenter Server	By using a single console, vCenter Server provides centralized management of the virtual machines (VMs) for the VMware ESXi hypervisor. VMware vCenter can be used to perform live migration (called VMware vMotion), which allows a running VM to be moved from one physical server to another without downtime. Redundancy for vCenter Server is achieved through VMware high availability (HA). The vCenter Server also contains a licensing server for VMware ESXi.
vCenter SQL Server	vCenter Server for VMware ESXi hypervisor requires an SQL database. The vCenter SQL server might be Microsoft® Data Engine (MSDE), Oracle, or SQL Server. Because the vCenter SQL server is a critical component, redundant servers must be available to provide fault tolerance. Customer SQL databases (including respective redundancy) can be used.
View Event database	VMware Horizon can be configured to record events and their details into a Microsoft SQL Server or Oracle database. Business intelligence (BI) reporting engines can be used to analyse this database.
Clients	VMware Horizon supports a broad set of devices and all major device operating platforms, including Apple iOS, Google Android, and Google ChromeOS. Each client device has a VMware View Client, which acts as the agent to communicate with the virtual desktop.
Thin-client Manager	The Lenovo Thin-client Manager (LTM) is used to manage and support Lenovo thin-client devices individually or in groups.
RDP, PCoIP	The virtual desktop image is streamed to the user access device by using the display protocol. Depending on the solution, the choice of protocols available are Remote Desktop Protocol (RDP) and PC over IP (PCoIP).

For more information, see the Lenovo Client Virtualization base reference architecture document that is available at this website: lenovopress.com/lp0756.

7.3 VMware Horizon provisioning

VMware Horizon supports stateless and persistent virtual desktop models. Provisioning for VMware Horizon is a function of vCenter server and View Composer for linked clones.

vCenter Server allows for manually created pools and automatic pools. It allows for provisioning full clones and linked clones of a parent image for dedicated and stateless virtual desktops.

Because persistent virtual desktops use large amounts of storage, linked clones can be used to reduce the storage requirements. Linked clones are created from a snapshot (replica) that is taken from a golden master image. One pool can contain up to 2000 linked clones.

This document describes the use of automated pools (with linked clones) for dedicated and stateless virtual desktops. The deployment requirements for full clones using Nutanix de-duplication functionality is beyond the scope of this document.

7.4 Management VMs

A key part of the VMware Horizon environment is the various management VMs used to manage the VDI infrastructure and user VMs. Table 23 lists the VM requirements and performance characteristics of each management service.

Table 23: Characteristics of VMware Horizon management services

Management service VM	Virtual processors	System memory	Storage	Windows OS	HA needed	Performance characteristic
vCenter Server	8	12 GB	60 GB	2012 R2	No	Up to 2000 VMs.
vCenter SQL Server	4	8 GB	200 GB	2012 R2	Yes	Double the virtual processors and memory for more than 2500 users.
View Connection Server	4	16 GB	60 GB	2012 R2	Yes	Up to 2000 connections.

These management VMs can be run on separate servers from the HX series cluster or within the cluster itself. Separating out the VMs means that the management VMs can be separately managed and sized to the requirements and dedicated servers used for the user VMs. Putting all of the VMs together in one cluster means that the compute servers will execute less user VMs and need to leave enough resources for the much larger and more granular management VMs. Lenovo recommends that the management and user VMs are separated for all but the smallest deployments (i.e. less than 600 users).

Table 3 lists the number of management VMs for each size of users following the requirements for high-availability and performance. The number of vCenter servers is half of the number of vCenter clusters because each vCenter server can handle two clusters of up to 1000 desktops.

Table 24: Management VMs needed

Horizon management service VM	300 users	600 users	1200 users	3000 users
vCenter servers	1	1	2	2
vCenter SQL servers	2 (1+1)	2 (1+1)	2 (1+1)	2 (1+1)
View Connection Server	2 (1+1)	2 (1+1)	2 (1+1)	2 (1+1)

It is assumed that common services, such as Microsoft Active Directory, Dynamic Host Configuration Protocol (DHCP), domain name server (DNS), and Microsoft licensing servers exist in the customer environment.

7.5 Graphics acceleration

This section is specific to the Lenovo ThinkAgile HX3520-G that supports GPU acceleration. The VMware ESXi hypervisor supports the following options for graphics acceleration:

- Dedicated GPU with one GPU per user, which is called virtual dedicated graphics acceleration (vDGA) mode.
- GPU hardware virtualization (vGPU) that partitions each GPU for 1 - 8 users.
- Shared GPU with users sharing a GPU, which is called virtual shared graphics acceleration (vSGA) mode and is not recommended because of user contention for shared use of the GPU.

The vDGA option has a low user density as it restricts a single user to access each very powerful GPU. This option is not flexible and is no longer cost effective even for high-end power users. Therefore vDGA is no longer recommended especially given that the performance of the equivalent vGPU mode is similar.

When using the vGPU option with ESXi 6.5 and the latest drivers from NVidia, it is necessary to change the default GPU mode from “Shared” (vSGA) to “Shared Direct” (vGPU) for each GPU using VMware vCenter. This enables the correct GPU support for the VMs which would otherwise result in the VM not powering on correctly and the standard “graphics resources not available” error message. The host needs to be rebooted for the changes to take effect.

The performance of graphics acceleration was tested using the Lenovo ThinkSystem SR650 servers. Each server supports up to two GPU adapters. The Heaven benchmark is used to measure the per user frame rate for different GPUs, resolutions, and image quality. This benchmark is graphics-heavy and is fairly realistic for designers and engineers. Power users or knowledge workers usually have less intense graphics workloads and can achieve higher frame rates. Table 4 lists the results of the Heaven benchmark as FPS that are available to each user with the GRID 2,0 M60 adapter by using vGPU mode with DirectX 11.

Table 25: Performance of GRID 2.0 M60 vGPU modes with DirectX 11

Quality	Tessellation	Anti-Aliasing	Resolution	M60-8Q	M60-4Q	M60-2Q	M60-4A	M60-2A
High	Normal	0	1280x1024	Untested	Untested	32.03	59.81	32.98
High	Normal	0	1680x1050	Untested	49.97	25.41	N/A	N/A
High	Normal	0	1920x1200	Untested	41.36	21.03	N/A	N/A
Ultra	Extreme	8	1280x1024	Untested	Untested	18.02	37.01	18.68
Ultra	Extreme	8	1680x1050	56.01	29.67	14.18	N/A	N/A
Ultra	Extreme	8	1920x1080	50.38	25.69	12.76	N/A	N/A
Ultra	Extreme	8	1920x1200	46.01	22.79	Untested	N/A	N/A
Ultra	Extreme	8hai	2560x1600	27.42	14.16	Untested	N/A	N/A

Lenovo recommends that a medium to high powered CPU, such as the Xeon Scalable 6130, is used for accelerated graphics applications tend to also require extra load on the processor. For vGPU mode, Lenovo recommends at least 384GB of server memory. Because there are many variables when graphics acceleration is used, Lenovo recommends that testing is done in the customer environment to verify the performance for the required user workloads.

7.6 Performance testing

This section describes the performance benchmarking tool and the results obtained for different configurations of a cluster of 4 Lenovo ThinkAgile HX3320 appliances.

7.6.1 Login VSI benchmarking tool

Login VSI is a vendor-independent benchmarking tool that is used to objectively test and measure the performance and scalability of server-based Windows desktop environments. Leading IT analysts recognize and recommend Login VSI as an industry-standard benchmarking tool for client virtualization and can be used by user organizations, system integrators, hosting providers, and testing companies.

Login VSI provides multiple workloads to simulate real user work and suitable in performing load test, benchmarking and capacity planning for VDI environments. Table 26 lists the characteristics of the Login VSI 4.1 workloads that are used in the Lenovo testing.

Table 26. Login VSI Workload Comparison

Workload Name	Login VSI Version	Apps Open	CPU Usage	Disk Reads	Disk Writes	IOPS	Memory	vCPU
Office worker	4.1	5-8	82%	90%	101%	8.1	2GB	1vCPU
Knowledge worker	4.1	5-9	100%	100%	100%	8.5	2GB	2vCPU
Power worker	4.1	8-12	119%	133%	123%	10.8	3GB	3vCPU

The VSImax score parameter (the number indicates user density) is used to determine the performance of a particular system configuration. The following parameters and rules are used for Login VSI tests:

- User login interval: 30 seconds per node
- Workload: Office Worker, Knowledge Worker, or Power User
- All virtual desktops were pre-booted before the tests
- The number of powered-on VMs was adjusted to stay within a 10% margin of VSImax to avoid unreasonable overhead by “idling” virtual machines
- VSImax score is derived using the “classic model” calculation

7.6.2 Performance results for virtual desktops

This section shows the virtual desktop performance results for Lenovo ThinkAgile HX3320 appliances each configured with dual Xeon Scalable 6130 processors, 768 GB of memory, two 1.92 TB SATA SSDs, and six 2 TB SATA disk drives.

The recommended configuration of the Nutanix CVM is as follows:

- vCPU 12
- CPU Reservation 10000 MHz
- Memory 24GB
- Memory Reservation 24GB
- NUMA No Affinity
- Advance CPU – Scheduling Affinity No Affinity

Table 27 lists the Login VSI performance results of a HX Series appliance 4 node cluster using ESXi 6.5 U1 and Windows 10.

Table 27: Login VSI Performance

Processor	Workload	Stateless	Dedicated
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Office worker	958 users	1008 users
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Knowledge worker	765 users	790 users
Two Scalable 6130 processors 2.10 GHz, 16C 125W	Power worker	629 users	684 users

7.6.3 Performance results from boot storm testing

A boot storm occurs when a substantial number of VMs are all booted within a short period of time. Booting a large number of VMs simultaneously requires large IOPS otherwise the VMs become slow and unresponsive.

Different numbers of VMs were booted on a cluster of 4 HX3320 hybrid appliances. The VMs were unpowered in vCenter and the boot storm created by powering on all of the VMs simultaneously. The time for all of the VMs to become visible in VMware Horizon was measured.

Figure 36 shows a comparison of the boot times for a variety of VMs. With an even spread of VMs on each node, the boot time for the VMs on each node was similar to the overall cluster boot time.

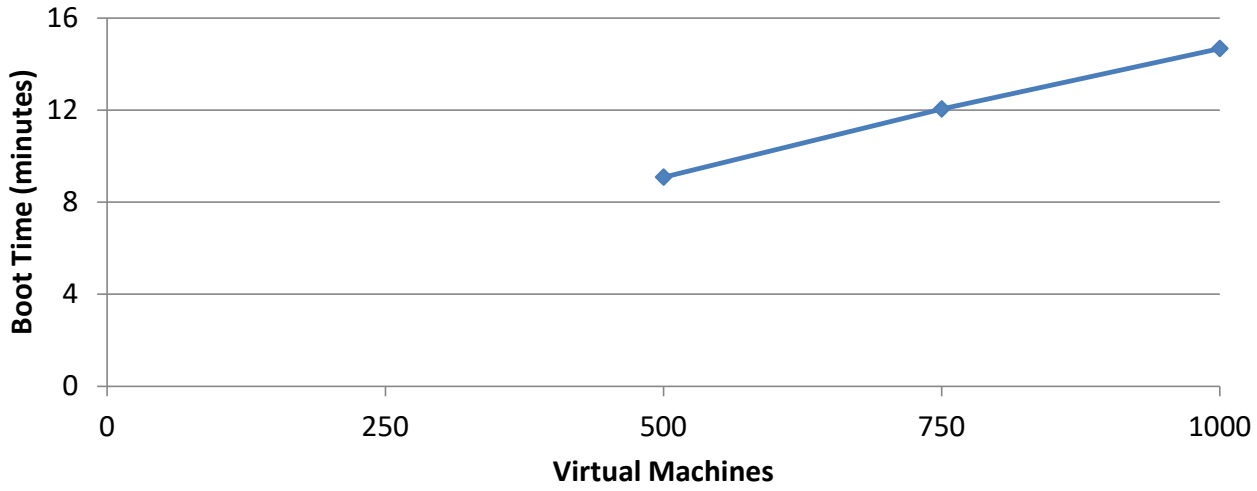


Figure 36: Boot storm comparison

7.7 Performance recommendations

This section provides performance recommendations for both sizing of ThinkAgile HX Series appliances and for best practices. These appliances can be configured into a complete ThinkAgile SXN solution delivered from the factory.

7.7.1 Sizing recommendations for virtual desktops

The default recommendation is two Xeon Scalable 6130 processors and 768 GB of system memory because this configuration provides the best coverage and density for a range of users. Assuming there is enough storage configured for the VMs, this configuration is recommended for any of the HX 3000 Series appliances.

For an office worker, Lenovo testing shows that 180 users per server is a good baseline and has an average of 81% usage of the processors in the server. If a server goes down, users on that server must be transferred to the remaining servers. For this degraded failover case, Lenovo testing shows that 216 users per server have an average of 92% usage of the processors. It is important to keep this 25% headroom on servers to cope with possible failover scenarios. Lenovo recommends a general failover ratio of 5:1. By using a target of 180 users per server, the maximum number of office workers is 11,520 in a 64 node cluster.

For a knowledge worker, Lenovo testing shows that 155 users per server is a good baseline and has an average of 78% usage of the processors in the server. For the degraded failover case, Lenovo testing shows that 186 users per server have an average of 86% usage of the processors. By using a target of 155 users per server, the maximum number of knowledge workers is 9,920 in a 64 node cluster.

For a power, Lenovo testing shows that 125 users per server is a good baseline and has an average of 69% usage of the processors in the server. For the degraded failover case, Lenovo testing shows that 150 users per server have an average of 87% usage of the processors. By using a target of 125 users per server, the maximum number of knowledge workers is 8,000 in a 64 node cluster.

Table 28 summarizes the processor usage with ESXi for the recommended user counts for normal mode and failover mode.

Table 28: Processor usage

Processor	Workload	Users per Server	CPU Utilization
Two 6130	Office worker	180 users – Normal Mode	81%
Two 6130	Office worker	216 users – Failover Mode	92%
Two 6130	Knowledge worker	155 users – Normal Mode	78%
Two 6130	Knowledge worker	186 users – Failover Mode	86%
Two 6130	Power worker	125 users – Normal Mode	69%
Two 6130	Power worker	150 users – Failover Mode	87%

Table 29 lists the recommended number of virtual desktops per server for different workload types and VM memory sizes. The number of users is reduced in some cases to fit within the available memory and still maintain a reasonably balanced system of compute and memory.

Table 29: Recommended number of virtual desktops per server

Workload	Office worker	Knowledge worker	Power worker
Processor	Two 6130	Two 6130	Two 6130
VM memory size	3 GB	4 GB	5 GB
System memory	768 GB	768 GB	768 GB
Memory overhead of CVM	24 GB	24 GB	24 GB
Desktops per server (normal mode)	180	155	125
Desktops per server (failover mode)	216	186	150

Table 30 lists the approximate number of compute servers that are needed for different numbers of users and Office worker workloads.

Table 30: Compute servers needed for Office workers and different numbers of users

Office workers	300 users	600 users	1200 users	3000 users
Compute servers @180 users (normal)	3	4	7	17
Compute servers @210 users (failover)	2	3	6	15

Table 31 lists the approximate number of compute servers that are needed for different numbers of users and Knowledge worker workloads.

Table 31: Compute servers needed for Knowledge workers and different numbers of users

Knowledge workers	300 users	600 users	1200 users	3000 users
Compute servers @155 users (normal)	3	5	8	20
Compute servers @186 users (failover)	2	4	7	16

Table 32 lists the approximate number of compute servers that are needed for different numbers of users and Power worker workloads.

Table 32: Compute servers needed for Power workers and different numbers of users

Power workers	300 users	600 users	1200 users	3000 users
Compute servers @125 users (normal)	3	5	10	24
Compute servers @150 users (failover)	2	4	8	20

7.7.2 Best practices

The number of desktops that can be run on a specific server depends upon the available system memory, compute power of the processors, and number of logons per second during a logon storm. For a cost-effective solution, the maximum number of users should be put on each server to balance processor, memory, storage I/O, and networking. Lenovo recommends using all flash appliances for situations where the user logon rate is high or time to reboot all the VMs on a node must be less than 10 minutes.

Another important consideration for compute servers is system memory. For stateless users, the typical range of memory that is required for each desktop is 2 GB - 4 GB. For dedicated users, the range of memory for each desktop is 2 GB - 6 GB. In general, power users that require larger memory sizes also require more virtual processors. This reference architecture standardizes on 2 GB per desktop as the minimum requirement of a Windows 10 desktop. The virtual desktop memory should be large enough so that swapping is not needed and vSwap can be disabled.

It is a best practice not to overcommit on memory as swapping to disk can have a severe effect on performance; a better strategy is to give each desktop more memory. Alternatively, a monitoring tool can be run to gather information about existing desktops. The desktop memory size that is required does not necessarily have to match the memory supplied in a desktop machine; it can be larger or smaller.

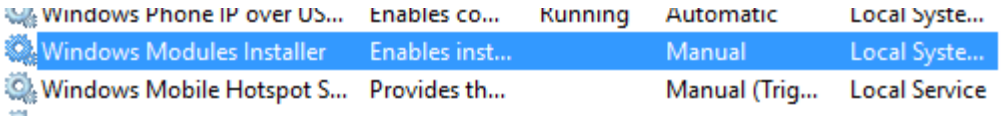
Lenovo recommends the use of VLANs to partition the network traffic. The following VLANs should be used:

- User (for web protocols, display protocols, and support service protocols)
- Management (for management protocols)
- Storage (for NDFS)

Lenovo recommends to always perform user virtualization, even if users have dedicated desktops. This separation of user-specific data makes it much easier to manage and perform upgrades.

Windows 10 was used for all of the performance testing. In general Windows 10 requires 10% to 20% more compute power than Windows 7. The following optimizations are recommended for the Windows 10 base image:

- Applied #VDILIKEAPRO Tuning Template(developed by loginVSI) – see the following for more details:
  loginvsi.com/blog/520-the-ultimate-windows-10-tuning-template-for-any-vdi-environment
- Set Adobe acrobat as a default app for PDF files using steps in following webpage:
  adobe.com/devnet-docs/acrobatetk/tools/AdminGuide/pdfviewer.html
- Disabled **Windows Modules installer** service on the base image because the CPU utilization can remain high after rebooting all the VMs. By default this service is set to manual rather than disabled.



Please refer below links for best practices and optimizations recommended by VMware:

- View Architecture Planning – VMware Horizon 6.0:
  pubs.vmware.com/horizon-view-60/topic/com.vmware.ICbase/PDF/horizon-view-60-architecture-planning.pdf
- VMware Horizon 6 with View Performance and Best Practices:
  vmware.com/files/pdf/view/vmware-horizon-view-best-practices-performance-study.pdf

8 VMware vCloud Suite

VMware vCloud Suite is an integrated offering that brings together VMware's industry-leading vSphere hypervisor and VMware vRealize Suite multi-vendor hybrid cloud management platform. This chapter covers the following VMware products:

- vSphere 6.5 U1, which provides compute virtualization
- vCloud Suite 7.0, which provides a VMware vSphere-based private cloud using vRealize Suite products and additional products to support vSphere Data Protection and Availability
- vRealize Suite 7.0, which provides cloud management capabilities for private, public and hybrid clouds with support for multiple hypervisors
- VMware Hybrid Cloud Manager 2.0 and VMware vCloud Connector 2.7.2 which provide hybrid cloud integration between vCloud Air, vCloud Director Cloud and an on-premise vSphere Cloud
- AWS Management Portal for VMware vCenter 2.8.1.16 and AWS Server Migration Service Connector 1.0.1.7 which provide hybrid cloud integration between AWS public cloud and an on-premise vSphere cloud

VMware NSX 6.3.1 provides network virtualization by using software defined networking (SDN) and supports integration with hardware layer 2 gateways. The use of NSX with Lenovo ThinkAgile HX appliances was verified but a full description is outside the scope of this Reference Architecture. For more details see: www.nutanix.com/go/vmware-nsx-for-vsphere.php.

8.1 Solution Overview

This section gives an architectural overview of vCloud Suite products. Figure 37 gives an overview of how those products are deployed into shared edge and compute, management, and additional compute clusters.

This separation of function into these clusters allows for scaling in larger environments.

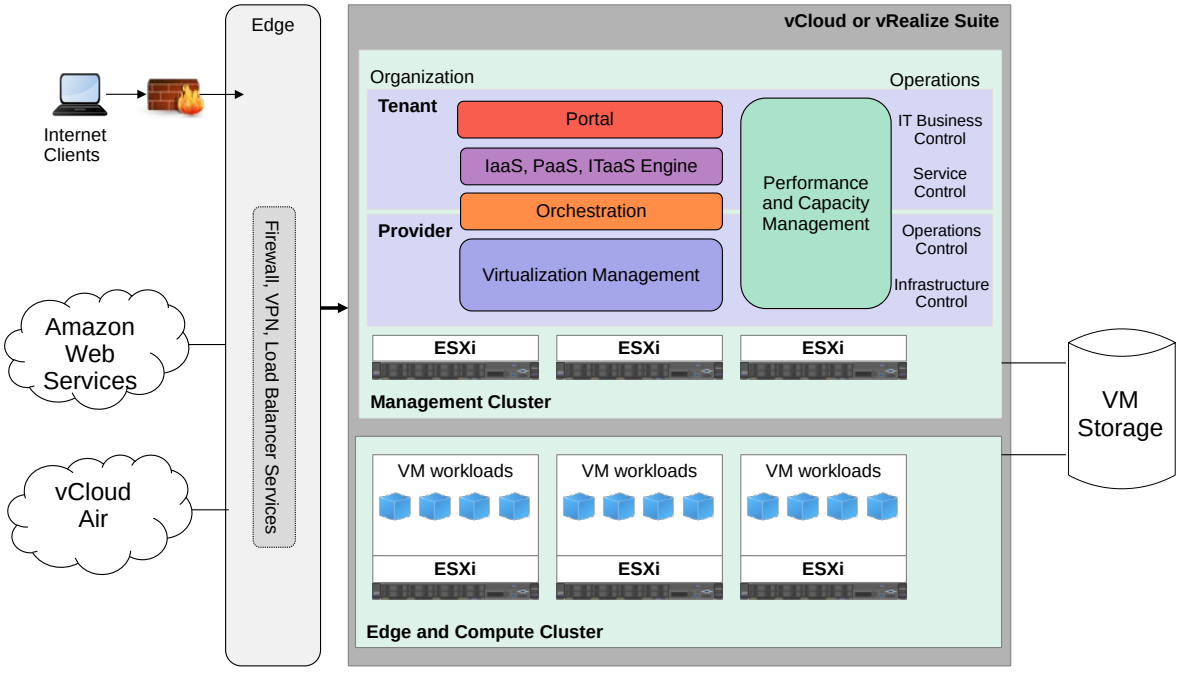


Figure 37: Conceptual design of vCloud Suite

The management cluster runs the components required to support vCloud Suite and is used for management, monitoring, and infrastructure services. A management cluster provides resource isolation which helps these services to operate at their best possible performance level. A separate cluster can satisfy an organization's policy to have physical isolation between management and production hardware and a single management cluster is required for each physical location.

The shared edge and compute cluster supports virtualized infrastructure services as well as network devices that provide interconnectivity between environments. It provides protected capacity by which internal data center networks connect via gateways to external networks. Networking edge services and network traffic management occur in this cluster and all external facing network connectivity ends in this cluster. The shared edge and compute cluster also supports the delivery of all other (non-edge) customer workloads and there can be one or more compute clusters, depending on the customer environment. Multiple compute clusters can be for different organizations or tenants, different workload types, or to spread the load in a large enterprise.

8.2 Component model

This section describes the component model for VMware vCloud Suite and optionally extending it into public clouds with hybrid cloud connections, vCloud and vRealize licensing, and VMware NSX.

Figure 38 shows an overview of the major components of the VMware vCloud Suite.

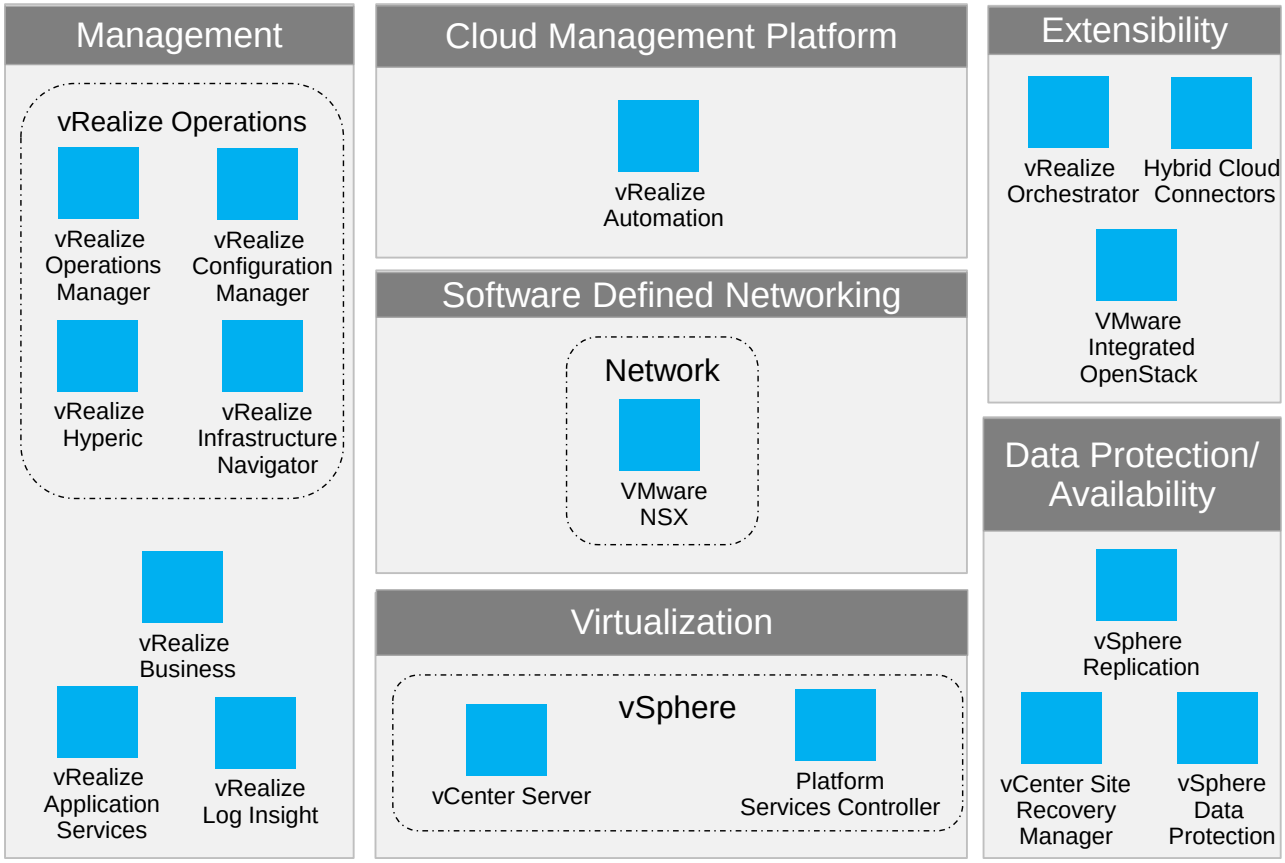


Figure 38: vCloud Suite components

The VMware vCloud Suite features the following components:

ESXi hypervisor	Provides bare-metal virtualization of servers so you can consolidate your applications on less hardware.
vCenter Server	Provides a centralized platform for managing vSphere environments and includes vSphere replication and vSphere data protection.
Platform Services Controller (PSC)	Provides a set of common infrastructure services that encompasses single sign-on (SSO), licensing, and a certificate authority (CA).
vRealize Automation	Provides a self-service, policy-enabled IT and application services catalog for deploying and provisioning of business-relevant cloud services across private and public clouds, physical infrastructure, hypervisors, and public cloud providers.
vRealize Operations	Provides a set of components for automation of operations including infrastructure health, configurations and compliance, application discovery, and monitoring of hardware and software.
• vRealize Operations Manager	Provides comprehensive visibility and insights into the performance, capacity and health of your infrastructure.
• vRealize Configuration Manager	Provides automation of configuration and compliance management across your virtual, physical, and cloud environments, which assesses them for operational and security compliance.
• vRealize Infrastructure Navigator	Provides automated discovery of application services, visualizes relationships, and maps dependencies of applications on virtualized compute, storage, and network resources.
• vRealize Hyperic	Provides monitoring of operating systems, middleware, and applications that are running in physical, virtual, and cloud environments.
vRealize Business	Provides transparency and control over the costs and quality of IT services that are critical for private (vCloud Suite) or hybrid cloud (vRealize Suite) success.
vRealize Log Insight	Provides analytics capabilities to unstructured data and log management, which gives operational intelligence and deep, enterprise-wide visibility across all tiers of the IT infrastructure and applications. Standard for vRealize Suite.
vCenter Site Recovery Manager (SRM)	Provides disaster recovery capability with which you can perform automated orchestration and non-disruptive testing for virtualized applications by using ESXi hypervisor only. SRM is standard for vCloud Suite and optional for vRealize Suite.

vRealize Orchestrator	Provides the capability to create workflows that automate activities, such as provisioning VM, performing scheduled maintenance, and starting backups.
NSX	NSX provides virtualization of networking and is optional for vCloud Suite deployments.
VMware Integrated OpenStack (VIO)	Provides a VMware-supported OpenStack distribution (distro) that makes it easier for IT to run a production-grade, OpenStack-based deployment on top of their VMware infrastructure. For more information, see this website: vmware.com/products/openstack.
Hybrid Cloud Connectors	Allows an administrator to provide hybridization using public cloud providers such as Amazon AWS and vCloud Air powered by OVH. See the next section for more information.

The vCloud Suite products also have dependencies on the following external components:

Identity source	Identity sources (Active Directory, OpenLDAP, or Local OS) or similar is required to implement and operate the vCloud Suite or vRealize Suite infrastructure.
DNS	DNS must be configured for connectivity between vCenter Server, Active Directory, ESXi hosts, and the VMs
DHCP/TFTP	PXE boot is required for vSphere Auto Deploy functionality.
Time synchronization	Accurate time keeping and time synchronization is critical for a healthy infrastructure. All components (including ESXi hosts, vCenter Server, the SAN, physical network infrastructure, and VM guest operating systems) must have accurate time keeping.
Microsoft SQL Server or Oracle database	Many of the vCloud Suite components come with embedded databases or they can use external databases such as Microsoft SQL Server or Oracle, depending on the component and the intended environment.

Other software components such as Lenovo XClarity Administrator are not shown. As well as providing management of Lenovo hardware, XClarity Administrator also has plugins for VMware vCenter, VMware vRealize Orchestrator, and VMware vRealize Log Insight which are further described in “Systems management” on page 86.

8.2.1 Hybrid Clouds

vCloud Air powered by OVH (called vCloud Air henceforth) is a VMware vSphere based public cloud platform. The fundamental resource is a virtual data center (VDC) that provides compute, storage and networking services. It is an abstraction of underlying resources that allows VMs to be created, stored, and executed. vCloud Air supports two types of public clouds:

- Dedicated Cloud which provides a single tenant private cloud with dedicated computing servers, layer-2 network isolation for workload traffic, persistent storage volumes, and a dedicated cloud management instance. Infrastructure capacity can be allocated to a single VDC or multiple VDCs.
- Virtual Private Cloud which provides a multi-tenant virtual private cloud with logically isolated resources on a shared physical infrastructure, configured as a single VDC with networking resources.

The Amazon Elastic Compute Cloud (EC2) provides scalable computing capacity in the Amazon Web Services (AWS) public cloud by offering compute, storage, networking, software, and development tools. AWS provides Virtual Private Cloud and Dedicated Hosts for compute and different services. It supports a hybrid architecture by integrating networking, security and access control, automated workload migrations and controlling AWS from an on-premise infrastructure management tool.

Figure 39 shows a conceptual view of the major components of a VMware hybrid cloud although not all are necessarily in use at the same time. The dashed items are managed by VMware in the vCloud Air public cloud.

The light purple shows vCloud Connector with connections into another on-premise private cloud, a vCloud Air virtual private cloud, or a vCloud Air dedicated cloud. The light green shows the VMware Hybrid Cloud Manager with a connection into a vCloud Air dedicated cloud. The light orange shows the AWS cloud components.

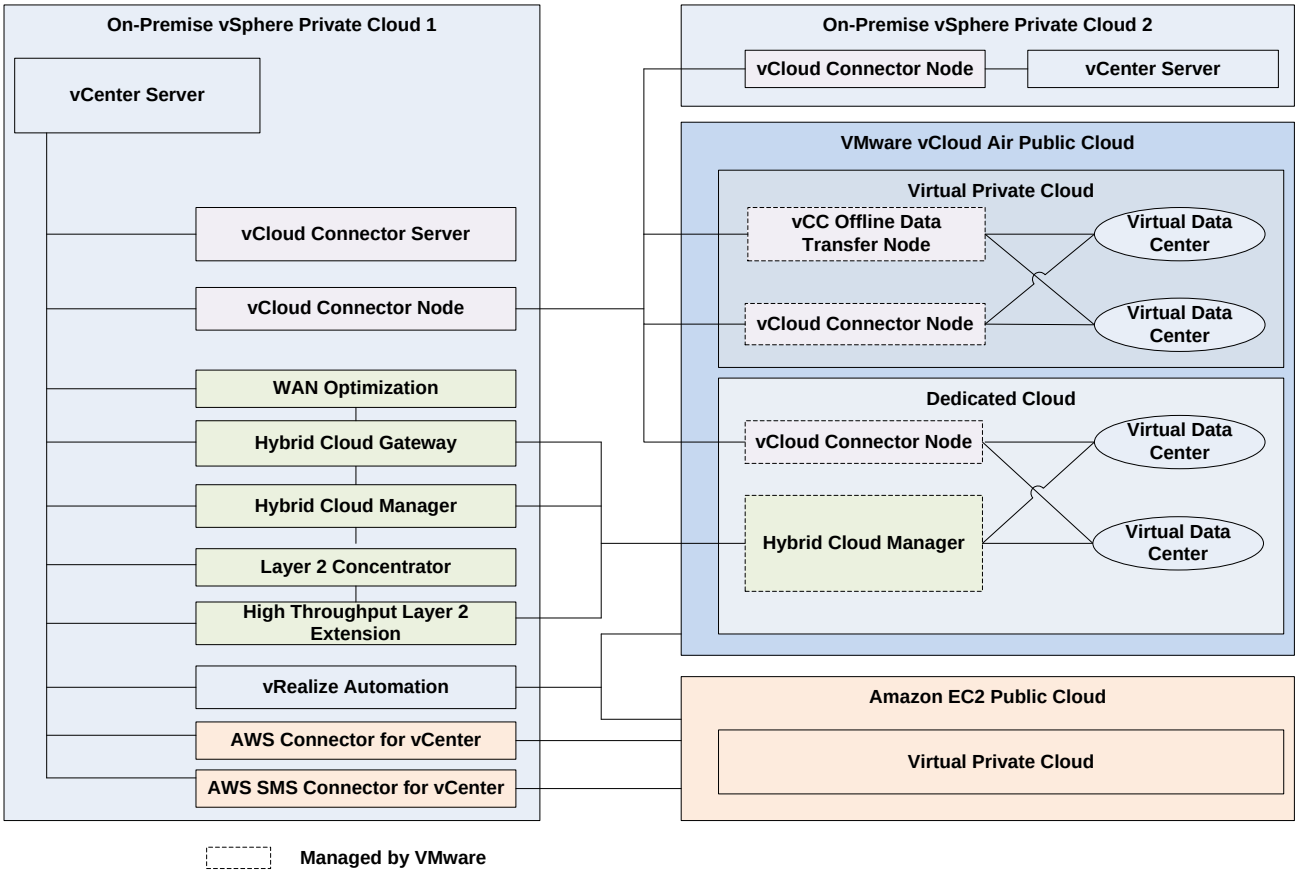


Figure 39: Hybrid Cloud components

There are four kinds of connectors between clouds:

- vCloud Connector — The VMware vCloud Connector provides unified view and management across vSphere based private and public clouds. The virtual machines, vApps and templates can be copied and migrated across vSphere private and public clouds. The vCloud Connector only supports cold migration. It does support common content library and templates which can be distributed and synchronized across vSphere clouds.
- Hybrid Cloud Manager — The VMware Hybrid Cloud Manager provides capabilities to migrate running workloads between vSphere private cloud and vCloud Air and also supports network extension into the public cloud. Workloads can be migrated with zero downtime using a built-in WAN feature to migrate workloads in optimized way. It is integrated with vSphere Replication and supports vCloud Air dedicated cloud service.
- AWS Connector — The AWS Connector is a vCenter plugin which supports migration of VMs and templates to Amazon EC2 and also allows management of AWS resources from vCenter. A migrated VM is converted into an Amazon Machine Image (AMI) and then instances are launched from AMIs. To migrate VMs from AWS to vCenter, the instances are migrated to Amazon S3 buckets as OVA files and then downloaded into vCenter.
- AWS SMS Connector — AWS Server Migration Service (AWS SMS) is an agentless service to migrate on-premise workloads from vCenter to AWS. It supports incremental replications and migration can be performed faster while minimizing network bandwidth consumption and reducing server downtime. Each server volume replicated is saved as a new Amazon Machine Image (AMI) which can be launched as an EC2 instance (VM) in the AWS cloud. The AWS Server Migration Service replicates server volumes from on-premises environment to S3 temporarily and purges them from S3 immediately after creating the Elastic Block Store (EBS) snapshots.

Table 33 summarises the supported connection options between different clouds.

Table 33: Cloud connection options

	vCloud Connector	**Hybrid Cloud Manager**	**AWS Connector**	**AWS SMS Connector**
Source Cloud	• vSphere • vCloud Director • vCloud Air	• vSphere • vCloud Director	• vSphere	• vSphere
Destination Cloud	• vSphere • vCloud Director • vCloud Air	• vCloud Air	• AWS	• AWS

Figure 39 above also shows some of the other facilitating components used for the VMware vCloud Connector and VMware Hybrid Cloud Manager. These components are described below:

vCloud Connector Server	This service provides the vCloud Connector user interface in the vSphere Client. It controls all the vCloud Connector nodes and co-ordinates the activities among them.
vCloud Connector Node	This service handles transferring content from one cloud to other and it supports HTTP(s) and UDP protocols. Both source and destination clouds should be associated a vCloud Connector node. vCloud Air provides its own multi-tenant vCloud connector node by default.
Hybrid Cloud Gateway	This service establishes secure tunnel between on-premise vSphere and vCloud Air. It incorporates vSphere replication to perform bidirectional migration and it gets deployed at both the on-premise cloud and vCloud Air when installation is initiated from vSphere.
WAN Optimization	WAN Optimization reduces latency and bandwidth usage and ensures the best use of available network capacity to expedite data transfer to and from vCloud Air. It incorporates deduplication and forward error correction methods to handle redundant traffic patterns efficiently.
Layer 2 Concentrator (L2C)	This service extends the Layer 2 network from on-premise vSphere environment to vCloud Air. This service works with Hybrid Cloud Manager to send encapsulated overlay traffic and application data to and from vCloud Air. This service can either route all traffic through Hybrid Cloud Gateway or it can have its own routable IP Address. This service gets installed at both the on-premise vSphere and vCloud Air when installation is initiated from vSphere.
High Throughput Layer 2 Extension	This service requires its own routable management IP address and it does not route through Hybrid Cloud Gateway. This also supports jumbo frames and allows one connection per vLAN whereas the legacy L2C supports multiple connections for a VLAN. It uses either IP SEC or Direct Connect option to connect to vCloud Air.
vCC Offline Data Transfer Node	The Offline Data Transfer node is provided by VMware in the vCloud Air public cloud. From the vCloud Connector node at the on-premise vSphere cloud, the virtual machines, vApps and templates can be exported to the external storage device and the offline data transfer node at the vCloud Air side can use the same device to import data into vCloud Air. While exporting data, the user can choose the vCloud Air network the deployment options.

Table 34 describes the features supported by the connectors available for vCloud Air and AWS public clouds. Lenovo verified all of the functionality in the table below except for layer 2 extension and offline data transfers.

Table 34: Hybrid Cloud Features

Feature	vCloud Connector	Hybrid Cloud Manager	AWS Connector	AWS SMS Connector
Bi-Directional Migration	Yes	Yes	No	No
Integration with vCenter	Yes	Yes	Yes	Yes
vCenter→Connector Association	1-1	1-1	1-1	Many-Many
Connector→Public Cloud Association	1-1	1-Many	1-1	1-1
vCenter linked Mode support	No	Yes	No	No
Integration with vSphere client	Yes	No	Yes	Use AWS Management Console
Integration with vSphere web client	No	Yes	Yes	Use AWS Management Console
Integration with vSphere Replication	No	Yes	No	No
Integration with vRealize Automation	No	No	No	No
Multi-tenant support	Yes	Yes	No	No
VM Management public cloud	Basic	No	Basic	Use AWS Management Console
VM Management on-premise	Yes	No	No	No
Migration to all public cloud regions	Yes	Yes	Yes	Limited Currently
Copy/Migrate Templates to public cloud	Yes	No	Yes (AMI)	Yes (AMI)
Deploy VM from Template to public cloud	Yes	No	Yes (AMI)	Yes (AMI)
Live Migration to public cloud	No	Yes (vMotion)	Yes	Yes
Cold Migration to public cloud	Yes	Yes	Yes	Yes
Bulk Migration to public cloud	No	Yes for powered on VMs (uses vSphere Replication)	No	Yes
Layer 2 Extension	No	Yes (DVSwitch only)	No	No
Migrate VM to on-premise	Yes	Yes	No (OVA download)	No (OVA download)
Offline Data Transfer	Yes	No	No	No
Common Content Library	Yes	No	No	No
Number of Concurrent Migration	5	15	5 per region	50 per account
License	Free	Licensed	Free	90 days Free
vSphere Standard Switch Support	Yes	Yes	Yes	Yes

Feature	vCloud Connector	Hybrid Cloud Manager	AWS Connector	AWS SMS Connector
vSphere Distributed Switch Support	vSphere→ vCloud Air only	Yes	Yes	Yes

8.2.2 VMware Licensing

The licensing for vSphere is based on a CPU metric and licensing for other products is based on the number of OS instances. The vCloud Suite license is a single perpetual license that includes vSphere Enterprise Plus and vRealize Suite. For vSphere environments, the license can be purchased separately for vSphere Enterprise Plus and vRealize Suite. Other components have their own separate licenses and are optional add-ons.

Table 35 lists the standard and optional components that are provided with a vCloud Suite License or vRealize Suite License.

Table 35: VMware Licensing

License	Component	vCloud Standard	vCloud Advanced	vCloud Enterprise	vRealize Standard	vRealize Advanced	vRealize Enterprise
Base	vSphere	Enterprise Plus	Enterprise Plus	Enterprise Plus			
	vRealize Automation	N/A	Advanced	Enterprise	N/A	Advanced	Enterprise
	vRealize Operations • vRealize Operations Mgr • vRealize Configuration Mgr • vRealize Infrastructure Nav • vRealize Hyperic	Advanced	Advanced	Enterprise	Advanced	Advanced	Enterprise
	vRealize Business	Standard	Advanced	Advanced	Standard	Advanced	Advanced
	vSphere Replication	Included	Included	Included	N/A	N/A	N/A
	vSphere Data Protection	Included	Included	Included	N/A	N/A	N/A
	vRealize Log Insight	Included	Included	Included	Included	Included	Included
	vCenter Site Recovery Mgr	Add On	Add On	Add On	Add On	Add On	Add On
Other licenses	vRealize Orchestrator	Add On	Advanced	Enterprise	Add On	Advanced	Enterprise
	vRealize Automation Public Cloud Extension	N/A	Add On	Add On	Add On	Add On	Add On
	vRealize Operations Public Cloud Extension	N/A	Add On	Add On	Add On	Add On	Add On
	VMware Integrated OpenStack	Free	Free	Free	Add On	Add On	Add On
	vCloud Connector	Free	Free	Free	Free	Free	Free

8.3 Shared edge and compute cluster

The shared edge and compute cluster uses its own dedicated vCenter server.

8.3.1 Edge and Infrastructure Services VMs

The VMs used for infrastructure services such as Active Directory, DNS/DHCP, firewalls, proxy and anti-virus are deployed in the shared edge and compute cluster. Table 36 lists each infrastructure service VM with the recommended sizes in terms of virtual CPUs, RAM, storage, and networking.

Table 36: Infrastructure services VMs

VM description	CPU (vCPUs)	Memory (GB)	Storage (GB)	Network bandwidth	High availability
AD, DHCP, DNS server	2	4	70	1 GbE	clustered
http proxy server	2	4	30	1 GbE	clustered

8.3.2 Hybrid cloud VMs

Table 37 lists the cloud connectivity VMs with the recommended sizes in terms of virtual CPUs, RAM, storage, networking, and location. Note that these VMs do not have options for high availability.

Table 37: Cloud connectivity VMs

VM description	CPU (vCPUs)	Memory (GB)	Storage (GB)	Network bandwidth	Location
VMware vCloud Connector Server	4	4	20	1 GbE	On-Premise
VMware vCloud Connector Node	4	4	20	1 GbE	On-Premise and vCloud Air
VMware Hybrid Cloud Manager Appliance	4	12	60	1 GbE	On-Premise and vCloud Air
VMware Hybrid Cloud Gateway	8	3	2	1 GbE	On-Premise and vCloud Air
VMware WAN Optimization	8	14	100	1 GbE	On-Premise
VMware Layer 2 Concentrator	6	8	2	1 GbE	On-Premise and vCloud Air
High Throughput Layer 2 Extension	8	2	1	1 GbE	On-Premise
AWS Connector for vCenter	1	2	280	1 GbE	On-Premise
AWS SMS Connector for vCenter	2	4	300	1 GbE	On-Premise

8.3.3 Server configuration

Since the shared cluster hosts compute workloads and edge services, the servers need to be sized appropriately. See other chapters in this Reference Architecture for specific workloads.

8.3.4 Load balancing and protection

An essential part of the infrastructure is load balancing of the server VMs and recognizing when a server is down and failing over to a second server.

For the shared edge and compute cluster connected to the Internet, it is also important to provide a firewall and protection against external threats. There are many ways to solve these problems such as using a F5 Big-IP edge gateway device or virtual machine. Using F5 protection and load balancing is outside the scope of this document.

8.4 Management cluster

The number of VMware vCloud Suite components in the management cluster increases as capabilities are added. This section addresses the management components that could be used. Third party add-ons must be sized separately.

8.4.1 Management cluster VMs

There are several considerations that contribute to an end-to-end sizing of an entire VMware vCloud environment including Lenovo software for systems management. This section is intended to provide some high-level guidance for management cluster configuration sizing. The recommended number of virtual CPUs, memory size, storage size, and network bandwidth is given for each VM and the VMs are grouped by each major component or appliance.

An essential part of the infrastructure is load balancing of the server VMs and recognizing when a server is down and failing over to another server. The following cases are available for VMs in the management cluster:

- vSphere HA: vCenter automatically restarts the VM on another server, but there is some downtime while the VM starts up.
- Microsoft SQL server clustering: The SQL server cluster automatically handles failover.
- Clustering within component to provide built-in high availability.
- Load balancing: An external load balancer such as a Big-IP switch from F5

Table 38 lists each management cluster VM for vSphere with its recommended size in terms of virtual CPUs, RAM, storage, and networking.

Table 38: Management cluster VMs for vSphere

VM description	CPU (vCPUs)	Memory (GB)	Storage (GB)	Network bandwidth	High availability
vCenter Server(1) Management Cluster	8	24	50	1 GbE	load balancer
vCenter Server(2) Edge and Compute Cluster	8	24	50	1 GbE	load balancer
vCenter Server Database (MS SQL)	4	8	200	1 GbE	SQL AlwaysOn Availability Group
Platform Service Controller (1) Management Cluster	2	4	50	1 GbE	load balancer
Platform Service Controller (2) Edge and Compute Cluster	2	4	50	1 GbE	load balancer
vSphere Replication	2	4	20	1 GbE	not required
vSphere Data Protection	4	4	1600	1 GbE	not required
vRealize Orchestrator Appliance	2	3	12	1 GbE	Clustered

Table 39 lists each management cluster VM for vRealize Automation with its size in terms of virtual CPUs, RAM, storage, and networking.

Table 39: Management cluster VMs for vRealize Automation

VM description	CPU (vCPUs)	Memory (GB)	Storage (GB)	Network bandwidth	High availability
vRealize Automation Appliance	4	16	30	1 GbE	load balancer
IaaS Database (MS SQL)	8	16	100	1 GbE	SQL AlwaysOn Availability Group
Infrastructure Web Server	2	4	40	1 GbE	load balancer
Infrastructure Manager Server	2	4	40	1 GbE	load balancer
Distributed Execution Manager (DEM)	2	6	40	1 GbE	load balancer
vSphere Proxy Agent	2	4	40	1 GbE	load balancer
vRealize Application Services	8	16	50	1 GbE	vSphere HA

Table 40 lists each management cluster VM for vRealize Operations Manager with its size in terms of virtual CPUs, RAM, storage, and networking.

Table 40: Management cluster VMs for vRealize Operations Manager

VM description	CPU (vCPUs)	Memory (GB)	Storage (GB)	Network bandwidth	High availability
vRealize Operations Manager – Master	4	16	500	1 GbE	clustered
vRealize Operations Manager – Data	4	16	500	1 GbE	not required
vRealize Configuration Manager – Collector	4	16	72	1 GbE	not required
vRealize Configuration Manager Database (MS SQL)	4	16	1000	1 GbE	SQL AlwaysOn Availability Group
vRealize Hyperic Server	8	12	16	1 GbE	load balancer
vRealize Hyperic Server - Postgres DB	8	12	75	1 GbE	load balancer
vRealize Infrastructure Navigator	2	4	24	1 GbE	not required

Table 41 lists each of the remaining management cluster VMs.

Table 41: Other Management cluster VMs

VM description	CPU (vCPUs)	Memory (GB)	Storage (GB)	Network bandwidth	High Availability
vRealize Business Standard	2	4 GB	50 GB	1 GbE	vSphere HA
Site Recovery Manager	4	4 GB	20 GB	1 GbE	not required
Site Recovery Manager Database (MS SQL)	2	4 GB	100 GB	1 GbE	SQL AlwaysOn Availability Group
vRealize Log Insight	8	16	100 GB	1 GbE	Cluster of 3 nodes

Table 42 lists the VMs that are needed for Lenovo software for systems management.

Table 42: Lenovo System Management VMs

VM description	CPU (vCPUs)	Memory (GB)	Storage (GB)	Network bandwidth	High availability
Lenovo XClarity Administrator	2	4	64	1 GbE	not required
Lenovo XClarity Integrator (Windows OS)	1	2	30	1 GbE	not required

8.4.2 Server configuration

The management cluster should have a minimum of four hosts for high availability. Because of the large number of management VMs that can be used in the management cluster, the following configuration is recommended for each server:

- Lenovo ThinkAgile HX3320 or HX3720
- 2 x Intel® Xeon® Gold 6130 Processor (2.10 GHz 16 cores)
- 384 GB of system memory
- Dual M.2 boot drives with ESXi 6.5 U1

8.5 Hybrid networking to public clouds

This section contains deployment considerations for hybrid networking from an on-premise cloud to public clouds such as vCloud Air and AWS.

8.5.1 vCloud Air networking

Table 43 shows the required connectivity for each component used for vCloud Air. For more details, see the Shared Edge and Compute cluster underlay for the deployment example on page 95.

Table 43: vCloud Air component connectivity

Virtual Machine	DvSwitch	http proxy support
VMware vCloud Connector Server	Edge-Compute	Yes
VMware vCloud Connector Node	Edge-Compute	Yes
VMware Hybrid Cloud Manager Appliance	Edge-Compute or Edge-Internet	Yes
VMware Hybrid Cloud Gateway	Edge-Compute or Edge-Internet	No
VMware WAN Optimization	(Connected to Hybrid Cloud Gateway)	No
VMware Layer 2 Concentrator	Edge-Compute	No
VMware High Throughput Layer 2 Extension	Edge-Compute	No

Edge-Compute means connection to vCloud Air via a vCloud connector node or the Hybrid Cloud Gateway. Edge-Internet means direct connection to Internet (via a firewall with appropriately opened ports).

8.5.2 AWS networking

Table 44 shows the required connectivity for each component used for AWS. . For more details, see the Shared Edge and Compute cluster underlay for the deployment example on page 59.

Table 44: AWS component connectivity

Virtual Machine	DvSwitch	http proxy support
AWS Connector for vCenter	Edge-Compute	Yes
AWS SMS Connector for vCenter	Edge-Compute	Yes

8.5.3 Best Practices

Both vCloud Air and Amazon Web Services (AWS) provide internet and direct connect accessibility options to connect from the vSphere private cloud environments. The AWS connectors leverage an http proxy to establish connectivity to the AWS cloud. The vCloud Connector server uses an http proxy to connect to the vCloud Air. The Hybrid Cloud Manager Appliance uses an http proxy to connect to the vCloud Air and the Hybrid Cloud Manager Services establishes an IPSec tunnel between the on-premise cloud and the gateway on the vCloud Air side. It is advisable to deploy them directly on the internet link or have a proper routing between the on-premise intranet and internet.

The Hybrid Cloud Manager only supports vCloud Air Dedicated Clouds whereas the vCloud Connector supports both Dedicated and Virtual Private Clouds. The Hybrid Cloud Manager and vCloud Connector nodes deployed at the vCloud Air side are multi-tenant and multiple on-premise vCenters can connect to them in parallel. The VMware team manages the vCloud Air components.

The Hybrid Cloud Manager services (Hybrid Cloud Gateway, WAN Optimization, Layer 2 Concentrator, and High Throughput layer 2 extension) need to be deployed separately for each virtual data center (VDC) targeted in the vCloud Air. The Hybrid Cloud Gateway is a prerequisite to deploy other services such as L2C and WAN Optimization. The L2C service only supports vSphere Distributed Switches and therefore deploying Hybrid Cloud Gateway on a vSphere Standard Switch does not enable L2C.

The server hardware for an on-premise vSphere cloud and vCloud Air may not use the same processor family. Lenovo recommends enabling Enhanced vMotion Compatibility (EVC) on the cluster to avoid compatibility errors during vMotion.

It is possible to use a local vCloud Connector node to connect to vCloud Air instead of the default one provided by VMware. This case is mostly for private vSphere cloud and vCloud Director clouds. Lenovo recommends deploying vCloud Connector nodes on the cloud on which they are associated. The disk size for the vCloud Connector node should be sized based on the staging area required during the migration.

AWS Connectors are deployed in an on-premise vSphere environment and they do not provide capabilities for bi-directional migration. The on-premise virtual machines can be migrated to AWS cloud but there is no option in the connectors to migrate a virtual machine back to vSphere environment. Instead the VMs need to be exported to OVA format and stored in S3. Then the image can be imported or downloaded to the on-premise vSphere environment.

8.6 Systems management

Lenovo XClarity™ Administrator is a centralized resource management solution that reduces complexity, speeds up response, and enhances the availability of Lenovo® server systems and solutions. See section 2.3.2 on page 7 for more details.

In addition Lenovo provides a number of plugins for VMware vCloud Suite components which are described below.

8.6.1 Lenovo XClarity integration

Lenovo also provides XClarity integration modules for VMware vCenter, VMware vRealize Orchestrator and VMware vRealize Log Insight. For more information, see this website: http://www3.lenovo.com/us/en/data-center/software/systems-management/c/systems-management.

By using the Lenovo XClarity Integrator for VMware vCenter, administrators can consolidate physical resource management in VMware vCenter, which reduces the time that is required for routine system administration.

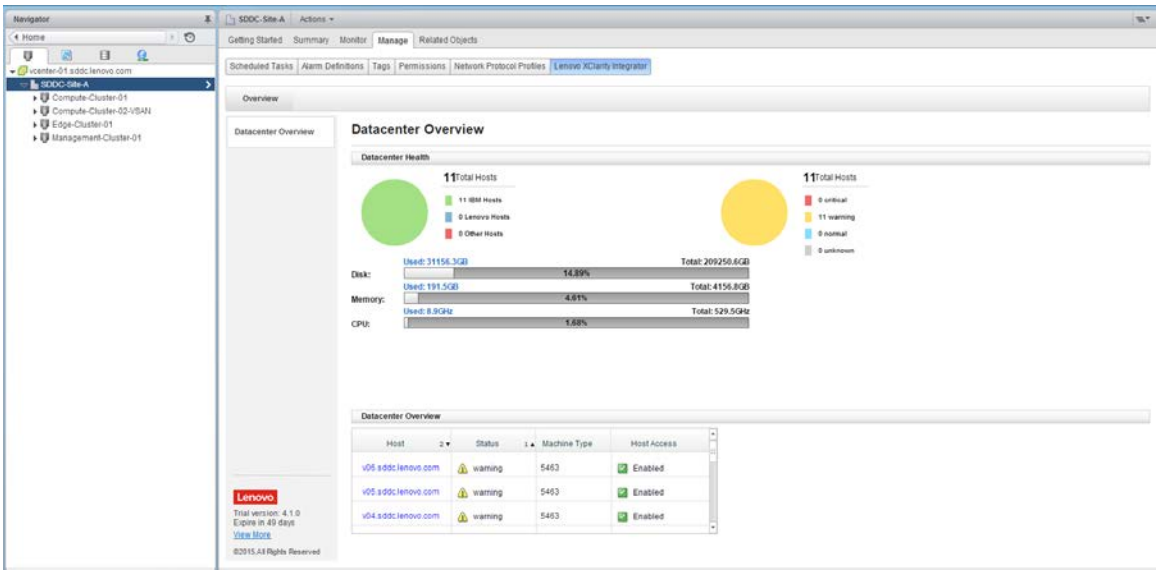


Figure 40: Lenovo XClarity Integrator for VMware vCenter

The Lenovo XClarity Integrator for VMware vCenter provides the following features and benefits:

- Extends Lenovo XClarity Administrator features to the virtualization management console
- Enables management of legacy infrastructure from the virtualization management console
- Reduces workload downtime by dynamically triggering workload migration in clustered environments during rolling server reboots or firmware updates, and predicted hardware failures

The Lenovo XClarity Integrator for VMware vRealize Orchestrator provides IT administrators with the ability to coordinate physical server provisioning features of Lenovo XClarity Pro with broader vRealize Orchestrator workflows. Lenovo XClarity Integrator for VMware vRealize Orchestrator provides a library of simple yet robust and customizable workflow routines and actions designed to automate complex, repetitive IT infrastructure tasks such as system discovery and configuration, hypervisor installation, and addition of new hosts to vCenter.

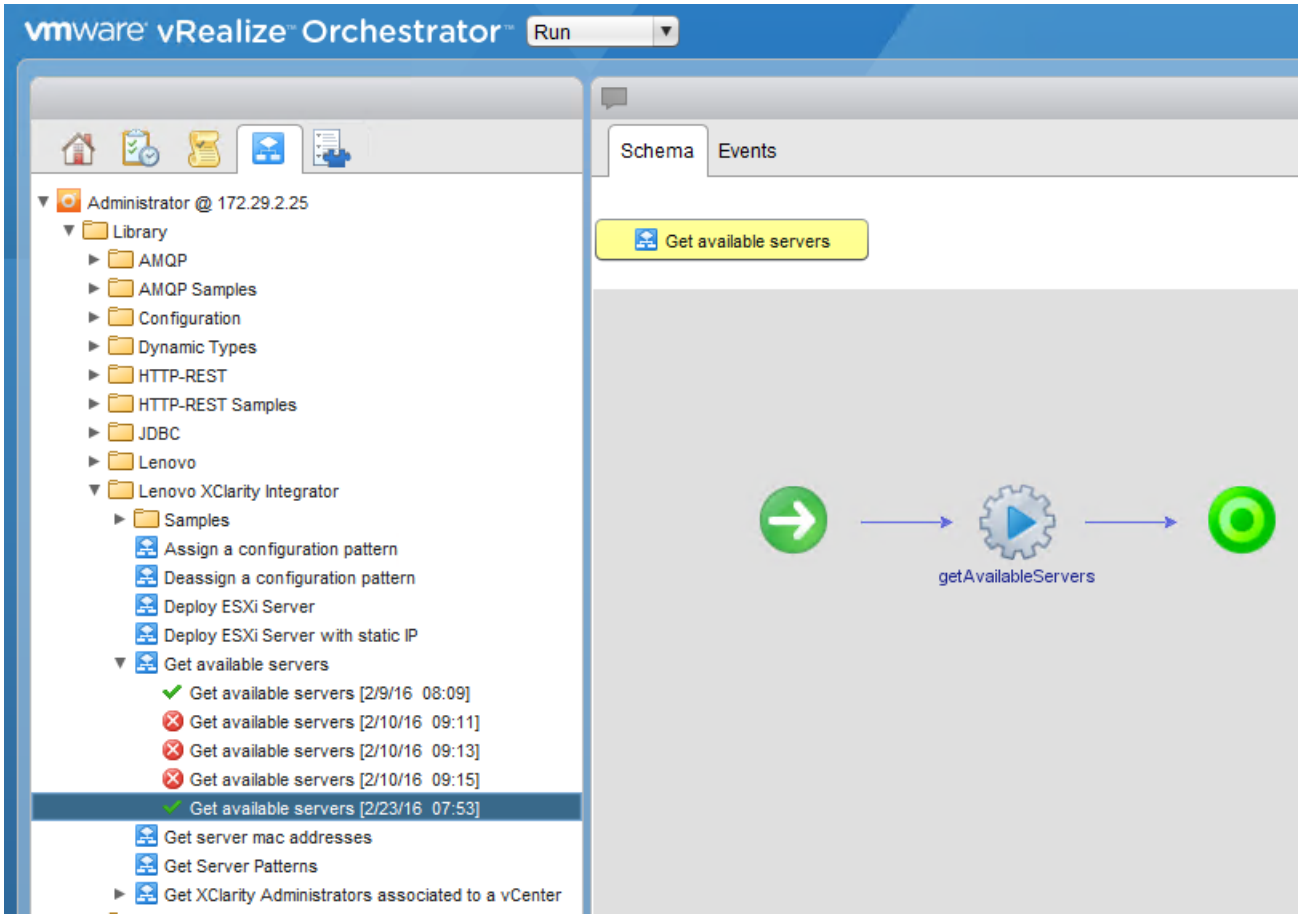


Figure 41: Lenovo XClarity Integrator for VMware vRealize Orchestrator interface

The Lenovo XClarity Administrator Content Pack for VMware vRealize Log Insight simplifies the collection and forwarding of Lenovo XClarity Administrator logs to VMware vRealize Log Insight for powerful processing and analytics, and displaying insightful information in an intuitive format.

The VMs for VMware vCenter, vRealize Orchestrator, Lenovo XClarity Administrator and Lenovo XClarity Administrator Integrator should have access to the management network used for managing servers, storage and networking.

Lenovo XClarity Integrator for vRealize Automation provides a set of blueprints to provision infrastructure services based on Lenovo servers, network switches and vSphere. This eases provisioning a new Lenovo server with vSphere installed, network isolation parameters configured on the Lenovo switches, apply vSphere distributed switch configurations and adding the server to the existing or new vSphere Cluster. These services leverage the workflows defined in the Lenovo vRealize SoftBundle for vRealize Orchestrator, Lenovo XClarity Integrator for vCenter, Lenovo XClarity Integrator for vRealize Orchestrator, and Lenovo Networking Integration plugin for vRealize Orchestrator.

The Lenovo vRealize SoftBundle package for vRealize Automation needs to imported into vRealize Orchestrator and then the Blueprints package is imported using the vRealize Cloud Client command line utility by Tenant Administrators and it creates catalog items automatically. The catalog items are created under Lenovo Servers, Lenovo Network, and Lenovo Virtualization services.

Figure 42 shows the workflows available in the Lenovo SoftBundle for vRealize Orchestrator.

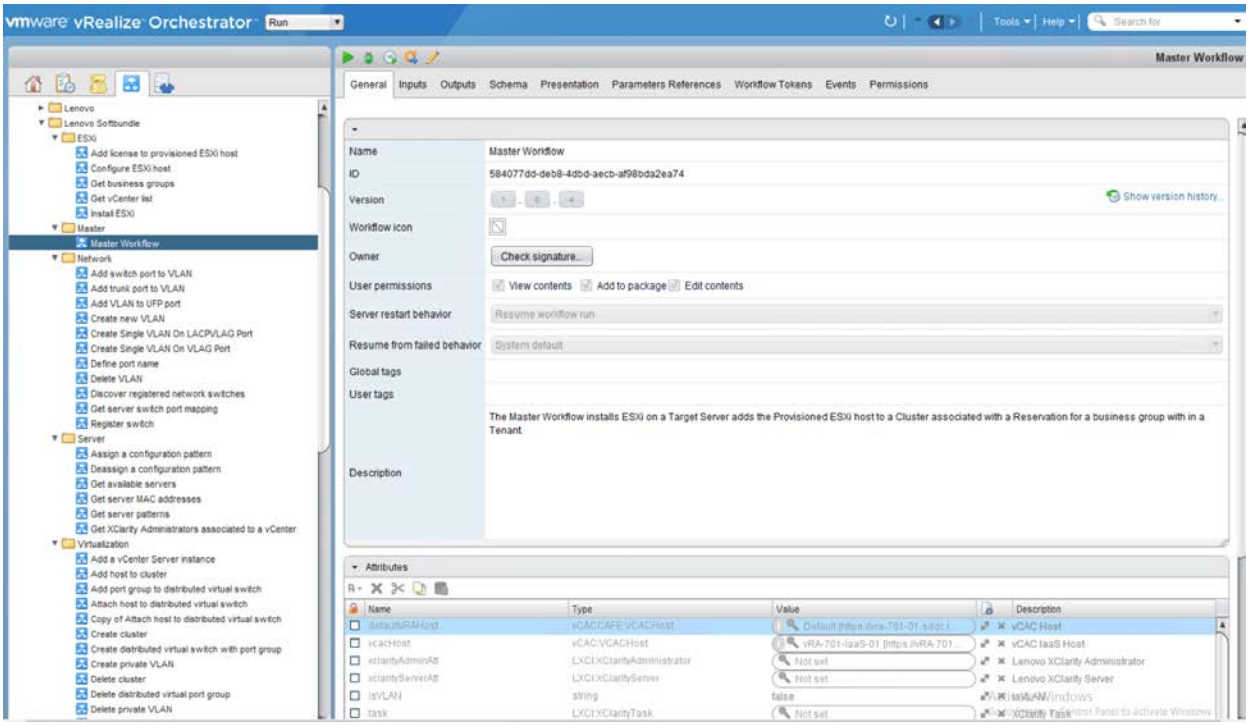


Figure 42: Lenovo SoftBundle workflows for vRealize Orchestrator

Figure 43 shows Lenovo XClarity Integrator catalog items for vRealize Automation.

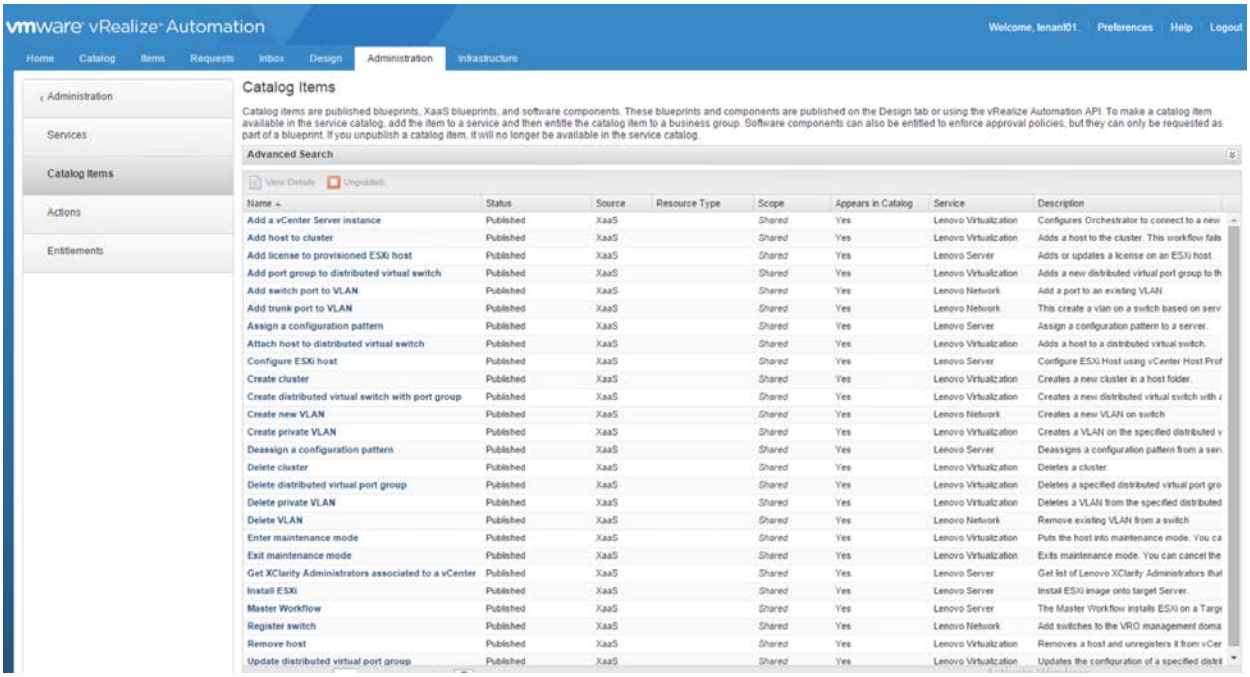


Figure 43: Lenovo XClarity Integrator for vRealize Automation Catalog Items

Figure 44 shows Lenovo XClarity Integrator services available for vRealize Automation.

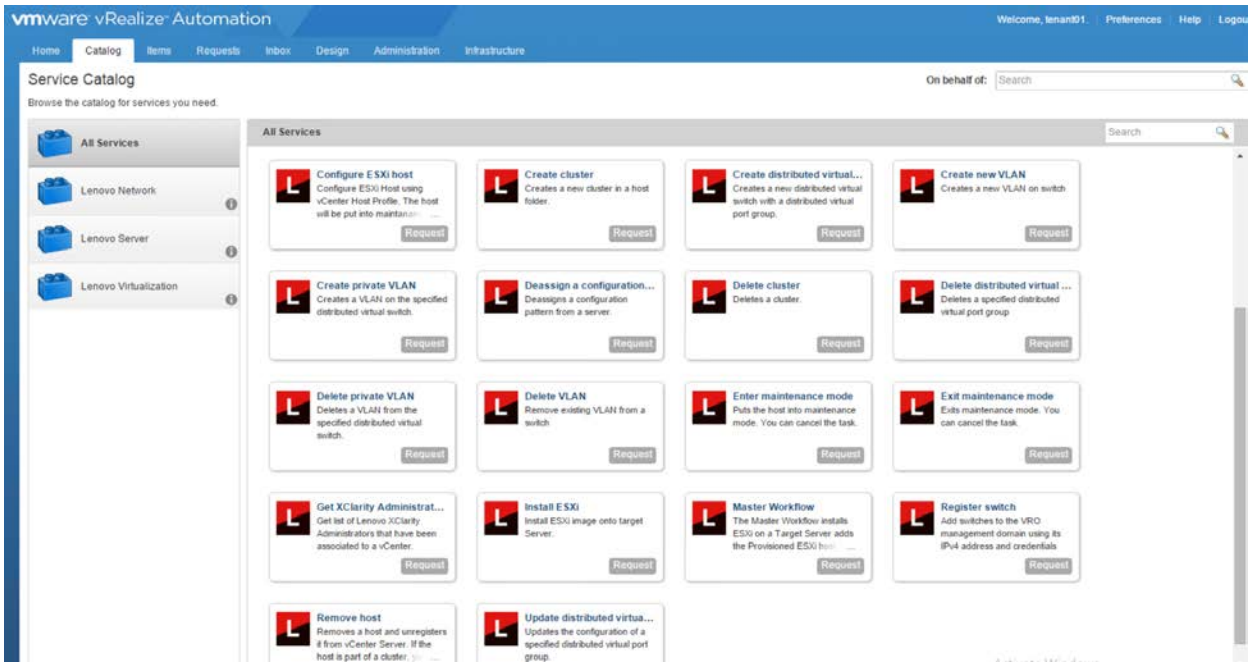


Figure 44: Lenovo XClarity Integrator for vRealize Automation Services Catalog

8.6.2 Lenovo network integration plug-ins

Lenovo also provides network integration plug-ins for VMware vRealize Orchestrator and vRealize Log Insight. For more information, see this website:

shop.lenovo.com/us/en/systems/software/systems-management/network-management

The Lenovo networking plug-In for VMware vRealize Orchestrator enables you to:

- Reduce new service delivery time on RackSwitch G8272, Flex System EN4093R, and Flex Systems Interconnect Fabric
- Leverage a comprehensive library of Lenovo Networking workflows and actions capturing network configuration best practices for rapid service orchestration
- Implement more Lenovo switch configuration activity through vRealize Orchestrator and vCenter with less reliance upon native switch interfaces.

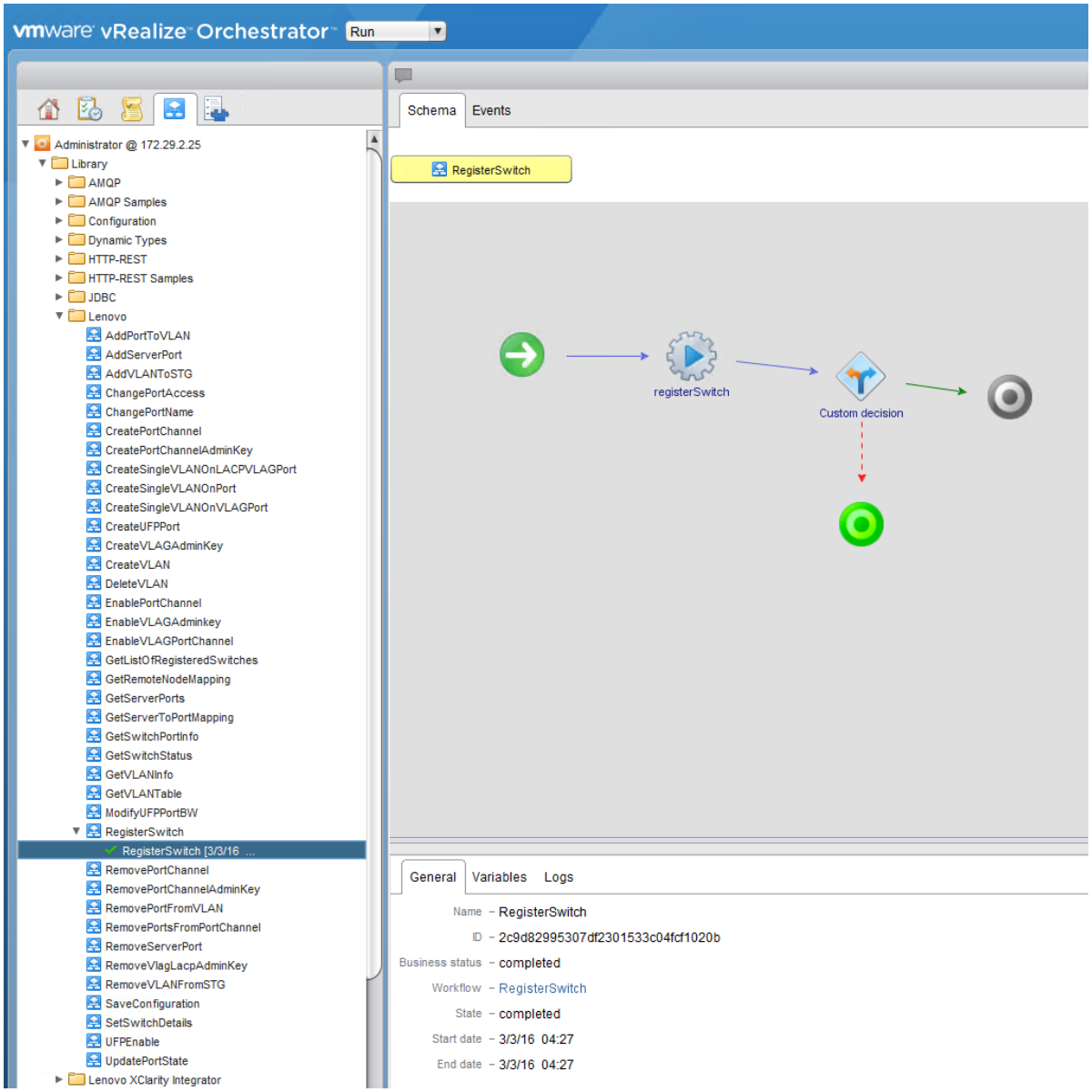


Figure 45: Lenovo networking plug-In for VMware vRealize Orchestrator interface

Lenovo Networking Content Pack for VMware vRealize Log Insight enables you to:

- Increase network reliability by allowing system or network administrators to monitor networks that feature Lenovo branded RackSwitch switches
- Gain access to extremely detailed switch log entries to facilitate deep insights into the network status
- Reduce initial provisioning time of Log Insight by using the 9 prebuilt dashboards and 12 predefined alarms featured in the pack

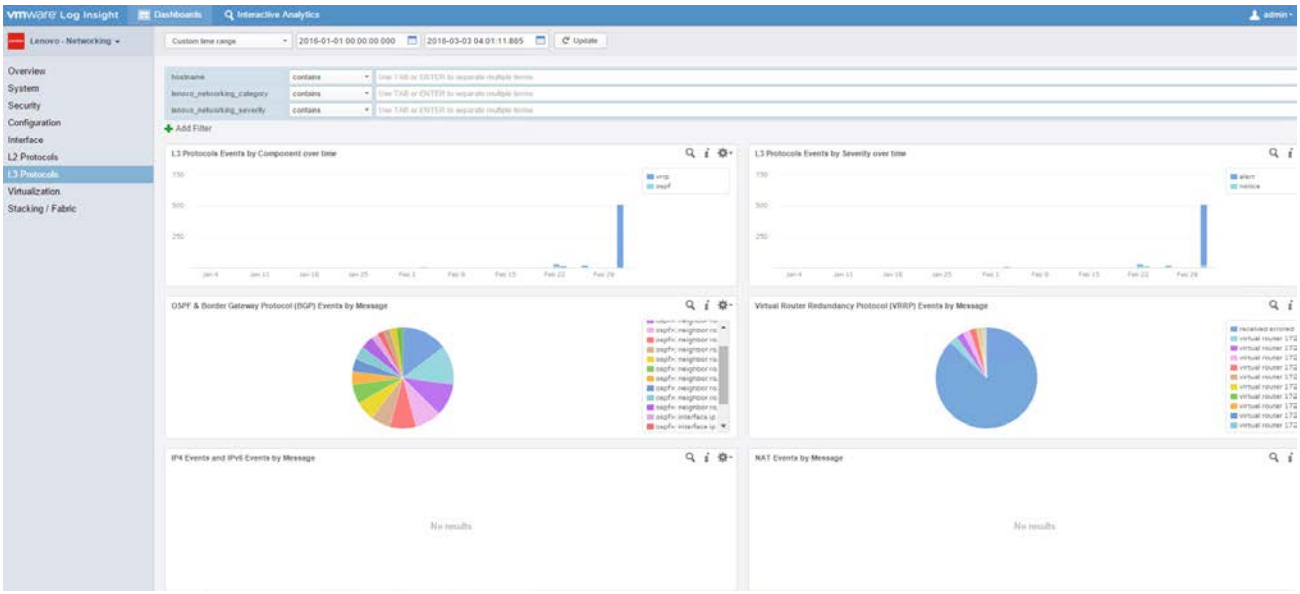


Figure 46: Lenovo Networking Content Pack for VMware vRealize Log Insight interface

6.9.3 Lenovo plug-ins compatibility

Table 45 below lists current versions of Lenovo integration plugins and the required or supported VMware vCenter and vRealize Suite products.

Table 45: Plug-in compatibility

Component Name	Version	Supported Product Versions
Lenovo XClarity Administrator(LXCA)	1.3.0	VMware vCenter 6.0U2/6.5, ESXi 6.0U2/6.5
Lenovo XClarity Integrator(LXCI) for vCenter	5.0.2	Lenovo XClarity Administrator 1.1.1, 1.2.0, 1.2.2, 1.3.0 VMware vCenter 5.x, 6.0U1/U2, 6.5
Lenovo XClarity Administrator content pack for VMWare vRealize Log Insight	1.1	Lenovo XClarity Administrator 1.1 or higher VMware vRealize Log Insight 3.0 or higher
Lenovo XClarity Integrator for VMware vRealize Automation	1.0.1	VMware vRealize Automation 7.x
Lenovo XClarity Integrator for VMware vRealize Orchestrator	1.0.4	VMware vRealize Automation 7.0 VMware vRealize Orchestrator 6.0/7.0
Lenovo Network Plugin for VMware vRealize Orchestrator	1.3.0	VMware vRealize Orchestrator 6.0/7.x
Lenovo Networking Content Pack for VMware vRealize Log Insight	1.2.0	VMware vRealize Log Insight 3.6 or Higher

8.7 Deployment example

There are 3 strategies to deploy vCloud Suite:

- Use VLANs for both user VMs and the Nutanix CVM
- Use NSX and VXLANs for user VMs and the Nutanix CVM in a VLAN
- Use NSX and VXLANs for both user VMs and the Nutanix CVM

This section describes an example deployment of vRealize Suite 7.2 using VLANs for all VMs. The term vRA is used as a short-hand to denote all of the vRealize Automation VMs.

The Lenovo ESXi 6.5 U1 image is used for this example deployment. To use ESXi 6.5 U1, download the Lenovo ThinkSystem custom image from the following website: my.vmware.com/web/vmware/info/slug/datacenter_cloud_infrastructure/vmware_vsphere/6_5#custom_iso.

8.7.1 Physical Model

Four physical servers are used for each of the shared edge and compute, management, and additional compute clusters. Lenovo ThinkSystem HX3320 appliances are used for the shared edge and compute cluster and management cluster. The servers for the additional compute cluster are workload- dependent and Lenovo ThinkSystem HX3520-G appliances are used in this case. Lenovo RackSwitch G8272 switches are used for the 10 GbE network. See also the “VMware vCloud Suite deployment model” on page 23.

Figure 47 shows a view of the physical 10 GbE network and connections to the external internet.

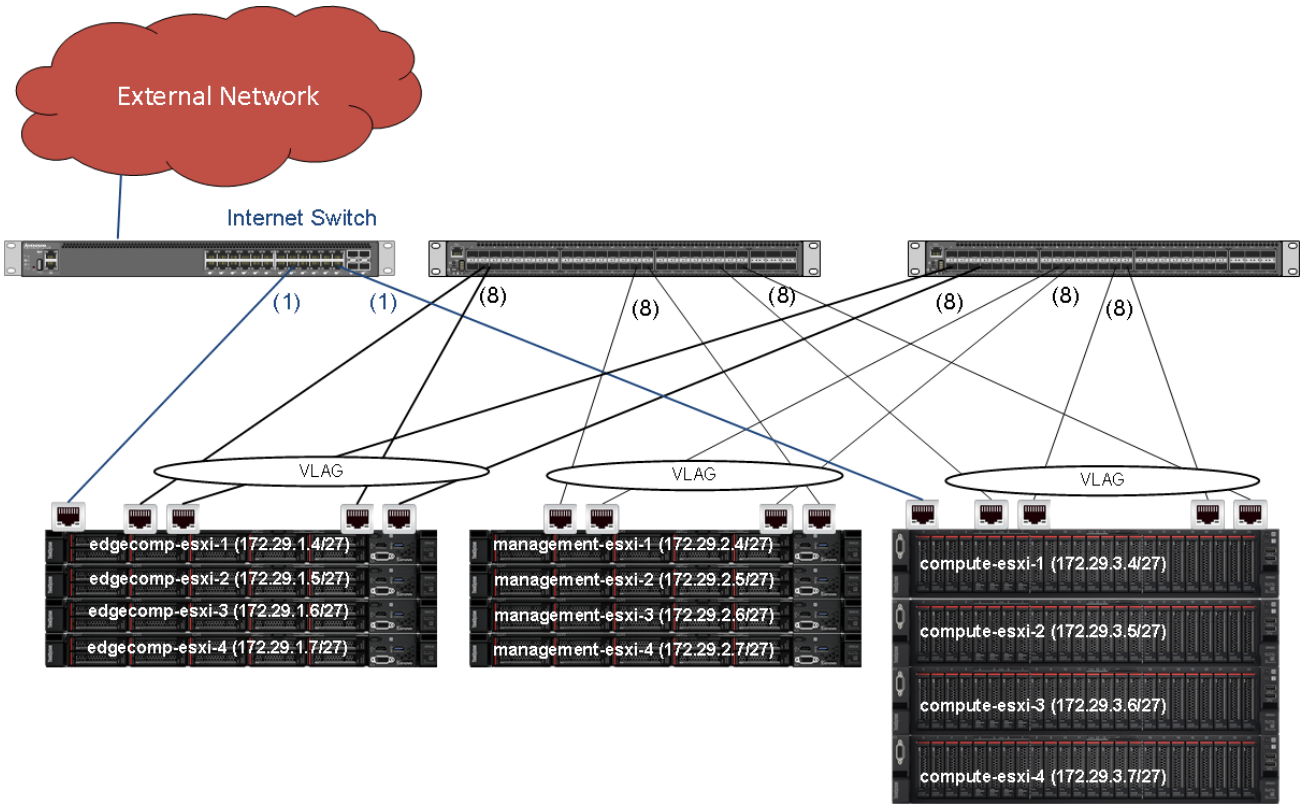


Figure 47: Networking Overview

For the shared edge and compute, management and additional compute clusters, the nodes use VLAG technology and as such are using a LAG configuration within the vSphere Distributed Switches. It is recommended to use VLAG for all the clusters connected to the same set of switches.

The servers in the shared edge and compute cluster and the additional compute cluster are connected to a 1G switch. This switch in turn is connected to the internet via a gateway and firewall (not shown).

8.7.2 IP/VLAN mapping

It is recommended to use different VLANs in each of the clusters (shared edge and compute, management, and compute). These different VLANs can be connected together by leveraging Layer 3 routing either in the G8272 physical switch or in upstream switches.

This example deployment uses the following five VLANs:

- Management (includes Nutanix CVM)
- vMotion
- FT
- vRA
- Comp (for customer specific computation data traffic)

It is a Nutanix best practice to include the CVM as part of the management VLAN. Alternatively the Nutanix CVM could be executed in its own Storage VLAN. Local storage traffic between VMs and the local CVM is done with a Nutanix specific vSwitch (vSwitchNutanix) using the svm-iscsi-pg port group. Do not modify vSwitchNutanix, as this provides critical CVM-to-hypervisor storage communication on CVM eth1.

Table 46 lists example IP address ranges for the VLANs in each cluster where RID means Rack ID.

Table 46: Network Segments

Cluster	Shared Edge and Compute (RID 1)		Management (RID 2)		Compute (RID 3)	
	Subnet	VLAN	Subnet	VLAN	Subnet	VLAN
Manage	172.29.1.0/27	101	172.29.2.0/27	201	172.29.3.0/27	301
vMotion	172.29.1.32/27	102	172.29.2.32/27	202	172.29.3.32/27	302
FT	172.29.1.64/27	103	172.29.2.64/27	203	172.29.3.64/27	303
vRA	N/A		172.29.2.192/27	207	N/A	
Comp	172.29.1.192/27	109	N/A		172.29.1.192/27	109

In this example, each cluster needs a minimum of five network segments within the 172.29.RID.x address range. Each segment does not require more than 30 IP addresses; therefore, a 255.255.255.224 (/27) netmask provides enough addresses. The same VLAN IDs can be used across racks with different IP segments as shown by VLAN 109.

8.7.3 Layer 3 Routing with VRRP

Virtual Routing Redundancy Protocol (VRRP) should be enabled in the switches for layer 3 routing. Each switch defaults to IP routing. VMs can use the respective routing IP to reach the switches. Routing occurs through either one of the switches and this causes intermittent routing failures when used with VLAG.

Layer 3 routing with VRRP removes this limitation by using a single routing IP address for both the switches. Each subnet requires 2 IPs reserved for normal layer 3 routers and one IP reserved for VRRP router.

Table 47 lists the example layer 3 routing IPs for each of the VLANs and the clusters.

Table 47: Layer 3 Example Routing

Cluster	VLAN	Subnet	L3 Interface IP		VRRP Router IP	
			G8272(1)	G8272(2)	G8272(1) Master	G8272(2) Backup
Shared Edge and Compute	Management	172.29.1.0/27	172.29.1.1	172.29.1.2	172.29.1.3	172.29.1.3
	vMotion	172.29.1.32/27	172.29.1.33	172.29.1.34	172.29.1.35	172.291.35
	FT	172.29.1.64/27	172.29.1.65	172.29.1.66	172.29.1.67	172.29.1.67
	Comp	172.29.1.192/27	172.29.1.193	172.29.1.194	172.29.1.195	172.29.1.195
Management	Management	172.29.2.0/27	172.29.2.1	172.29.2.2	172.29.2.3	172.29.2.3
	vMotion	172.29.2.32/27	172.29.2.33	172.29.2.34	172.29.2.35	172.29.2.35
	FT	172.29.2.64/27	172.29.2.65	172.29.2.66	172.29.2.67	172.29.2.67
	vRA	172.29.2.192/27	172.29.2.193	172.29.2.194	172.29.2.195	172.29.2.195
Additional Compute	Management	172.29.3.0/27	172.29.3.1	172.29.3.2	172.29.3.3	172.29.3.3
	vMotion	172.29.3.32/27	172.29.3.33	172.29.3.34	172.29.3.35	172.29.3.35
	FT	172.29.3.64/27	172.29.3.65	172.29.3.66	172.29.3.67	172.29.3.67
	Comp	172.29.1.192/27	172.29.1.193	172.29.1.194	172.29.1.195	172.29.1.195

8.7.4 Management cluster

Although a single distributed switch can be deployed across various clusters, it is recommended to deploy unique distributed switches per cluster. Figure 48 shows the distributed switch for the management cluster.

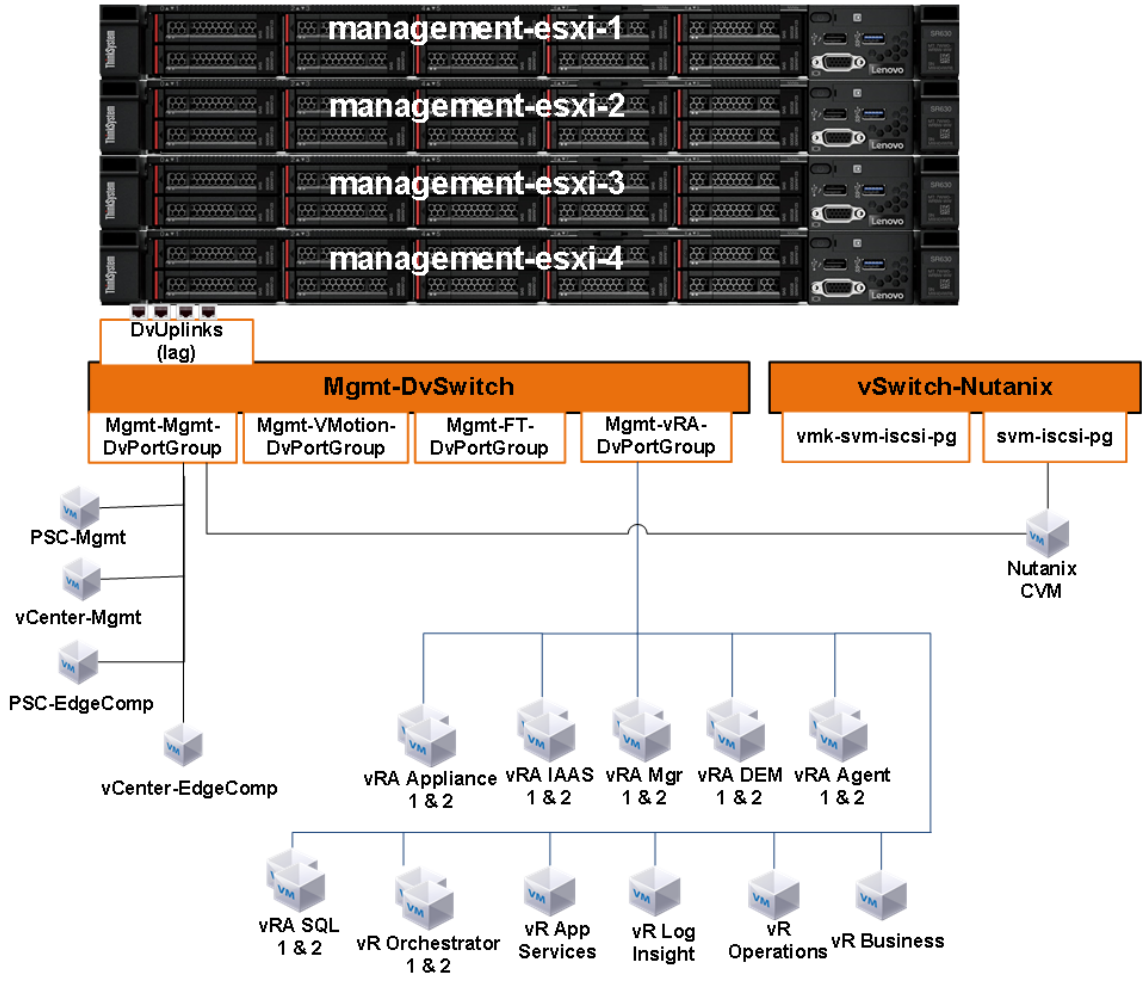


Figure 48: Management Cluster VDS

The infrastructure uses single SSO domain and all platform service controllers and vCenter servers are connected to this domain. All VMs in the management cluster can be configured on the same network segment. Separate vCenter and platform service controller instances are used for management cluster and shared edge and compute cluster. It is recommended that vCenter is deployed in a highly available configuration (depending on each customer's needs) which can result in multiple vCenters, multiple PSCs, and physical load balancers.

8.7.5 Shared Edge and Compute cluster

Figure 49 shows the distributed switches for the edge and compute cluster. One DVS is used for accessing the Internet via a 1GbE port on the server. The other DVS is used for all of the edge and compute network flows.

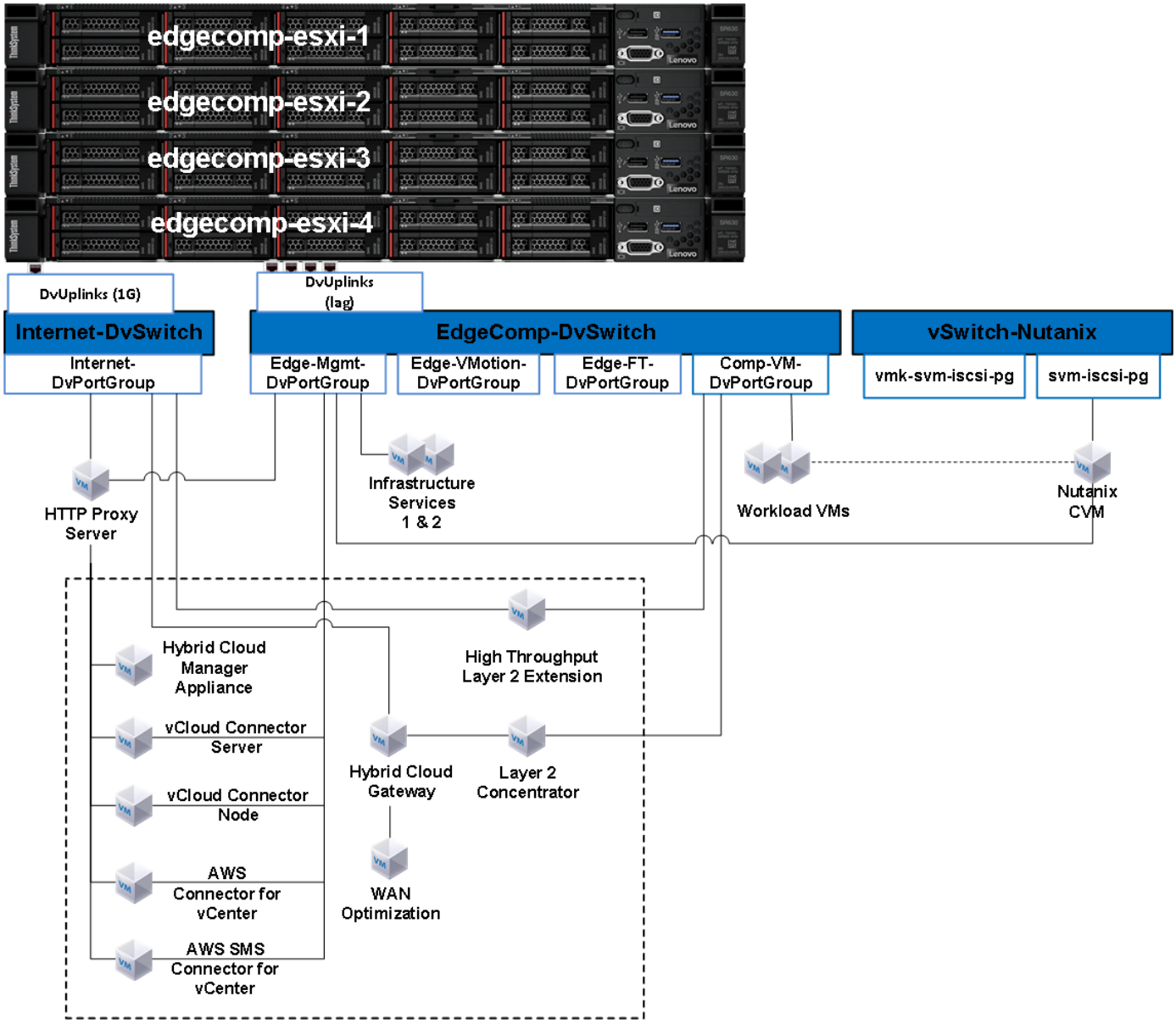


Figure 49: Shared Edge and Compute Cluster VDS

Infrastructure service VMs, such as Active Directory, DHCP, DNS, and NTP might exist in the customers' environment and these services are accessed through a clustered configuration, as shown in this example. However, if there is a requirement to virtualize these services within this environment, then they can be accessed through Edge-Mgmt-DvPortGroup, as shown in Figure 49.

The Comp-VM-DvPortGroup is used for the workload VMs.

The VMware hybrid cloud connector VMs shown in the dashed box are deployed in the shared edge and compute cluster. These VMs leverage an http proxy, routed network, or non-routed network to connect to their respective public clouds.

The hybrid cloud connector VMs running on the EdgeComp-DvSwitch need routing configured to the internet switch to seamlessly establish channel to the public clouds for bidirectional communication. The AWS connector and AWS SMS Connector are deployed on the Edge-Mgmt-DvPortGroup. The Hybrid Cloud Manager and Hybrid Cloud gateway are deployed on the Internet-DvPortGroup and Layer 2 Concentrator leverages the IPSec tunnel established by Hybrid Cloud Gateway with vCloud Air.

The WAN Optimization service works with Hybrid Cloud Gateway. The High Throughput Layer 2 Extension requires routing to the Internet using the IPSec tunnel. The Layer 2 Concentrator and High Throughput Layer 2 Extension need to be deployed on the respective tenant DvPortGroup (e.g. Comp-VM-DvPortGroup) which requires a Layer 2 extension.

8.7.6 Compute cluster

Figure 50 shows the distributed switch for the compute cluster. Workload-specific DvPortGroups and VMs are not shown because they are highly dependent on the specific workloads. More than one compute cluster can be used to add more workloads.

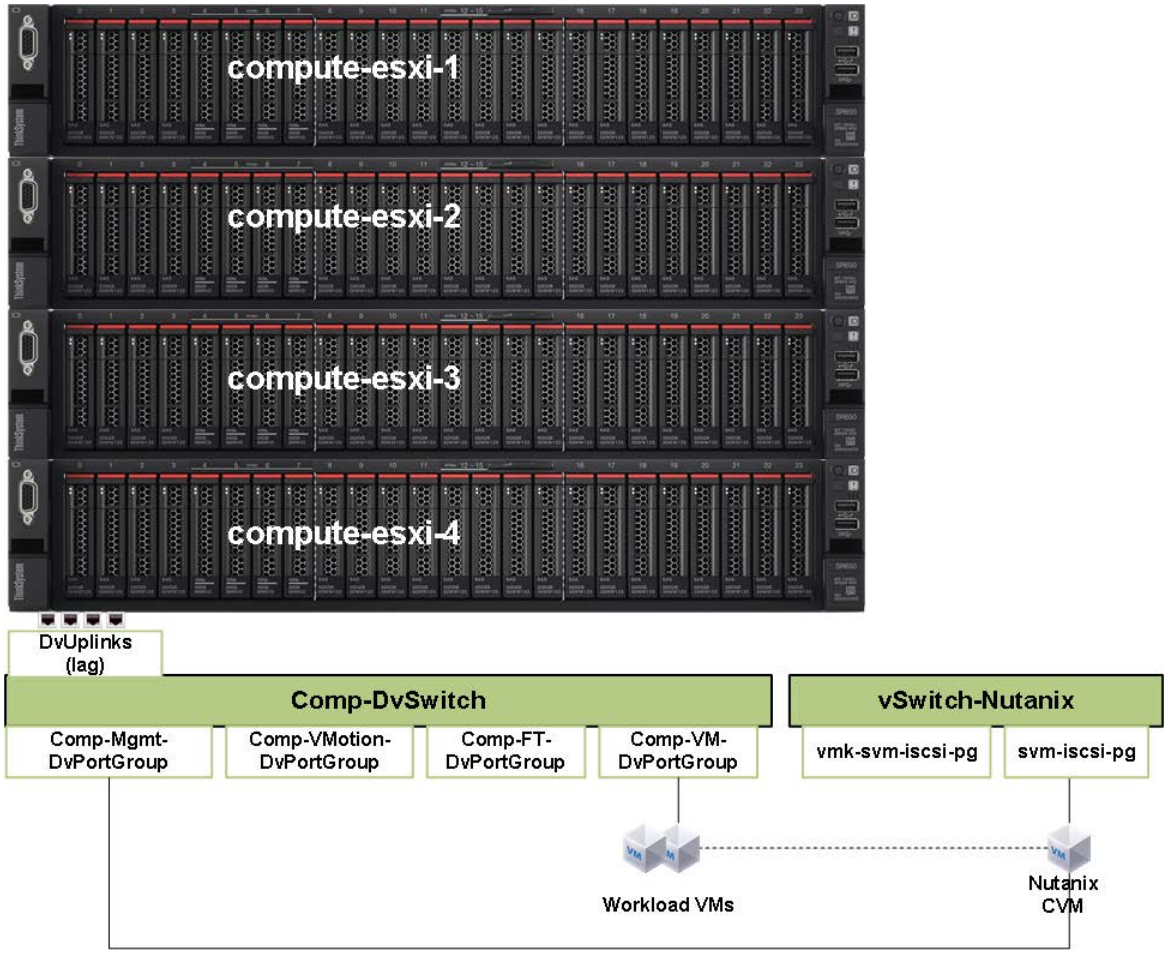


Figure 50: Compute Cluster VDS

Resources

- Nutanix Portal (requires registration)

  portal.nutanix.com

- Nutanix Bible

  nutanixbible.com/

- Nutanix Tech Note: VMware vSphere Networking on Nutanix

  go.nutanix.com/rs/nutanix/images/Nutanix_TechNote-VMware_vSphere_Networking_with_Nutanix.pdf

- VMware vSphere

  vmware.com/products/datacenter-virtualization/vsphere

Document History

Version 1.0	31 October 2017	• Initial version
Version 1.1	15 November 2017	• Added chapter for Microsoft SQL Server workload • Added rack deployment models with more detail on ThinkAgile SXN
Version 1.2	10 December 2017	• Added chapter for Microsoft Exchange 2013 workload • Added deployment model for Microsoft Exchange
Version 1.3	22 January 2018	• Added Nutanix AHV hypervisor and Citrix Workspace Appliance (CWA) for Citrix XenDesktop • Added Microsoft Exchange 2016 • Added ThinkSystem NE1072T switch • Added ThinkSystem NE2572 switch
Version 1.4	29 January 2018	• Added chapter for VMware vCloud Suite • Added deployment model for VMware vCloud Suite • Added performance results for VDI graphics acceleration • Add Microsoft Exchange 2016 results for all flash appliances

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