



Reference Architecture: Lenovo Client Virtualization with Citrix XenDesktop and System x Servers

Last update: 27 March 2017

Version 1.4

**Reference Architecture for
Citrix XenDesktop**

**Contains performance data and
sizing recommendations for
servers, storage, and networking**

**Describes a variety of storage
models including SAN storage
and hyper-converged systems**

**Contains a detailed bill of materials
for servers, storage, networking,
and racks**

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1 Introduction

The intended audience for this document is technical IT architects, system administrators, and managers who are interested in server-based desktop virtualization and server-based computing (terminal services or application virtualization) that uses Citrix XenDesktop. In this document, the term *client virtualization* is used as to refer to all of these variations. Compare this term to *server virtualization*, which refers to the virtualization of server-based business logic and databases.

This document describes the reference architecture for Citrix XenDesktop 7.11 and also supports the previous versions of Citrix XenDesktop 7.x. This document should be read with the Lenovo Client Virtualization (LCV) base reference architecture document that is available at this website: lenovopress.com/tips1275

The business problem, business value, requirements, and hardware details are described in the LCV base reference architecture document and are not repeated here for brevity.

This document gives an architecture overview and logical component model of Citrix XenDesktop. The document also provides the operational model of Citrix XenDesktop by combining Lenovo® hardware platforms such as Flex System™, System x®, and RackSwitch networking with OEM hardware and software such as Lenovo Storage V3700 V2 storage. The operational model presents performance benchmark measurements and discussion, sizing guidance, and some example deployment models. The last section contains detailed bill of material configurations for each piece of hardware.

See also the Reference Architecture for Workloads using the Lenovo Converged HX Series Nutanix Appliances for Citrix XenDesktop specific information for these appliances. This document is available at this website: lenovopress.com/lp0084.

2 Architectural overview

Figure 1 shows all of the main features of the Lenovo Client Virtualization reference architecture with Citrix XenDesktop. This reference architecture does not address the issues of remote access and authorization, data traffic reduction, traffic monitoring, and general issues of multi-site deployment and network management. This document limits the description to the components that are inside the customer's intranet.

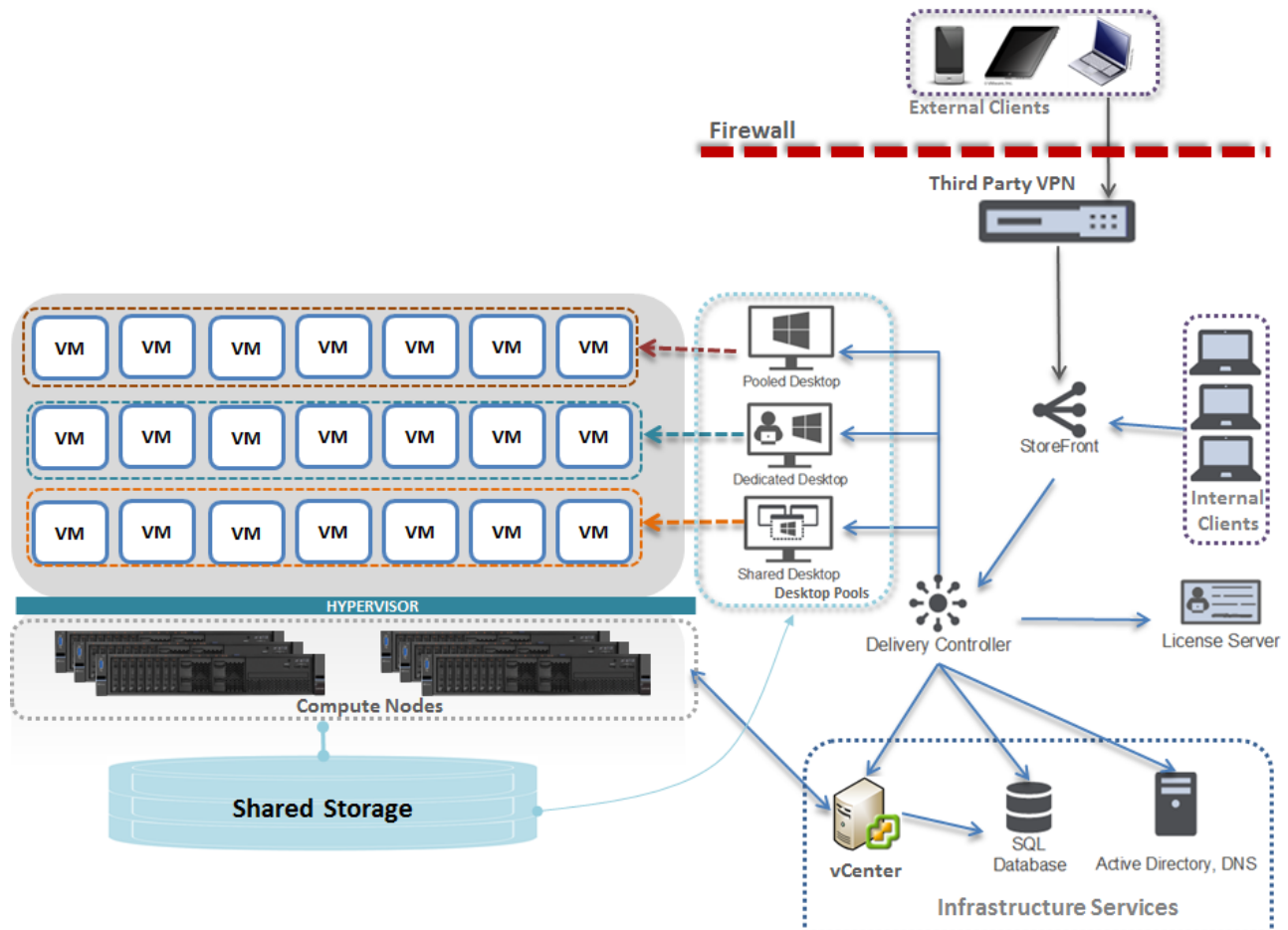


Figure 1: LCV reference architecture with Citrix XenDesktop

3 Component model

Figure 2 is a layered view of the LCV solution that is mapped to the Citrix XenDesktop virtualization infrastructure.

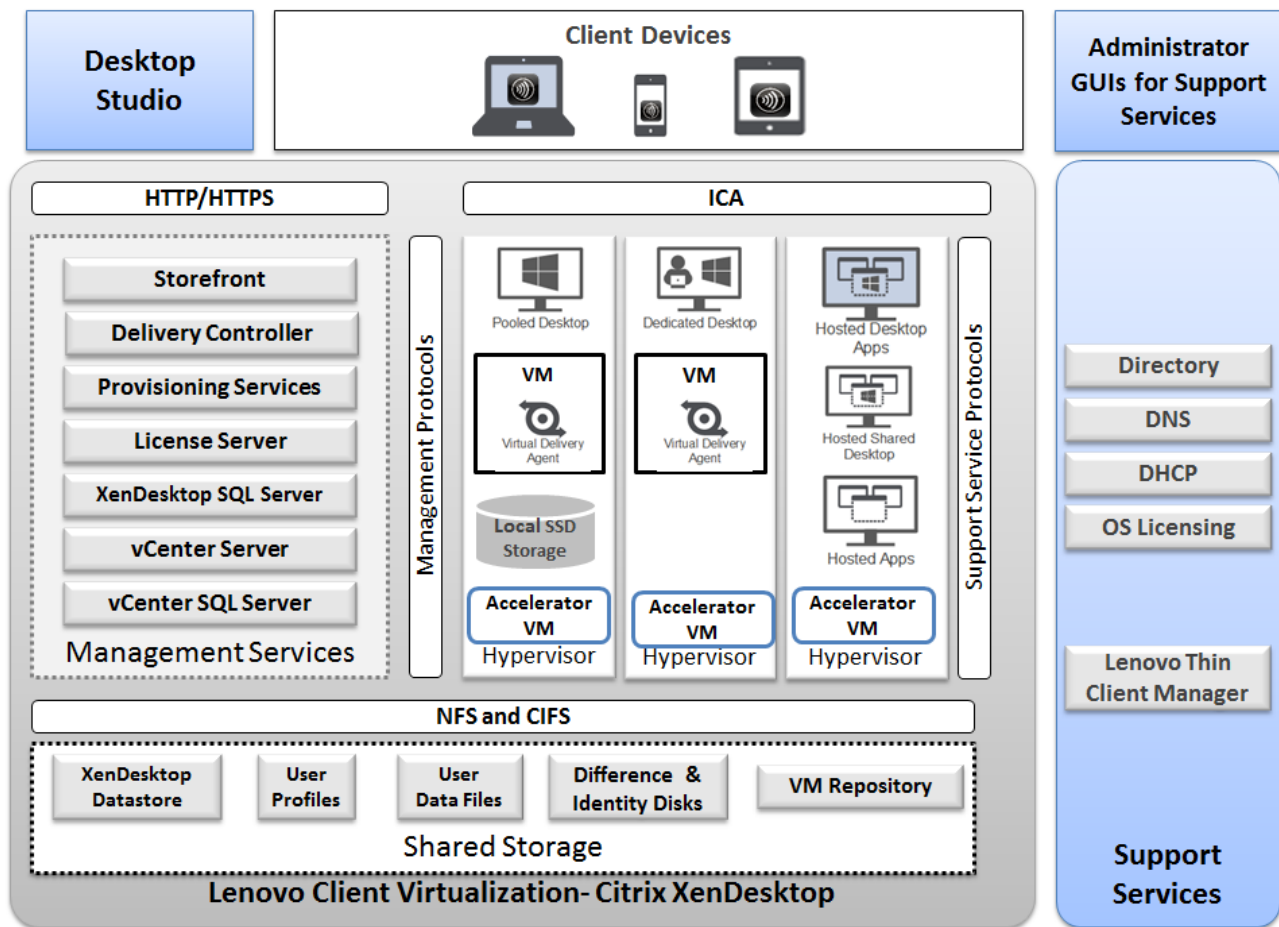


Figure 2: Component model with Citrix XenDesktop

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	<p>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.</p> <p>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.</p>
PVS and MCS	<p>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 5.</p>
License Server	<p>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.</p>
XenDesktop SQL Server	<p>Each Citrix XenDesktop site requires an SQL Server database that is called the <i>data store</i>, 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.</p>
vCenter Server	<p>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 <i>VMware vMotion</i>), which allows a running VM to be moved from one physical server to another without downtime.</p> <p>Redundancy for vCenter Server is achieved through VMware high availability (HA). The vCenter Server also contains a licensing server for VMware ESXi.</p>
vCenter SQL Server	<p>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.</p>

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.
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.
Hypervisor	XenDesktop has an open architecture that supports the use of several different hypervisors, such as VMware ESXi (vSphere), Citrix XenServer, and Microsoft Hyper-V.
Accelerator VM	The optional accelerator VM.
Shared storage	Shared storage is used to store user profiles and user data files. Depending on the provisioning model that is used, different data is stored for VM images. For more information, see “Storage model”. Shared storage can also be distributed storage as used in hyper-converged systems.

For more information, see the Lenovo Client Virtualization base reference architecture document that is available at this website: lenovopress.com/tips1275.

3.1 Citrix XenDesktop provisioning

Citrix XenDesktop features the following primary provisioning models:

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

3.1.1 Provisioning Services

Hosted VDI desktops can be deployed with or without Citrix PVS. The advantage of the use 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 3 shows the sequence of operations that are run by XenDesktop to deliver a hosted VDI virtual desktop.

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 shared storage.

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

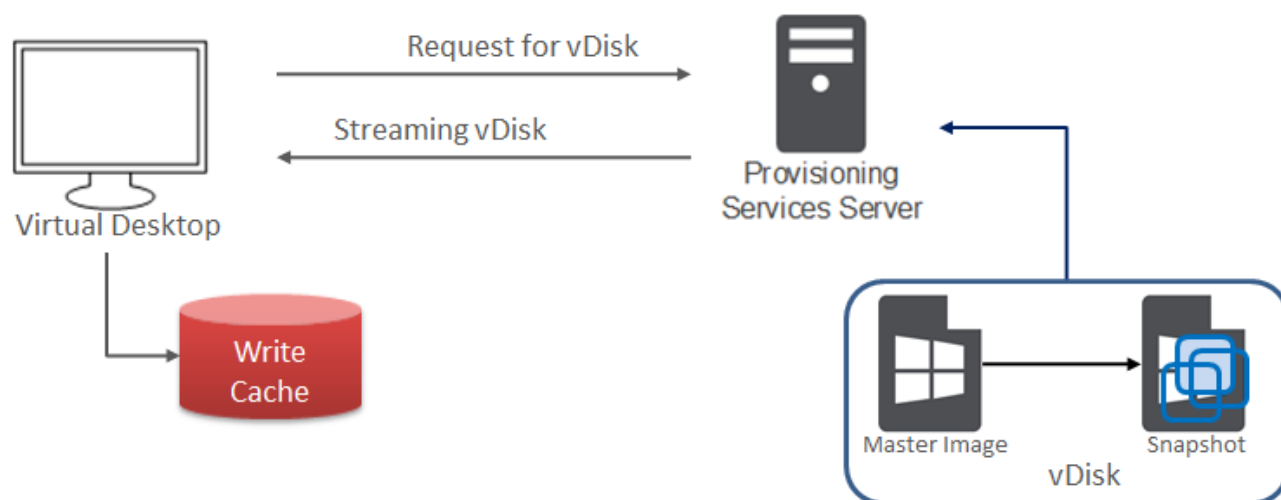


Figure 3: Using PVS for a stateless model

3.1.2 Machine Creation Services

Unlike PVS, MCS does not require more servers. Instead, it uses integrated functionality that is built into the hypervisor (VMware ESXi, Citrix XenServer, or Microsoft Hyper-V) and communicates through the respective APIs. Each desktop has one difference disk and one identity disk (as shown in Figure 4). 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.

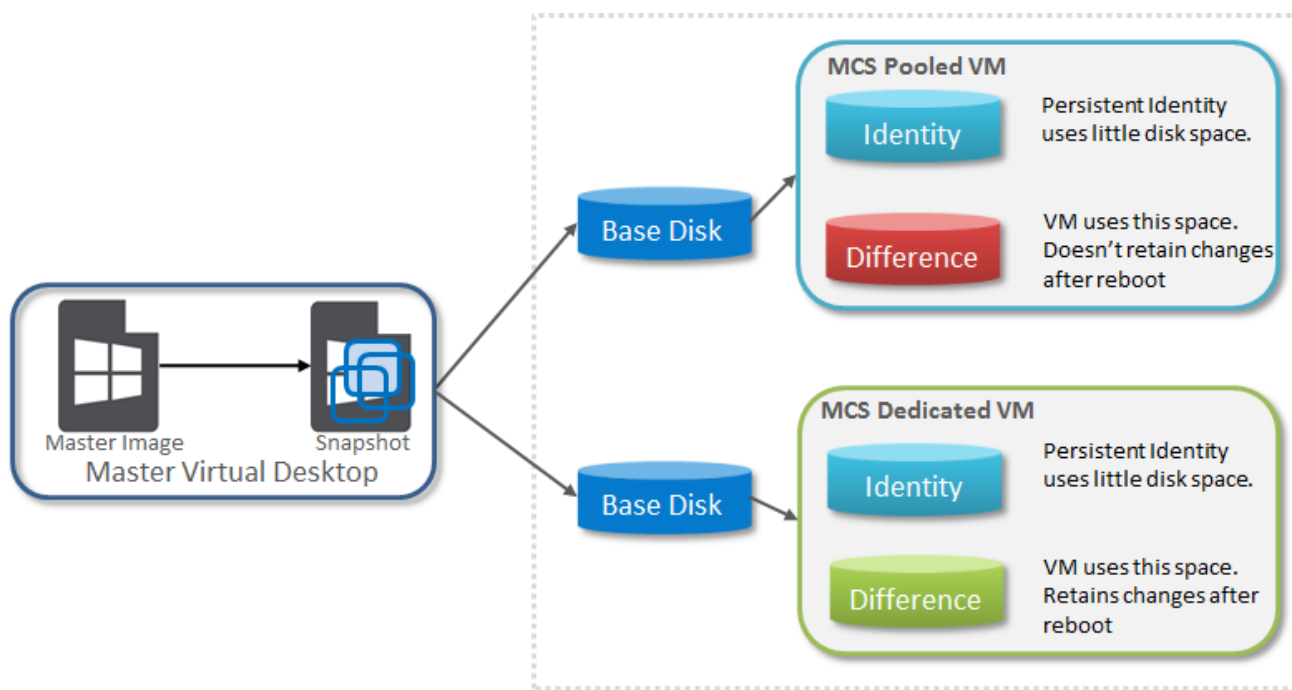


Figure 4: MCS image and difference/identity disk storage model

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. For this reason, MCS dedicated desktops are used for dedicated desktops.

There is a new caching option in Citrix XenDesktop 7.9 onwards for Pooled and Hosted Shared desktops. Figure 5 shows a screenshot of the option.

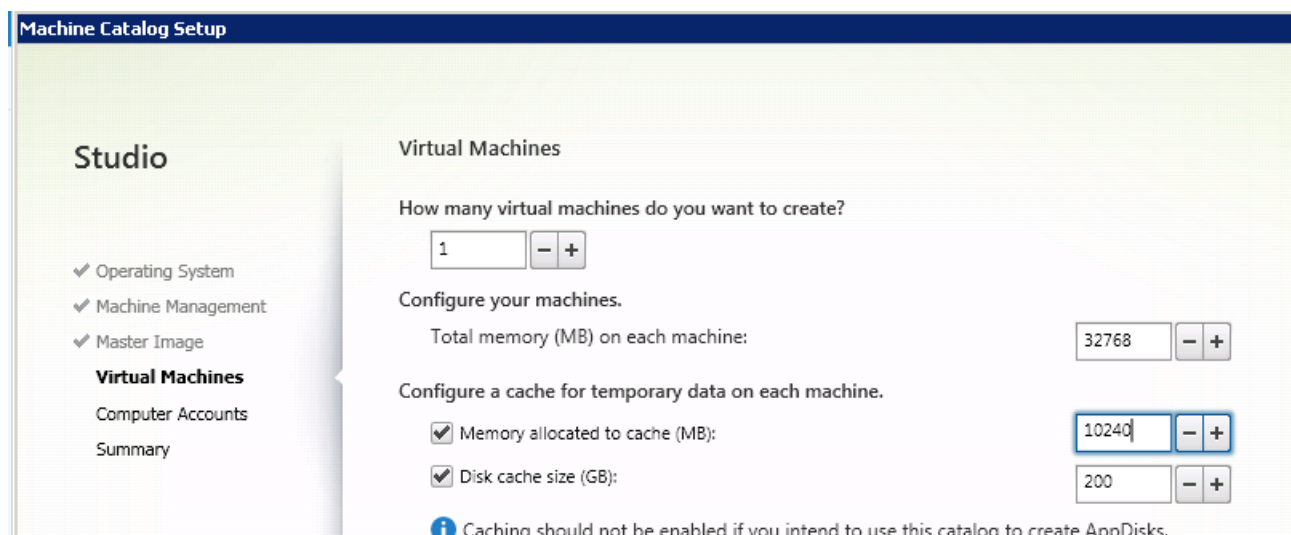


Figure 5: Caching option for Pooled and Hosted Shared desktops

3.2 Storage model

This section describes the different types of shared or distributed data stored for stateless and dedicated desktops. Stateless and dedicated virtual desktops should have the following common shared storage items:

- The master VM image and snapshots are stored by using Network File System (NFS) or block I/O shared storage.
- The paging file (or vSwap) is transient data that can be redirected to NFS storage. In general, it is recommended to disable swapping, which reduces storage use (shared or local). The desktop memory size should be chosen to match the user workload rather than depending on a smaller image and swapping, which reduces overall desktop performance.

- User profiles (from MSRP) are stored by using Common Internet File System (CIFS).
- User data files are stored by using CIFS.

Dedicated virtual desktops or stateless virtual desktops that need mobility require the following items to be on NFS or block I/O shared storage:

- Difference disks are used to store user's changes to the base VM image. The difference disks are per user and can become quite large for dedicated desktops.
- Identity disks are used to store the computer name and password and are small.
- Stateless desktops can use local solid-state drive (SSD) storage for the PVS write cache, which is used to store all image writes on local SSD storage. These image writes are discarded when the VM is shut down.

4 Operational model

This section describes the options for mapping the logical components of a client virtualization solution onto hardware and software. The “Operational model scenarios” section gives an overview of the available mappings and has pointers into the other sections for the related hardware. Each subsection contains performance data, has recommendations on how to size for that particular hardware, and a pointer to the BOM configurations that are described in section 5 on page 36. The last part of this section contains some deployment models for example customer scenarios.

4.1 Operational model scenarios

Figure 6 shows the following operational models (solutions) in Lenovo Client Virtualization: enterprise, small-medium business (SMB), and hyper-converged.

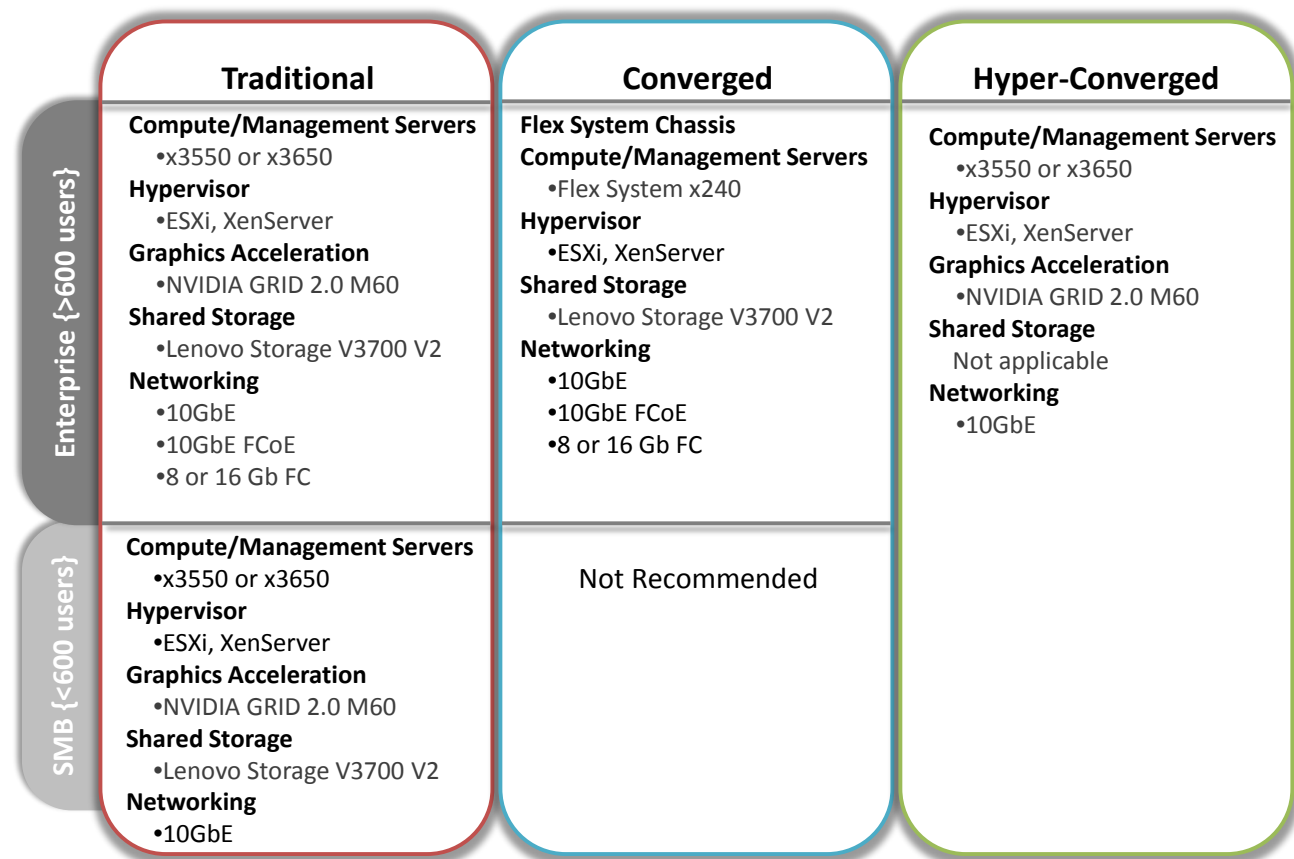


Figure 6: Operational model scenarios

The vertical axis is split into two halves: greater than 600 users is termed Enterprise and less than 600 is termed SMB. The 600 user split is not exact and provides rough guidance between Enterprise and SMB. The last column in Figure 6 (labelled “hyper-converged”) spans both halves because a hyper-converged solution can be deployed in a linear fashion from a small number of users (100) up to a large number of users (>4000).

The horizontal axis is split into three columns. The left-most column represents traditional rack-based systems with top-of-rack (TOR) switches and shared storage. The middle column represents converged systems where the compute, networking, and sometimes storage are converged into a chassis, such as the Flex System. The right-most column represents hyper-converged systems and the software that is used in these

systems. For the purposes of this reference architecture, the traditional and converged columns are merged for enterprise solutions; the only significant differences are the networking, form factor and capabilities of the compute servers.

Converged systems are not generally recommended for the SMB space because the converged hardware chassis can be more overhead when only a few compute nodes are needed. Other compute nodes in the converged chassis can be used for other workloads to make this hardware architecture more cost-effective.

4.1.1 Enterprise operational model

For the enterprise operational model, see the following sections for more information about each component, its performance, and sizing guidance:

- 4.2 Hypervisor support
- 4.3 Compute servers for virtual desktops
- 4.4 Compute servers for hosted shared desktops
- 4.5 Graphics Acceleration
- 4.6 Management servers
- 4.7 Systems management
- 4.8 Shared storage
- 4.9 Networking
- 4.10 Racks

To show the enterprise operational model for different sized customer environments, four different sizing models are provided for supporting 600, 1500, 4500, and 10000 users.

The SMB model is the same as the Enterprise model for traditional systems.

4.1.2 Hyper-converged operational model

Although not covered in this Reference Architecture, a variety of hyper-converged storage architectures can be used with Citrix XenDesktop including VMware VSAN using the ESXi hypervisor.

4.2 Hypervisor support

The Citrix XenDesktop reference architecture uses the VMware ESXi 6.5a, XenServer 6.5, or Microsoft Hyper-V 2012 hypervisors.

4.2.1 VMware ESXi

The VMware ESXi hypervisor is convenient because it can start from a USB flash drive and does not require any more local storage. Alternatively, ESXi can be booted from SAN shared storage. For the VMware ESXi hypervisor, the number of vCenter clusters depends on the number of compute servers.

For stateless desktops, local SSDs can be used to store the base image and pooled VMs for improved performance. Two replicas must be stored for each base image. Each stateless virtual desktop requires a linked clone, which tends to grow over time until it is refreshed at log out. Two enterprise high-speed 400 GB SSDs in a RAID 0 configuration should be sufficient for most user scenarios; however, 800 GB SSDs might be

needed. Because of the stateless nature of the architecture, there is little added value in configuring reliable SSDs in more redundant configurations.

To use the latest version ESXi, download the Lenovo custom image from the following website:
my.vmware.com/web/vmware/info/slug/datacenter_cloud_infrastructure/vmware_vsphere/6_5#custom_iso.

4.2.2 Citrix XenServer

For the Citrix XenServer hypervisor, it is necessary to install the OS onto drives in each compute server.

For stateless desktops, local SSDs can be used to improve performance by storing the delta disk for MCS or the write-back cache for PVS. Each stateless virtual desktop requires a cache, which tends to grow over time until the virtual desktop is rebooted. The size of the write-back cache depends on the environment. Two enterprise high-speed 200 GB SSDs in a RAID 0 configuration should be sufficient for most user scenarios; however, 400 GB (or even 800 GB) SSDs might be needed. Because of the stateless nature of the architecture, there is little added value in configuring reliable SSDs in more redundant configurations.

The Flex System x240 compute nodes has two 2.5" drives. It is possible to both install XenServer and store stateless virtual desktops on the same two drives by using larger capacity SSDs. The System x3550 and System x3560 rack servers do not have this restriction and use separate HDDs for Hyper-V and SSDs for local stateless virtual desktops.

For Internet Explorer 11, the software rendering option must be used for flash videos to play correctly with Login VSI 4.1.3.

4.2.3 Microsoft Hyper-V

For the Microsoft Hyper-V hypervisor, it is necessary to install the OS onto drives in each compute server. For anything more than a small number of compute servers, it is worth the effort of setting up an automated installation from a USB flash drive by using Windows Assessment and Deployment Kit (ADK).

The Flex System x240 compute nodes has two 2.5" drives. It is possible to both install XenServer and store stateless virtual desktops on the same two drives by using larger capacity SSDs. The System x3550 and System x3560 rack servers do not have this restriction and use separate HDDs for Hyper-V and SSDs for local stateless virtual desktops.

Dynamic memory provides the capability to overcommit system memory and allow more VMs at the expense of paging. In normal circumstances, each compute server must have 20% extra memory to allow failover. When a server goes down and the VMs are moved to other servers, there should be no noticeable performance degradation to VMs that is already on that server. The recommendation is to use dynamic memory, but it should only affect the system when a compute server fails and its VMs are moved to other compute servers.

For Internet Explorer 11, the software rendering option must be used for flash videos to play correctly with Login VSI 4.1.3.

The following configuration considerations are suggested for Hyper-V installations:

- Disable Large Send Offload (LSO) by using the **Disable-NetadapterLSO** command on the Hyper-V compute server.

- Disable virtual machine queue (VMQ) on all interfaces by using the **Disable-NetAdapterVmq** command on the Hyper-V compute server.
- Apply registry changes as per the Microsoft article that is found at this website: support.microsoft.com/kb/2681638
The changes apply to Windows Server 2008 and Windows Server 2012.
- Disable VMQ and Internet Protocol Security (IPSec) task offloading flags in the Hyper-V settings for the base VM.
- By default, storage is shared as hidden *Admin* shares (for example, e\$) on Hyper-V compute server and XenDesktop does not list *Admin* shares while adding the host. To make shared storage available to XenDesktop, the volume should be shared on the Hyper-V compute server.
- Because the SCVMM library is large, it is recommended that it is accessed by using a remote share.

4.3 Compute servers for virtual desktops

This section describes stateless and dedicated virtual desktop models. Stateless desktops that allow live migration of a VM from one physical server to another are considered the same as dedicated desktops because they both require shared storage. In some customer environments, stateless and dedicated desktop models might be required, which requires a hybrid implementation.

Compute servers are servers that run a hypervisor and host virtual desktops. There are several considerations for the performance of the compute server, including the processor family and clock speed, the number of processors, the speed and size of main memory, and local storage options.

The use of the Aero theme in Microsoft Windows® 7 or other intensive workloads has an effect on the maximum number of virtual desktops that can be supported on each compute server. Windows 8 also requires more processor resources than Windows 7, whereas little difference was observed between 32-bit and 64-bit Windows 7. Although a slower processor can be used and still not exhaust the processor power, it is a good policy to have excess capacity.

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. Designers and engineers that require graphics acceleration might need 8 GB - 16 GB of RAM per desktop. 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 7 desktop. The virtual desktop memory should be large enough so that swapping is not needed and vSwap can be disabled.

For more information, see “BOM for enterprise and SMB compute servers” on page 36.

4.3.1 Intel Xeon E5-2600 v4 and v3 processor family servers

This section shows the performance results and sizing guidance for Lenovo compute servers based on the Intel Xeon E5-2600 v4 processors (Broadwell) and Intel Xeon E5-2600 v3 processors (Haswell).

ESXi 6.5a performance results

Table 1 lists the Login VSI performance of E5-2600 v4 and E5-2600 v3 processors from Intel that use the Login VSI 4.1 office worker workload with ESXi 6.5a.

Table 1: Performance with office worker workload

Processor with office worker workload	Hypervisor	MCS Stateless	MCS Dedicated
Two E5-2650 v3 2.30 GHz, 10C 105W	ESXi 6.0	239 users	234 users
Two E5-2670 v3 2.30 GHz, 12C 120W	ESXi 6.0	283 users	291 users
Two E5-2680 v3 2.50 GHz, 12C 120W	ESXi 6.0	284 users	301 users
Two E5-2690 v3 2.60 GHz, 12C 135W	ESXi 6.0	301 users	306 users
Two E5-2680 v4 2.40 GHz, 14C 120W	ESXi 6.5a	316 users	327 users

Table 2 lists the results for the Login VSI 4.1 knowledge worker workload.

Table 2: Performance with knowledge worker workload

Processor with knowledge worker workload	Hypervisor	MCS Stateless	MCS Dedicated
Two E5-2680 v3 2.50 GHz, 12C 120W	ESXi 6.0	244 users	237 users
Two E5-2690 v3 2.60 GHz, 12C 135W	ESXi 6.0	252 users	246 users
Two E5-2680 v4 2.40 GHz, 14C 120W	ESXi 6.5a	269 users	275 users
Two E5-2699 v4 2.20 GHz, 22C 145W	ESXi 6.5a	356 users	361 users

Table 3 lists the results for the Login VSI 4.1 power worker workload.

Table 3: Performance with power worker workload

Processor with power worker workload	Hypervisor	MCS Stateless	MCS Dedicated
Two E5-2680 v3 2.50 GHz, 12C 120W	ESXi 6.0	203 users	202 users
Two E5-2699 v4 2.20 GHz, 22C 145W	ESXi 6.5a	279 users	283 users

These results indicate the comparative processor performance. The following conclusions can be drawn:

- The performance for stateless and dedicated virtual desktops is similar.
- The Xeon E5-2680v4 processor has 4-24% performance improvement over the previously recommended Xeon E5-2680v3 processor with similar power utilization (in watts) depending on the type of user workload.
- The Xeon E5-2699v4 processor has significantly better performance than the Xeon E5-2680v4 but at an added cost.

The Xeon E5-2680v4 processor has a good cost/user density ratio. Many configurations are bound by memory; therefore, a faster processor might not provide any added value. Some users require the fastest

processor and for those users, the Xeon E5-2699v4 processor is the best choice. The Xeon E5-2680v4 processor is recommended for an average configuration.

XenServer performance results

Table 4 lists the Login VSI performance of E5 2600 v3 processors from Intel that uses the Office worker workload with XenServer 6.5.

Table 4: XenServer 6.5 performance with Office worker workload

Processor with office worker workload	Hypervisor	MCS stateless	MCS dedicated
Two E5-2650 v3 2.30 GHz, 10C 105W	XenServer 6.5	225 users	224 users
Two E5-2680 v3 2.50 GHz, 12C 120W	XenServer 6.5	274 users	278 users

Table 5 shows the results for the same comparison that uses the Knowledge worker workload.

Table 5: XenServer 6.5 performance with Knowledge worker workload

Processor with knowledge worker workload	Hypervisor	MCS stateless	MCS dedicated
Two E5-2680 v3 2.50 GHz, 12C 120W	XenServer 6.5	210 users	208 users

Table 6 lists the results for the Login VSI 4.1 power worker workload.

Table 6: XenServer 6.5 performance with power worker workload

Processor with power worker workload	Hypervisor	MCS Stateless	MCS Dedicated
Two E5-2680 v3 2.50 GHz, 12C 120W	XenServer 6.5	181 users	179 users

Hyper-V Server 2012 R2 performance results

Table 7 lists the Login VSI performance of E5 2600 v3 processors from Intel that uses the Office worker workload with Hyper-V Server 2012 R2.

Table 7: Hyper-V Server 2012 R2 performance with Office worker workload

Processor with office worker workload	Hypervisor	MCS stateless	MCS dedicated
Two E5-2650 v3 2.30 GHz, 10C 105W	Hyper-V	270 users	272 users

Table 8 shows the results for the same comparison that uses the Knowledge worker workload.

Table 8: Hyper-V Server 2012 R2 performance with Knowledge worker workload

Processor with knowledge worker workload	Hypervisor	MCS stateless	MCS dedicated
Two E5-2680 v3 2.50 GHz, 12C 120W	Hyper-V	250 users	247 users

Table 9 lists the results for the Login VSI 4.1 power worker workload.

Table 9: Hyper-V Server 2012 R2 performance with power worker workload

Processor with power worker workload	Hypervisor	MCS Stateless	MCS Dedicated
Two E5-2680 v3 2.50 GHz, 12C 120W	Hyper-V	216 users	214 users

Compute server recommendation for Office workers

The default recommendation for this processor family is the Xeon E5-2680v4 processor and 512 GB of system memory because this configuration provides the best coverage for a range of users. Lenovo testing shows that 225 users per server is a good baseline and has an average of 75% 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 270 users per server have an average of 87% 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. Table 10 lists the processor usage with ESXi for the recommended user counts for normal mode and failover mode.

Table 10: Processor usage

Processor	Workload	Users per Server	Stateless Utilization	Dedicated Utilization
Two E5-2680 v4	Office worker	225 – normal node	76%	74%
Two E5-2680 v4	Office worker	270 – failover mode	88%	86%

Table 11 lists the recommended number of virtual desktops per server for different 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 11: Recommended number of virtual desktops per server

Processor	E5-2680v4	E5-2680v4	E5-2680v4
VM memory size	2 GB (default)	3 GB	4 GB
System memory	512 GB	768 GB	1024 GB
Desktops per server (normal mode)	210	210	210
Desktops per server (failover mode)	252	252	252

Table 12 lists the approximate number of compute servers that are needed for different numbers of users and VM sizes.

Table 12: Compute servers needed for different numbers of users and VM sizes

	600 users	1500 users	4500 users	10000 users
Compute servers @225 users (normal)	4	7	20	45
Compute servers @270 users (failover)	3	6	17	37
Failover ratio	3:1	6:1	6:1	5:1

Compute server recommendation for knowledge workers and power workers

For knowledge workers the default recommendation for this processor family is the Xeon E5-2680v4 processor and 512 GB of system memory. Lenovo testing shows that 175 users per server is a good baseline and has an average of 77% 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 210 users per server have an average of 85% usage of the processor.

For power workers, the default recommendation for this processor family is the Xeon E5-2699v4 processor and 768 GB of system memory. Lenovo testing shows that 175 users per server is a good baseline and has an average of 72% 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 210 users per server have an average of 81% usage of the processor. 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.

Table 13 lists the processor usage with ESXi for the recommended user counts for normal mode and failover mode.

Table 13: Processor usage

Processor	Workload	Users per Server	Stateless Utilization	Dedicated Utilization
Two E5-2680 v4	Knowledge worker	175 – normal node	77%	76%
Two E5-2680 v4	Knowledge worker	210 – failover mode	84%	85%
Two E5-2699 v4	Power worker	175 – normal node	71%	72%
Two E5-2699 v4	Power worker	210 – failover mode	80%	81%

Table 14 lists the recommended number of virtual desktops per server for different VM memory. The number of power users is reduced to fit within the available memory and still maintain a reasonably balanced system of compute and memory.

Table 14: Recommended number of virtual desktops per server

Processor	E5-2680V4 or E5-2699v4	E5-2680V4 or E5-2699v4	E5-2680V4 or E5-2699v4
VM memory size	3 GB (default)	4 GB	5 GB
System memory	768 GB	1024 GB	1024 GB
Desktops per server (normal mode)	175	175	170
Desktops per server (failover mode)	210	210	204

Table 15 lists the approximate number of compute servers that are needed for different numbers of users and VM sizes.

Table 15: Compute servers needed for different numbers of users and VM sizes

	600 users	1500 users	4500 users	10000 users
Compute servers @175 users (normal)	4	10	26	58
Compute servers @210 users (failover)	3	8	22	48
Failover ratio	3:1	4:1	5.5:1	5:1

4.4 Compute servers for hosted shared desktops

This section describes compute servers for hosted shared desktops that use Citrix XenDesktop 7.x. This functionality was in the separate XenApp product, but it is now integrated into the Citrix XenDesktop product. Hosted shared desktops are more suited to task workers that require little in desktop customization.

As the name implies, multiple desktops share a single VM; however, because of this sharing, the compute resources often are exhausted before memory. Lenovo testing showed that 128 GB of memory is sufficient for servers with two processors.

Other testing showed that the performance differences between four, six, or eight VMs is minimal; therefore, four VMs are recommended to reduce the license costs for Windows Server 2012 R2.

For more information, see “BOM for hosted desktops” section on page 40.

4.4.1 Intel Xeon E5-2600 v4 and E5-2600 v3 processor family servers

Table 16 lists the processor performance results for different size workloads that use four Windows Server 2012 R2 VMs with the Xeon E5-2600v3 series processors and ESXi 6.0 hypervisor.

Table 16: ESXi 6.0 results for shared hosted desktops

Processor	Hypervisor	Workload	Hosted Desktops
Two E5-2650 v3 2.30 GHz, 10C 105W	ESXi 6.0	Office Worker	222 users
Two E5-2670 v3 2.30 GHz, 12C 120W	ESXi 6.0	Office Worker	255 users
Two E5-2680 v3 2.50 GHz, 12C 120W	ESXi 6.0	Office Worker	264 users
Two E5-2690 v3 2.60 GHz, 12C 135W	ESXi 6.0	Office Worker	280 users
Two E5-2680 v4 2.40 GHz, 14C 120W	ESXi 6.5a	Office Worker	321 users
Two E5-2680 v3 2.50 GHz, 12C 120W	ESXi 6.0	Knowledge Worker	231 users
Two E5-2690 v3 2.50 GHz, 12C 120W	ESXi 6.0	Knowledge Worker	237 users
Two E5-2680 v4 2.40 GHz, 14C 120W	ESXi 6.5a	Knowledge Worker	284 users
Two E5-2699 v4 2.20 GHz, 22C 145W	ESXi 6.5a	Knowledge Worker	379 users

Table 17 lists the processor performance results for different size workloads that use four Windows Server 2012 R2 VMs with the Xeon E5-2600v3 series processors and XenServer 6.5 hypervisor.

Table 17: XenServer 6.5 results for shared hosted desktops

Processor	Hypervisor	Workload	Hosted Desktops
Two E5-2650 v3 2.30 GHz, 10C 105W	XenServer 6.5	Office Worker	225 users
Two E5-2670 v3 2.30 GHz, 12C 120W	XenServer 6.5	Office Worker	243 users
Two E5-2680 v3 2.50 GHz, 12C 120W	XenServer 6.5	Office Worker	262 users
Two E5-2690 v3 2.60 GHz, 12C 135W	XenServer 6.5	Office Worker	271 users

Two E5-2680 v3 2.50 GHz, 12C 120W	XenServer 6.5	Knowledge Worker	223 users
Two E5-2690 v3 2.50 GHz, 12C 120W	XenServer 6.5	Knowledge Worker	226 users

Table 18 lists the processor performance results for different size workloads that use four Windows Server 2012 R2 VMs with the Xeon E5-2600v3 series processors and Hyper-V Server 2012 R2.

Table 18: Hyper-V Server 2012 R2 results for shared hosted desktops

Processor	Hypervisor	Workload	Hosted Desktops
Two E5-2650 v3 2.30 GHz, 10C 105W	Hyper-V	Office Worker	337 users
Two E5-2680 v3 2.50 GHz, 12C 120W	Hyper-V	Office Worker	295 users
Two E5-2680 v3 2.50 GHz, 12C 120W	Hyper-V	Knowledge Worker	264 users

For office workers the default recommendation for this processor family is the Xeon E5-2680v4 processor and 128 GB of system memory for the 4 Windows Server 2012 R2 VMs. Lenovo testing shows that 225 hosted desktops per server is a good baseline. If a server goes down, users on that server must be transferred to the remaining servers. For this degraded failover case, Lenovo recommends 270 hosted desktops per server. It is important to keep 25% headroom on servers to cope with possible failover scenarios. Lenovo recommends a general failover ratio of 5:1.

Table 19 lists the processor usage for the recommended number of users.

Table 19: Processor usage

Processor	Workload	Users per Server	Utilization
Two E5-2680 v4	Office worker	225 – normal node	73%
Two E5-2680 v4	Office worker	270 – failover mode	84%
Two E5-2680 v4	Knowledge worker	200– normal node	68%
Two E5-2680 v4	Knowledge worker	240 – failover mode	78%

Table 20 lists the number of compute servers that are needed for different numbers of office worker users. Each compute server has 128 GB of system memory for the four VMs.

Table 20: Compute servers needed for different numbers of users and VM sizes

	600 users	1500 users	4500 users	10000 users
Compute servers for 225 users (normal)	4	7	20	45
Compute servers for 270 users (failover)	3	6	17	37
Failover ratio	3:1	6:1	6:1	5:1

4.5 Graphics 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 XenServer 6.5 hypervisor supports the following options for graphics acceleration:

- Dedicated GPU with one GPU per user which is called pass-through mode.
- GPU hardware virtualization (vGPU) that partitions each GPU for 1 to 8 users.

The performance of graphics acceleration was tested on the NVIDIA GRID 2.0 M60 GPU adapter by using the Lenovo System x3650 M5 servers. Each server supports up to two M60 GPU adapters.

Because the vDGA mode and pass-through mode offer a low user density, it is recommended that this configuration is used only for power users, designers, engineers, or scientists that require powerful graphics acceleration.

Lenovo recommends that a high powered CPU, such as the E5-2680v4, is used because accelerated graphics applications tend to also require extra load on the processor. For the vDGA mode and pass-through mode, with only four users per server, 128 GB of server memory should be sufficient even for the high end GRID 2.0 M60 users who might need 16 GB or even 24 GB per VM. For vGPU mode, Lenovo recommends at least 256GB of server memory.

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 21 lists the results of the Heaven benchmark as FPS that is available to each user with the GRID 2.0 M60 adapter by using vDGA mode with DirectX 11.

Table 21: Performance of GRID 2.0 M60 vDGA mode with DirectX 11

Quality	Tessellation	Anti-Aliasing	Resolution	vDGA
Ultra	Extreme	8	1680x1050	54.4
Ultra	Extreme	8	1920x1080	48.5
Ultra	Extreme	8	1920x1200	44.9
Ultra	Extreme	8	2560x1600	26.3

Table 22 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 22: 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	30.38	58.93	31.1
High	Normal	0	1680x1050	Untested	47.55	24.46	N/A	N/A
High	Normal	0	1920x1200	Untested	39.13	19.65	N/A	N/A
Ultra	Extreme	8	1280x1024	Untested	Untested	16.55	35.5	17.08
Ultra	Extreme	8	1680x1050	52.51	27.65	12.89	N/A	N/A
Ultra	Extreme	8	1920x1080	47.60	24.69	11.59	N/A	N/A
Ultra	Extreme	8	1920x1200	44.47	22.99	Untested	N/A	N/A
Ultra	Extreme	8	2560x1600	26.63	14.01	Untested	N/A	N/A

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.

For more information about the bill of materials (BOM) for GRID 2.0 M60 GPUs for Lenovo System x3650 M5 servers, see the following corresponding BOMs:

- “BOM for enterprise and SMB compute servers” on page 36

4.6 Management servers

Management servers should have the same hardware specification as compute servers so that they can be used interchangeably in a worst-case scenario. The Citrix XenDesktop management servers also use the same hypervisor, but have management VMs instead of user desktops. Table 23 lists the VM requirements and performance characteristics of each management service for Citrix XenDesktop.

Table 23: 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
Web Interface	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

Management service VM	Virtual processors	System memory	Storage	Windows OS	HA needed	Performance characteristic
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
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

PVS servers often are run natively on Windows servers. The testing showed that they can run well inside a VM, if it is sized per Table 23. The disk space for PVS servers is related to the number of provisioned images.

Table 24 lists the number of management VMs for each size of users following the high availability and performance characteristics. 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

XenDesktop management service VM	600 users	1500 users	4500 users	10000 users
Delivery Controllers	2 (1+1)	2 (1+1)	2 (1+1)	2(1+1)
Includes Citrix Licensing server	Y	N	N	N
Includes Web server	Y	N	N	N
Web Interface	N/A	2 (1+1)	2 (1+1)	2 (1+1)
Citrix licensing servers	N/A	1	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)	4 (2+2)	8 (6+2)	14 (10+4)
ESXi management service VM	600 users	1500 users	4500 users	10000 users
vCenter servers	1	1	3	7
vCenter SQL servers	2 (1+1)	2 (1+1)	2 (1+1)	2 (1+1)

Each management VM requires a certain amount of virtual processors, memory, and disk. There is enough capacity in the management servers for all of these VMs. Table 25 lists an example mapping of the management VMs to the four physical management servers for 4500 users.

Table 25: Management server VM mapping (4500 users)

Management service for 4500 stateless users	Management server 1	Management server 2	Management server 3	Management server 4
vCenter servers (3)	1	1	1	
vCenter database (2)	1	1		
XenDesktop database (2)			1	1
Delivery controller (2)	1			1
Web Interface (2)			1	1
License server (1)		1		
PVS servers for stateless desktops (8)	2	2	2	2

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.

For shared storage systems that support block data transfers only, it is also necessary to provide some file I/O servers that support CIFS or NFS shares and translate file requests to the block storage system. For high availability, two or more Windows storage servers are clustered.

Based on the number and type of desktops, Table 26 lists the recommended number of physical management servers. In all cases, there is redundancy in the physical management servers and the management VMs.

Table 26: Management servers needed

Management servers	600 users	1500 users	4500 users	10000 users
Stateless desktop model	2	2	4	7
Dedicated desktop model	2	2	2	4
Windows Storage Server 2012	2	2	3	4

For more information, see “BOM for enterprise and SMB management servers” on page 43.

4.7 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.

The Lenovo XClarity Administrator provides agent-free hardware management for Lenovo's System x® rack servers and Flex System™ compute nodes and components, including the Chassis Management Module (CMM) and Flex System I/O modules. Figure 7 shows the Lenovo XClarity administrator interface, where Flex System components and rack servers are managed and are seen on the dashboard. Lenovo XClarity Administrator is a virtual appliance that is quickly imported into a virtualized environment server configuration.

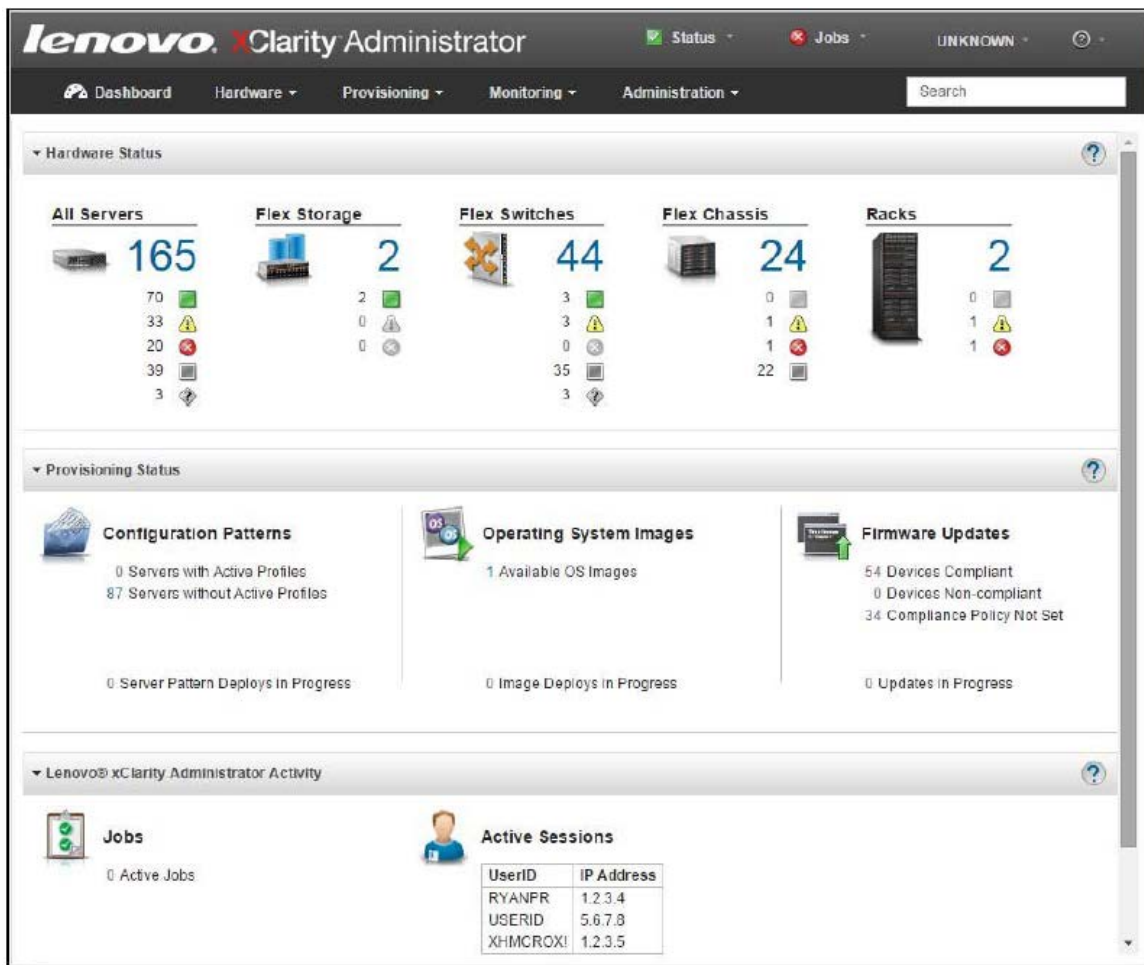


Figure 7: XClarity Administrator interface

4.8 Shared storage

VDI workloads such as virtual desktop provisioning, VM loading across the network, and access to user profiles and data files place huge demands on network shared storage.

Experimentation with VDI infrastructures shows that the input/output operation per second (IOPS) performance takes precedence over storage capacity. This precedence means that more slower speed drives are needed to match the performance of fewer higher speed drives. Even with the fastest HDDs available today (15k rpm), there can still be excess capacity in the storage system because extra spindles are needed to provide the IOPS performance. From experience, this *extra* storage is more than sufficient for the other types of data such as SQL databases and transaction logs.

The large rate of IOPS, and therefore, large number of drives needed for dedicated virtual desktops can be ameliorated to some extent by caching data in flash memory or SSD drives. The storage configurations are based on the peak performance requirement, which usually occurs during the so-called “logon storm.” This is when all workers at a company arrive in the morning and try to start their virtual desktops, all at the same time.

It is always recommended that user data files (shared folders) and user profile data are stored separately from the user image. By default, this has to be done for stateless virtual desktops and should also be done for

dedicated virtual desktops. It is assumed that 100% of the users at peak load times require concurrent access to user data and profiles.

Stateless virtual desktops are provisioned from shared storage using PVS. The PVS write cache is maintained on a local SSD. Table 27 summarizes the peak IOPS and disk space requirements for stateless virtual desktops on a per-user basis.

Table 27: Stateless virtual desktop shared storage performance requirements

Stateless virtual desktops	Protocol	Size	IOPS	Write %
vSwap (recommended to be disabled)	NFS or Block	0	0	0
User data files	CIFS/NFS	5 GB	1	75%
User profile (through MSRP)	CIFS	100 MB	0.8	75%

Table 28 summarizes the peak IOPS and disk space requirements for dedicated or shared stateless virtual desktops on a per-user basis. Persistent virtual desktops require a high number of IOPS and a large amount of disk space. Stateless users that require mobility and have no local SSDs also fall into this category. The last three rows of Table 28 are the same as Table 27 for stateless desktops.

Table 28: Dedicated or shared stateless virtual desktop shared storage performance requirements

Dedicated virtual desktops	Protocol	Size	IOPS	Write %
Master image	NFS or Block	30 GB	18	85%
Difference disks	NFS or Block	10 GB		
User “AppData” folder				
vSwap (recommended to be disabled)	NFS or Block	0	0	0
User files	CIFS/NFS	5 GB	1	75%
User profile (through MSRP)	CIFS	100 MB	0.8	75%

The sizes and IOPS for user data files and user profiles that are listed in Table 27 and Table 28 can vary depending on the customer environment. For example, power users might require 10 GB and five IOPS for user files because of the applications they use. It is assumed that 100% of the users at peak load times require concurrent access to user data files and profiles.

Many customers need a hybrid environment of stateless and dedicated desktops for their users. The IOPS for dedicated users outweigh those for stateless users; therefore, it is best to bias towards dedicated users in any storage controller configuration.

The storage configurations that are presented in this section include conservative assumptions about the VM size, changes to the VM, and user data sizes to ensure that the configurations can cope with the most demanding user scenarios. Refer to the "BOM for shared storage" on page 46 for more details.

This reference architecture describes the following different shared storage solutions:

- Block I/O to Lenovo Storage V3700 V2 using Fibre Channel (FC)
- Block I/O to Lenovo Storage V3700 V2 using Internet Small Computer System Interface (iSCSI)

4.8.1 Lenovo Storage V3700 V2

The Lenovo V3700 V2 storage system supports up to 240 drives by using up to 9 expansion enclosures. The maximum size of the cache is 16 GB. The cache acts as a read cache and a write-through cache and is useful to cache commonly used data for VDI workloads. The read and write cache are managed separately. The write cache is divided up across the storage pools that are defined for the storage system.

In addition, Lenovo storage offers the Easy Tier® function, which allows commonly used data blocks to be transparently stored on SSDs. There is a noticeable improvement in performance when Easy Tier is used, which tends to tail off as SSDs are added. It is recommended that approximately 10% of the storage space is used for SSDs to give the best balance between price and performance.

The tiered storage support also allows a mixture of different disk drives. Slower drives can be used for shared folders and profiles; faster drives and SSDs can be used for dedicated virtual desktops and desktop images.

To support file I/O (CIFS and NFS) into Lenovo storage, Windows storage servers must be added, as described in “Management servers” on page 20.

The fastest HDDs that are available are 15k rpm drives in a RAID 10 array. Storage performance can be significantly improved with the use of Easy Tier. If this performance is insufficient, SSDs or alternatives (such as a flash storage system) are required.

For this reference architecture, it is assumed that each user has 5 GB for shared folders and profile data and uses an average of 2 IOPS to access those files. Investigation into the performance shows that 600 GB 10k rpm drives in a RAID 10 array give the best ratio of input/output operation performance to disk space. If users need more than 5 GB for shared folders and profile data then 900 GB (or even 1.2 TB), 10k rpm drives can be used instead of 600 GB. If less capacity is needed, the 300 GB 15k rpm drives can be used for shared folders and profile data.

Dedicated virtual desktops require both: a high number of IOPS and a large amount of disk space for the linked clones. The linked clones can grow in size over time as well. For dedicated desktops, 300 GB 15k rpm drives configured as RAID 10 were not sufficient and extra drives were required to achieve the necessary performance. Therefore, it is recommended to use a mixture of both speeds of drives for dedicated desktops and shared folders and profile data.

Depending on the number of master images, one or more RAID 1 array of SSDs can be used to store the VM master images. This configuration help with performance of provisioning virtual desktops; that is, a “boot storm”. Each master image requires at least double its space. The actual number of SSDs in the array depends on the number and size of images. In general, more users require more images.

Table 29: VM images and SSDs

	600 users	1500 users	4500 users	10000 users
Image size	30 GB	30 GB	30 GB	30 GB
Number of master images	2	4	8	16
Required disk space (doubled)	120 GB	240 GB	480 GB	960 GB
400 GB SSD configuration	RAID 1 (2)	RAID 1 (2)	Two RAID 1 arrays (4)	Four RAID 1 arrays (8)

Table 30 lists the storage configuration that is needed for each of the stateless user counts. Only one control enclosure is needed for a range of user counts.

Table 30: Storage configuration for stateless users

Stateless storage	600 users	1500 users	4500 users	10000 users
400 GB SSDs in RAID 1 for master images	2	2	4	8
Hot spare SSDs	2	2	4	4
600 GB 10k rpm in RAID 10 for users	12	28	80	168
Hot spare 600 GB drives	2	2	4	12
V3700 V2 control enclosures	1	1	1	1
V3700 V2 expansion enclosures	0	1	3	7

Table 31 lists the storage configuration that is needed for each of the dedicated or shared stateless user counts. The top four rows of Table 31 are the same as for stateless desktops. Based on the assumptions in Table 31, the Lenovo V3700 V2 storage system can support up to 3000 users.

Table 31: Lenovo Storage V3700 V2 storage configuration for dedicated or shared stateless users

Dedicated or shared stateless storage	600 users	1500 users	2400 users
400 GB SSDs in RAID 1 for master images	2	2	4
Hot spare SSDs	2	2	2
600 GB 10k rpm in RAID 10 for users	12	28	48
Hot spare 600 GB 10k rpm drives	2	2	2
300 GB 15k rpm in RAID 10 for dedicated desktops	40	104	160
Hot spare 300 GB 15k rpm drives	2	4	4
800 GB SSDs for Easy Tier	4	12	20
Storage control enclosures	1	1	2
Storage expansion enclosures	2	6	9

4.9 Networking

The main driver for the type of networking that is needed for VDI is the connection to shared storage. If the shared storage is block-based (such as the Lenovo V3700 V2), it is likely that a SAN that is based on 8 or 16 Gbps FC, or 10 GbE iSCSI connection is needed. Other types of storage can be network attached by using 1 Gb or 10 Gb Ethernet.

Also, there is user and management virtual local area networks (VLANs) available that require 1 Gb or 10 Gb Ethernet as described in the Lenovo Client Virtualization reference architecture, which is available at this website: lenovopress.com/tips1275.

Automated failover and redundancy of the entire network infrastructure and shared storage is important. This failover and redundancy is achieved by having at least two of everything and ensuring that there are dual paths between the compute servers, management servers, and shared storage.

If only a single Flex System Enterprise Chassis is used, the chassis switches are sufficient and no other TOR switch is needed. For rack servers, more than one Flex System Enterprise Chassis TOR switches are required.

For more information, see “BOM for networking” on page 47.

.10 GbE networking

For 10 GbE networking, the use of CIFS, NFS, or iSCSI, the Lenovo RackSwitch™ G8124E, and G8272 TOR switches are recommended because they support VLANs by using Virtual Fabric. Redundancy and automated failover is available by using link aggregation, such as [Link Aggregation Control Protocol](#) (LACP) and two of everything. For the Flex System chassis, pairs of the EN4093R switch should be used and connected to a G8124 or G8272 TOR switch. The TOR 10GbE switches are needed for multiple Flex chassis or external connectivity. iSCSI also requires converged network adapters (CNAs) that have the LOM extension. Table 32 lists the TOR 10 GbE network switches for each user size.

Table 32: TOR 10 GbE network switches needed

10 GbE TOR network switch	600 users	1500 users	4500 users	10000 users
G8124E – 24-port switch	2	2	0	0
G8272 – 64-port switch	0	0	2	2

4.9.1 Fibre Channel networking

Fibre Channel (FC) networking for shared storage requires switches. Pairs of the FC3171 8 Gbps FC or FC5022 16 Gbps FC SAN switch are needed for the Flex System chassis. For top of rack, the Lenovo 8 Gbps FC switches should be used. The TOR SAN switches are needed for multiple Flex System chassis. Table 33 lists the TOR FC SAN network switches for each user size.

Table 33: TOR FC network switches needed

Fibre Channel TOR network switch	600 users	1500 users	4500 users	10000 users
Lenovo B6505 – 24-port switch	2	2		

Lenovo B6510 – 48-port switch			2	2
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4.9.2 1 GbE administration networking

A 1 GbE network should be used to administer all of the other devices in the system. Separate 1 GbE switches are used for the IT administration network. Lenovo recommends that redundancy is also built into this network at the switch level. At minimum, a second switch should be available in case a switch goes down. Table 34 lists the number of 1 GbE switches for each user size.

Table 34: TOR 1 GbE network switches needed

1 GbE TOR network switch	600 users	1500 users	4500 users	10000 users
G8052 – 48 port switch	2	2	2	2

Table 35 shows the number of 1 GbE connections that are needed for the administration network and switches for each type of device. The total number of connections is the sum of the device counts multiplied by the number of each device.

Table 35: 1 GbE connections needed

Device	Number of 1 GbE connections for administration
System x rack server	1
Flex System Enterprise Chassis CMM	2
Flex System Enterprise Chassis switches	1 per switch (optional)
Lenovo Storage V3700 V2 storage controller	4
TOR switches	1

4.10 Racks

The number of racks and chassis for Flex System compute nodes depends upon the precise configuration that is supported and the total height of all of the component parts: servers, storage, networking switches, and Flex System Enterprise Chassis (if applicable). The number of racks for System x servers is also dependent on the total height of all of the components. For more information, see the “BOM for racks” on page 48.

4.11 Deployment models

This section describes the following examples of different deployment models:

- Hyper-converged using System x servers
- Flex System with 4500 stateless users
- System x server with Lenovo V3700 V2 and iSCSI
- Graphics acceleration for 128 CAD users

4.11.1 Deployment example 1: Hyper-converged using System x servers

This deployment example supports 1200 dedicated virtual desktops with VMware VSAN in hybrid mode (SSDs and HDDs). Each VM needs 3 GB of RAM. Assuming 200 users per server, six servers are needed, with a minimum of five servers in case of failures (ratio of 5:1).

Each virtual desktop is 40 GB. The total required capacity is 126 TB, assuming full clones of 1200 VMs, one complete mirror of the data (FFT=1), space for swapping, and 30% extra capacity. However, the use of linked clones for VSAN means that a substantially smaller capacity is required and 43.2 TB is more than sufficient.

This example uses six System x3550 M5 1U servers and two G8124E RackSwitch TOR switches. Each server has two E5-2680v4 CPUs, 768 GB of memory, two network cards, two 800 GB SSDs, and six 1.2TB HDDs. Two disk groups of one SSD and three HDDs are used for VSAN.

Figure 8 shows the deployment configuration for this example.

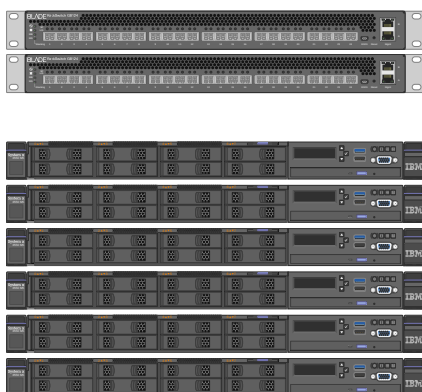


Figure 8: Deployment configuration for 1200 dedicated users using hyper-converged servers

4.11.2 Deployment example 2: Flex System with 4500 stateless users

As shown in Table 36, this example is for 4500 stateless users who are using a Flex System based chassis with each of the 36 compute nodes supporting 125 users in normal mode and 150 in the failover case.

Table 36: Deployment configuration for 4500 stateless users

Stateless virtual desktop	4500 users
Compute servers	36
Management servers	4
V3700 V2 Storage controller	1
V3700 V2 Storage expansion	3
Flex System EN4093R switches	6
Flex System FC3171 switches	6
Flex System Enterprise Chassis	3
10 GbE network switches	2 x G8272
1 GbE network switches	2 x G8052
SAN network switches	2 x B6505
Total height	44U
Number of racks	2

Figure 9 shows the deployment diagram for this configuration. The first rack contains the compute and management servers and the second rack contains the shared storage.

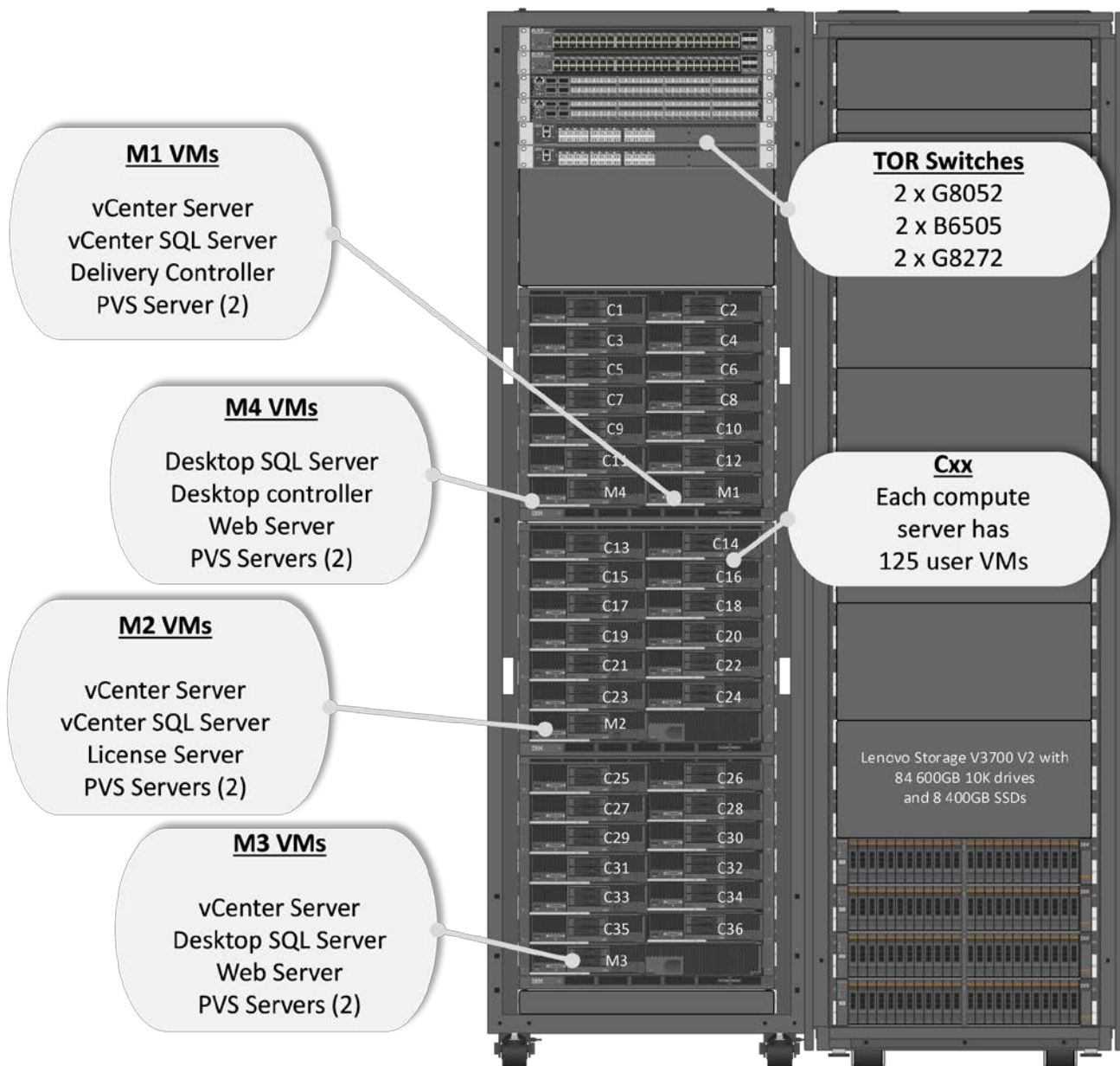


Figure 9: Deployment diagram for 4500 stateless users using Lenovo V3700 V2 shared storage

Figure 10 shows the 10 GbE and Fibre Channel networking that is required to connect the three Flex System Enterprise Chassis to the Lenovo V3700 V2 shared storage. The detail is shown for one chassis in the middle and abbreviated for the other two chassis. The 1 GbE management infrastructure network is not shown for the purpose of clarity.

Redundant 10 GbE networking is provided at the chassis level with two EN4093R switches and at the rack level by using two G8272 TOR switches. Redundant SAN networking is also used with two FC3171 pass-thru switches and two top of rack Lenovo B6505 switches. The two controllers in the Lenovo Storage V3700 V2 are redundantly connected to each of the B6505 switches.

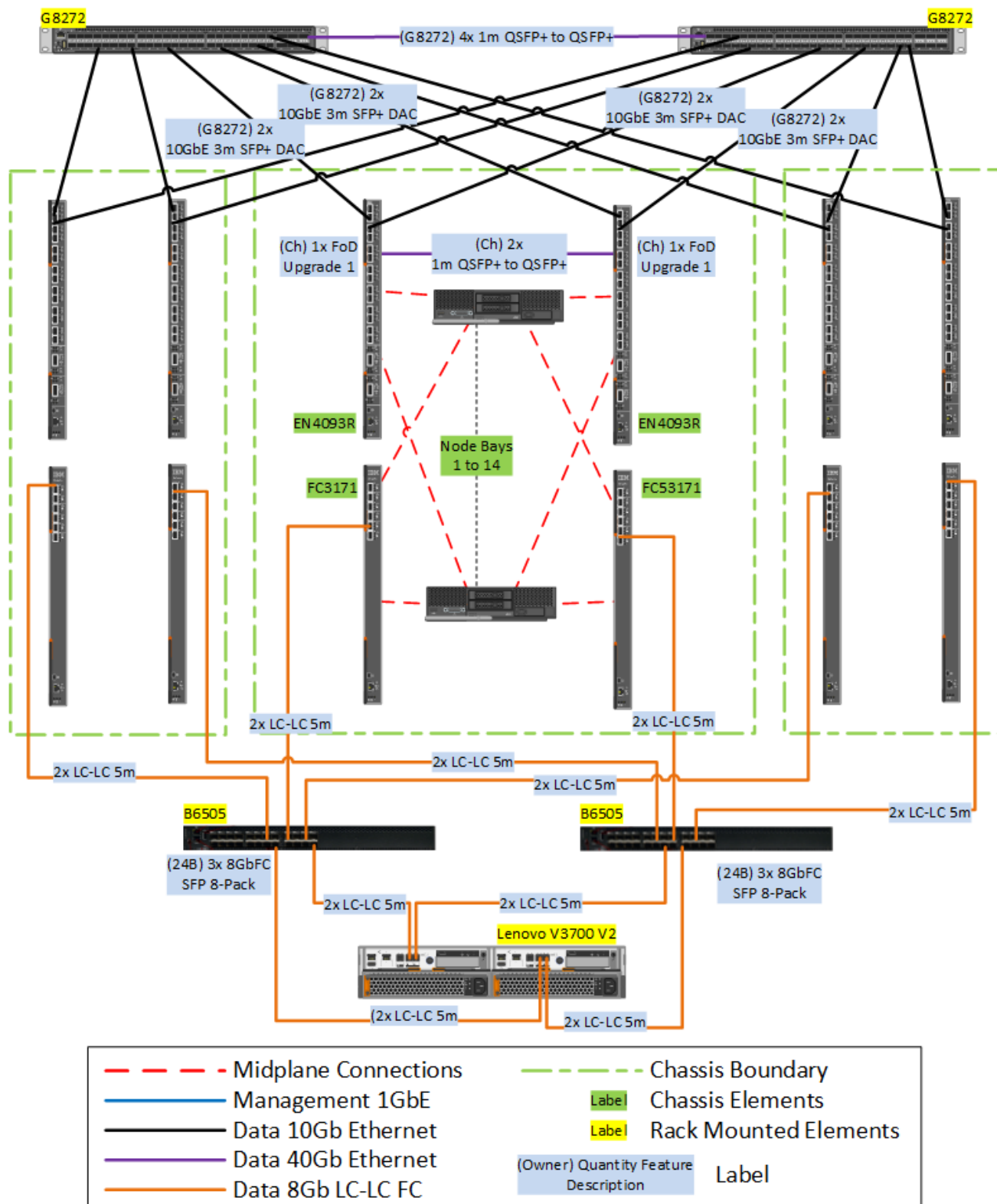


Figure 10: Network diagram for 4500 stateless users using Lenovo V3700 V2 shared storage

4.11.3 Deployment example 3: System x server with Lenovo V3700 V2 and iSCSI

This deployment example is derived from an actual customer deployment with 3000 users, 90% of which are stateless and need a 2 GB VM. The remaining 10% (300 users) need a dedicated VM of 3 GB. Therefore, the average VM size is 2.1 GB.

Assuming 125 users per server in the normal case and 150 users in the failover case, then 3000 users need 24 compute servers. A maximum of four compute servers can be down for a 5:1 failover ratio. Each compute server needs at least 315 GB of RAM (150×2.1), not including the hypervisor. This figure is rounded up to 384 GB, which should be more than enough and can cope with up to 125 users, all with 3 GB VMs.

Each compute server is a System x3550 server with two Xeon E5-2650v4 series processors, 384 GB of system memory, an embedded dual port 10 GbE virtual fabric adapter, and a license for iSCSI. For interchangeability between the servers, all of them have a RAID controller with 1 GB flash upgrade and two S3700 400 GB MLC enterprise SSDs that are configured as RAID 0 for the stateless VMs.

In addition, there are three management servers. For interchangeability in case of server failure, these extra servers are configured in the same way as the compute servers. All the servers have ESXi 6.0 U2.

There also are two Windows storage servers that are configured differently with HDDs in RAID 1 array for the operating system. Some spare, preloaded drives are kept to quickly deploy a replacement Windows storage server if one should fail. The replacement server can be one of the compute servers. The idea is to quickly get a replacement online if the second one fails. Although there is a low likelihood of this situation occurring, it reduces the window of failure for the two critical Windows storage servers.

All of the servers communicate with the Lenovo V3700 V2 shared storage by using iSCSI through two TOR RackSwitch G8272 10GbE switches. All 10 GbE connections are configured to be fully redundant.

For 300 dedicated users and 2700 stateless users, a mixture of disk configurations is needed. All of the users require space for user folders and profile data. Stateless users need space for master images and dedicated users need space for the virtual clones. Stateless users have local SSDs to cache everything else, which substantially decreases the amount of shared storage. For stateless servers with SSDs, a server must be taken offline and only have maintenance performed on it after all of the users are logged off rather than being able to use vMotion. If a server crashes, this issue is immaterial.

It is estimated that this configuration requires the following Lenovo Storage V3700 V2 drives:

Two 400 GB SSD	RAID 1 for master images
Thirty 300 GB 15K drives	RAID 10 for dedicated images
Four 400 GB SSD	Easy Tier for dedicated images
Sixty 600 GB 10K drives	RAID 10 for user folders

This configuration requires 96 drives, which fit into one Lenovo Storage V3700 V2 control enclosure and three expansion enclosures.

Figure 11 shows the deployment configuration for this example in a single rack. Because the rack has 36 items, it should have the capability for six power distribution units for 1+1 power redundancy, where each PDU has 12 C13 sockets.

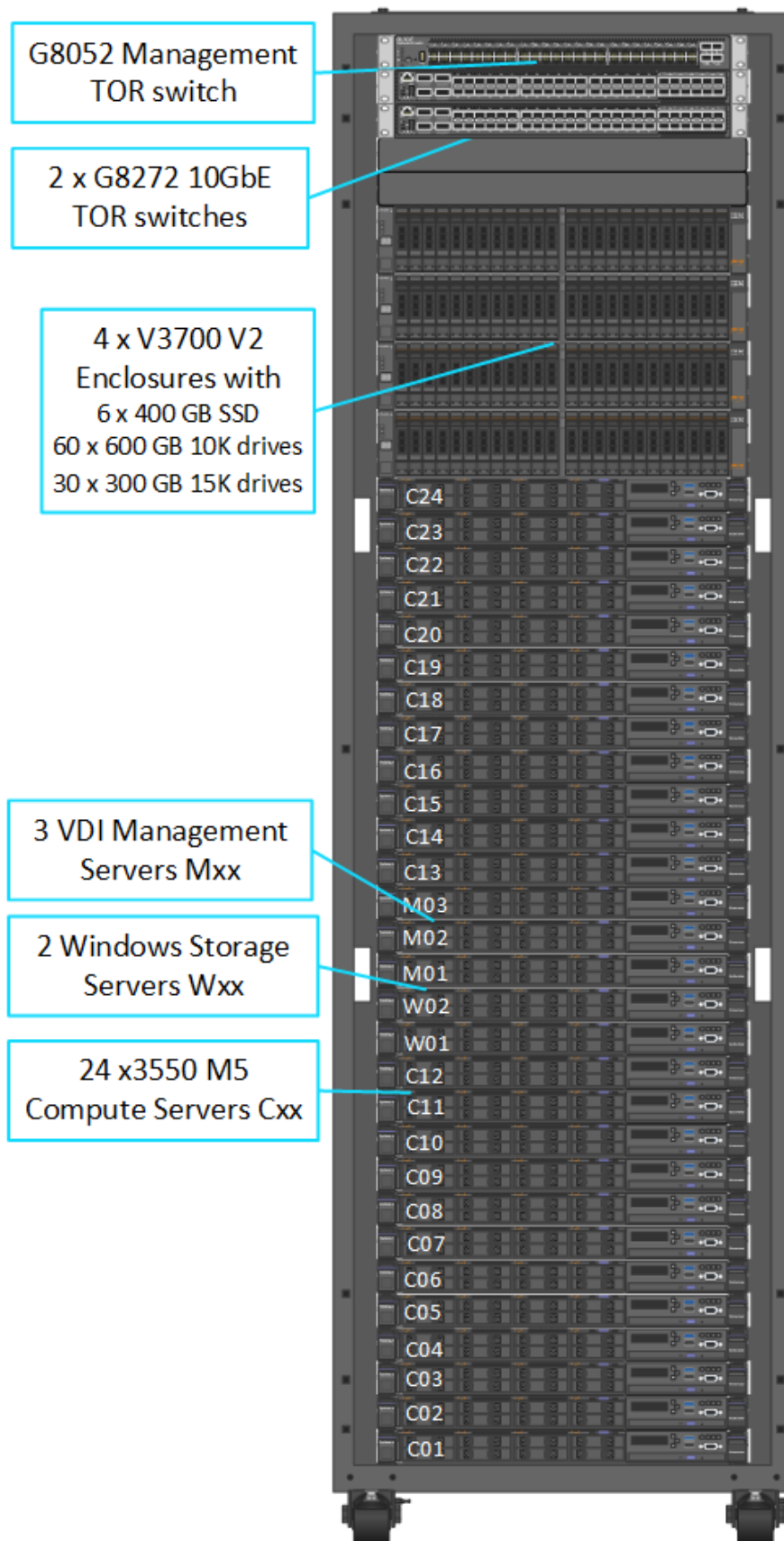


Figure 11: Deployment configuration for 3000 stateless users with System x servers

4.11.4 Deployment example 4: Graphics acceleration for 128 CAD users

This example is for medium level computer-aided design (CAD) users. Each user requires a dedicated virtual desktop with 12 GB of memory and 80 GB of disk space. Four CAD users share a M60 GPU that uses virtual GPU support with the M60-2Q profile. Therefore, there is a maximum of sixteen users per System x3650 M5 server with two GRID 2.0 M60 graphics adapters. Each server needs 256 GB of system memory.

For 128 CAD users, 8 servers are required and one extra is used for failover in case of a hardware problem.

Lenovo V3700 V2 shared storage is used for virtual desktops and the CAD data store. This example uses a total of seven enclosures, each with 22 HDDs and four SSDs. Each HDD is a 15k rpm 600 GB and each SSD is 400 GB. Assuming RAID 10 for the HDDs, the six enclosures can store about 36 TB of data. A total of 12 400 SSDs is more than the recommended 10% of the data capacity and is used for Easy tier function to improve read and write performance.

The 128 VMs for the CAD users can use as much as 10 TB, but that amount still leaves a reasonable 26 TB of storage for CAD data.

In this example, it is assumed that two redundant x3550 M5 servers are used to manage the CAD data store; that is, all accesses for data from the CAD virtual desktop are routed into these servers and data is downloaded and uploaded from the data store into the virtual desktops.

The total rack space for the compute servers, storage, and TOR switches for 1 GbE management network, 10 GbE user and iSCSI storage network is shown in Figure 12.

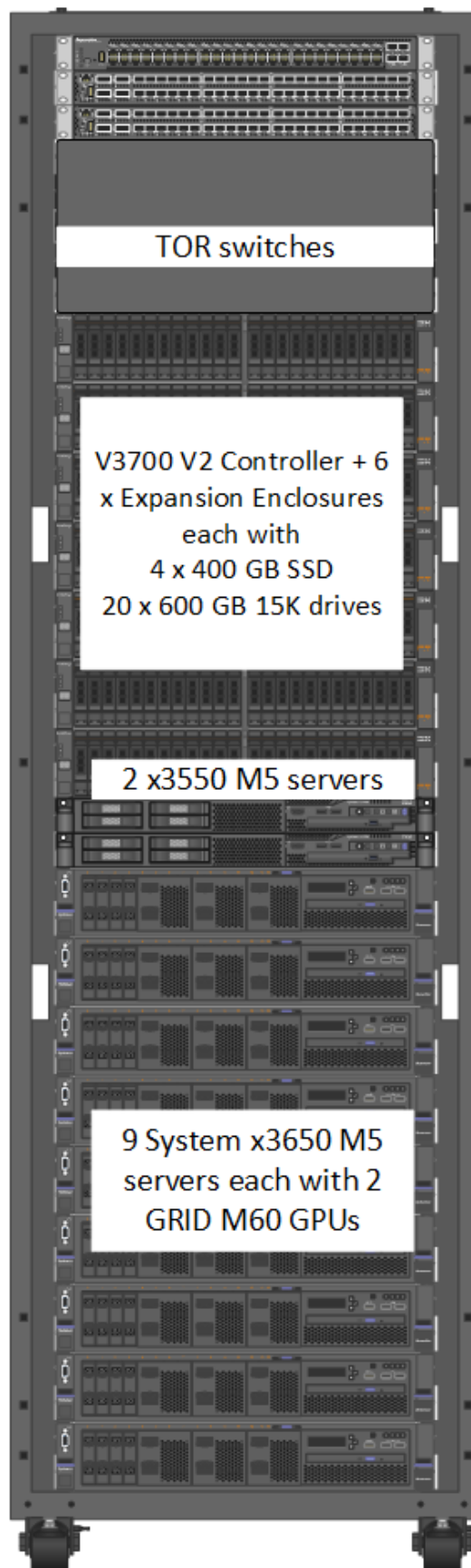


Figure 12: Deployment configuration for 128 CAD users using x3650 M5 servers with M60 GPUs

5 Appendix: Bill of materials

This appendix contains the bill of materials (BOMs) for different configurations of hardware for Citrix XenDesktop deployments. There are sections for user servers, management servers, storage, networking switches, chassis, and racks that are orderable from Lenovo. The last section is for hardware orderable from an OEM.

The BOM lists in this appendix are not meant to be exhaustive and must always be double-checked with the configuration tools. Any discussion of pricing, support, and maintenance options is outside the scope of this document.

For connections between TOR switches and devices (servers, storage, and chassis), the connector cables are configured with the device. The TOR switch configuration includes only transceivers or other cabling that is needed for failover or redundancy.

5.1 BOM for enterprise and SMB compute servers

This section contains the bill of materials for enterprise and SMB compute servers.

Flex System x240

Code	Description	Quantity
9532AC1	Flex System node x240 M5 Base Model	1
ATCH	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATD8	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
A5RM	Flex System x240 M5 Compute Node	1
A5S0	System Documentation and Software-US English	1
A5SG	Flex System x240 M5 2.5" HDD Backplane	1
A5RP	Flex System CN4052 2-port 10Gb Virtual Fabric Adapter	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5RV	Flex System CN4052 Virtual Fabric Adapter SW Upgrade (FoD)	1
A1BM	Flex System FC3172 2-port 8Gb FC Adapter	1
A1BQ	Flex System FC5172 2-port 16Gb FC Adapter	1
Select SSD storage for stateless virtual desktops		
5978	Select Storage devices - Lenovo-configured RAID	1
7860	Integrated Solid State Striping	1
AT9D	Intel S3710 400GB Enterprise Performance SATA G3HS 2.5" SSD	2
Select amount of system memory		
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	16
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
Select flash memory for ESXi hypervisor or 2 drives (RAID 1) for other hypervisors		
A5TJ	SD Media Adapter	1
ATZL	RAID Adapter for SD Media w/ VMware ESXi 6.0 U2 (2 SD Media, RAIDed)	1
A489	300GB 15K 6Gbps SAS 2.5" G3HS HDD	2

System x3550 M5

Code	Description	Quantity
8869AC1	Lenovo System x3550 M5	1
ATM3	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB Cache 2400MHz 120W	1
ATMU	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATKQ	x3550 M5 Base Chassis 8x2.5	1
ATKT	x3550 M5 MLK Planar	1
A5AG	System x3550 M5 PCIe Riser 1 (1x LP x16 CPU0)	1
A5AF	System x3550 M5 PCIe Riser 2, 1-2 CPU (LP x16 CPU1 + LP x16 CPU0)	1
A5AY	System x 750W High Efficiency Platinum AC Power Supply	2
6311	2.8m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
A1ML	Lenovo Integrated Management Module Advanced Upgrade	1
ATYV	System x Advanced LCD Light Path Kit	1
ATLK	System x3550 M5 front IO cage Advanced	1
A5AK	System x3550 M5 Slide Kit G4	1
ATL3	System Documentation and Software-US English	1
A59W	System x3550 M5 4x 2.5" HS HDD Kit	1
A59X	System x3550 M5 4x 2.5" HS HDD Kit PLUS	1
A3YZ	ServeRAID M5210 SAS/SATA Controller for System x	1
A3Z2	ServeRAID M5200 Series 2GB Flash/RAID 5 Upgrade	1
AT84	300GB 15K 12Gbps SAS 2.5" G3HS HDD	2
AT7S	Emulex VFA5.2 2x10 GbE SFP+ PCIe Adapter for System x	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5UV	Emulex VFA5 FCoE/iSCSI SW for PCIe Adapter (FoD)	1
3581	Emulex 8Gb FC Dual-port HBA	1
A2W6	Emulex 16Gb FC Dual-port HBA	1
88Y6854	5m LC-LC fiber cable (networking)	2
Select SSD storage for stateless virtual desktops		
5978	Select Storage devices - Lenovo-configured RAID	1
2302	RAID configuration	1
A2K6	Primary Array - RAID 0 (2 drives required)	1
2499	Enable selection of Solid State Drives for Primary Array	1
AT9D	Intel S3710 400GB Enterprise Performance SATA G3HS 2.5" SSD	2
Select amount of system memory		
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	16
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
Select flash memory for ESXi hypervisor or 2 drives (RAID 1) for other hypervisors		
A5TJ	SD Media Adapter	1
ATZL	RAID Adapter for SD Media w/ VMware ESXi 6.0 U2 (2 SD Media, RAIDed)	1
A489	300GB 15K 6Gbps SAS 2.5" G3HS HDD	2

System x3650 M5

Code	Description	Quantity
8871AC1	Lenovo System x3650 M5	1
ATET	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB Cache 2400MHz 120W	1
ATFJ	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATDY	2.5" Flexible Base (up to 24x 2.5") w/o Power Supply	1
ATE4	System x3650 M5 Planar BDW	1
A5FN	System x3650 M5 PCIe Riser 1 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
A5R5	System x3650 M5 PCIe Riser 2 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
A5AY	System x 750W High Efficiency Platinum AC Power Supply	2
6311	2.8m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
ATEC	System x3650 M5 Single Rotor Fan	6
A1ML	Lenovo Integrated Management Module Advanced Upgrade	1
ATE8	System x3650 M5 2.5" Bezel with LCD Light Path	1
ATE6	x3650 M5 Front IO Cage Std. (3x USB, Optional LCD/Optical drive)	1
ATG2	System Documentation and Software-US English	1
A5G6	x3650 M5 8x 2.5" HS HDD Assembly Kit (Single RAID)	1
A5FV	System x Enterprise Slides Kit	1
A3YZ	ServeRAID M5210 SAS/SATA Controller for System x	1
A3Z2	ServeRAID M5200 Series 2GB Flash/RAID 5 Upgrade	1
AT84	300GB 15K 12Gbps SAS 2.5" G3HS HDD	2
AT7S	Emulex VFA5.2 2x10 GbE SFP+ PCIe Adapter for System x	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5UV	Emulex VFA5 FCoE/iSCSI SW for PCIe Adapter (FoD)	1
3581	Emulex 8Gb FC Dual-port HBA	1
A2W6	Emulex 16Gb FC Dual-port HBA	1
88Y6854	5m LC-LC fiber cable (networking)	2
Select SSD storage for stateless virtual desktops		
5978	Select Storage devices - Lenovo-configured RAID	1
2302	RAID configuration	1
A2K6	Primary Array - RAID 0 (2 drives required)	1
2499	Enable selection of Solid State Drives for Primary Array	1
AT9D	Intel S3710 400GB Enterprise Performance SATA G3HS 2.5" SSD	2
Select amount of system memory		
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	16
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
Select flash memory for ESXi hypervisor		
A5TJ	SD Media Adapter	1
ATZL	RAID Adapter for SD Media w/ VMware ESXi 6.0 U2 (2 SD Media, RAIDed)	1
A489	300GB 15K 6Gbps SAS 2.5" G3HS HDD	2

System x3650 M5 with graphics acceleration

Code	Description	Quantity
8871AC1	Lenovo System x3650 M5	1
ATET	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB Cache 2400MHz 120W	1
ATFJ	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATDY	2.5" Flexible Base (up to 24x 2.5") w/o Power Supply	1
ATE4	System x3650 M5 Planar BDW	1
A5FN	System x3650 M5 PCIe Riser 1 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
A5R5	System x3650 M5 PCIe Riser 2 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
ASQE	System x 1500W High Efficiency Platinum AC Power Supply(200-240V)	2
6400	2.8m, 13A/125-10A/250V, C13 to IEC 320-C14 Rack Power Cable	2
ATEC	System x3650 M5 Single Rotor Fan	6
A1ML	Lenovo Integrated Management Module Advanced Upgrade	1
ATE8	System x3650 M5 2.5" Bezel with LCD Light Path	1
ATE6	x3650 M5 Front IO Cage Std. (3x USB, Optional LCD/Optical drive)	1
ATG2	System Documentation and Software-US English	1
A5G6	x3650 M5 8x 2.5" HS HDD Assembly Kit (Single RAID)	1
A5FV	System x Enterprise Slides Kit	1
ASQL	NVidia Tesla M60 GPU, PCIe (active)	2
A3YZ	ServeRAID M5210 SAS/SATA Controller for System x	1
A3Z2	ServeRAID M5200 Series 2GB Flash/RAID 5 Upgrade	1
AT84	300GB 15K 12Gbps SAS 2.5" G3HS HDD	2
AT7S	Emulex VFA5.2 2x10 GbE SFP+ PCIe Adapter for System x	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5UV	Emulex VFA5 FCoE/iSCSI SW for PCIe Adapter (FoD)	1
3581	Emulex 8Gb FC Dual-port HBA	1
A2W6	Emulex 16Gb FC Dual-port HBA	1
88Y6854	5m LC-LC fiber cable (networking)	2
Select SSD storage for stateless virtual desktops		
5978	Select Storage devices - Lenovo-configured RAID	1
2302	RAID configuration	1
A2K6	Primary Array - RAID 0 (2 drives required)	1
2499	Enable selection of Solid State Drives for Primary Array	1
AT9D	Intel S3710 400GB Enterprise Performance SATA G3HS 2.5" SSD	2
Select amount of system memory		
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	16
ATCB	32GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	24
Select flash memory for ESXi hypervisor or 2 drives (RAID 1) for other hypervisors		
A5TJ	SD Media Adapter	1
ATZL	RAID Adapter for SD Media w/ VMware ESXi 6.0 U2 (2 SD Media, RAIDed)	1
A489	300GB 15K 6Gbps SAS 2.5" G3HS HDD	2

5.2 BOM for hosted desktops

Table 20 on page 18 lists the number of management servers that are needed for the different numbers of users and this section contains the corresponding bill of materials.

Flex System x240

Code	Description	Quantity
9532AC1	Flex System node x240 M5 Base Model	1
ATCH	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATD8	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
A5RM	Flex System x240 M5 Compute Node	1
A5S0	System Documentation and Software-US English	1
A5SG	Flex System x240 M5 2.5" HDD Backplane	1
A5RP	Flex System CN4052 2-port 10Gb Virtual Fabric Adapter	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5RV	Flex System CN4052 Virtual Fabric Adapter SW Upgrade (FoD)	1
A1BM	Flex System FC3172 2-port 8Gb FC Adapter	1
A1BQ	Flex System FC5172 2-port 16Gb FC Adapter	1
Select amount of system memory		
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	8
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	16
Select flash memory for ESXi hypervisor		
A5TJ	SD Media Adapter	1
ATZL	RAID Adapter for SD Media w/ VMware ESXi 6.0 U2 (2 SD Media, RAIDed)	1
A489	300GB 15K 6Gbps SAS 2.5" G3HS HDD	2

System x3550 M5

Code	Description	Quantity
8869AC1	Lenovo System x3550 M5	1
ATM3	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB Cache 2400MHz 120W	1
ATMU	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATKQ	x3550 M5 Base Chassis 8x2.5	1
ATKT	x3550 M5 MLK Planar	1
A5AG	System x3550 M5 PCIe Riser 1 (1x LP x16 CPU0)	1
A5AF	System x3550 M5 PCIe Riser 2, 1-2 CPU (LP x16 CPU1 + LP x16 CPU0)	1
A5AY	System x 750W High Efficiency Platinum AC Power Supply	2
6311	2.8m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
A1ML	Lenovo Integrated Management Module Advanced Upgrade	1
ATYV	System x Advanced LCD Light Path Kit	1
ATLK	System x3550 M5 front IO cage Advanced	1
A5AK	System x3550 M5 Slide Kit G4	1
ATL3	System Documentation and Software-US English	1
A59W	System x3550 M5 4x 2.5" HS HDD Kit	1
A59X	System x3550 M5 4x 2.5" HS HDD Kit PLUS	1
AT7S	Emulex VFA5.2 2x10 GbE SFP+ PCIe Adapter for System x	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5UV	Emulex VFA5 FCoE/iSCSI SW for PCIe Adapter (FoD)	1
3581	Emulex 8Gb FC Dual-port HBA	1
A2W6	Emulex 16Gb FC Dual-port HBA	1
88Y6854	5m LC-LC fiber cable (networking)	2
Select amount of system memory		
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	8
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	16
Select flash memory for ESXi hypervisor or 2 drives (RAID 1) for other hypervisors		
A5TJ	SD Media Adapter	1
ATZL	RAID Adapter for SD Media w/ VMware ESXi 6.0 U2 (2 SD Media, RAIDed)	1
A489	300GB 15K 6Gbps SAS 2.5" G3HS HDD	2

System x3650 M5

Code	Description	Quantity
8871AC1	Lenovo System x3650 M5	1
ATET	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB Cache 2400MHz 120W	1
ATFJ	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATDY	2.5" Flexible Base (up to 24x 2.5") w/o Power Supply	1
ATE4	System x3650 M5 Planar BDW	1
A5FN	System x3650 M5 PCIe Riser 1 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
A5R5	System x3650 M5 PCIe Riser 2 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
A5AY	System x 750W High Efficiency Platinum AC Power Supply	2
6311	2.8m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
ATEC	System x3650 M5 Single Rotor Fan	6
A1ML	Lenovo Integrated Management Module Advanced Upgrade	1
ATE8	System x3650 M5 2.5" Bezel with LCD Light Path	1
ATE6	x3650 M5 Front IO Cage Std. (3x USB, Optional LCD/Optical drive)	1
ATG2	System Documentation and Software-US English	1
A5G6	x3650 M5 8x 2.5" HS HDD Assembly Kit (Single RAID)	1
A5FV	System x Enterprise Slides Kit	1
AT7S	Emulex VFA5.2 2x10 GbE SFP+ PCIe Adapter for System x	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5UV	Emulex VFA5 FCoE/iSCSI SW for PCIe Adapter (FoD)	1
3581	Emulex 8Gb FC Dual-port HBA	1
A2W6	Emulex 16Gb FC Dual-port HBA	1
88Y6854	5m LC-LC fiber cable (networking)	2
Select amount of system memory		
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	8
ATCA	16GB TruDDR4 Memory (2Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	16
Select flash memory for ESXi hypervisor or 2 drives (RAID 1) for other hypervisors		
A5TJ	SD Media Adapter	1
ATZL	RAID Adapter for SD Media w/ VMware ESXi 6.0 U2 (2 SD Media, RAIDed)	1
A489	300GB 15K 6Gbps SAS 2.5" G3HS HDD	2

5.3 BOM for enterprise and SMB management servers

Table 26 on page 22 lists the number of management servers that are needed for the different numbers of users. To help with redundancy, the bill of materials for management servers must be the same as compute servers. For more information, see “BOM for enterprise and SMB compute servers” on page 36.

Because the Windows storage servers use a bare-metal operating system (OS) installation, they require much less memory and can have a reduced configuration as listed below.

Flex System x240

Code	Description	Quantity
9532AC1	Flex System node x240 M5 Base Model	1
ATCH	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATD8	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
A5RM	Flex System x240 M5 Compute Node	1
A5S0	System Documentation and Software-US English	1
A5SG	Flex System x240 M5 2.5" HDD Backplane	1
5978	Select Storage devices - Lenovo-configured RAID	1
8039	Integrated SAS Mirroring - 2 identical HDDs required	1
AT84	300GB 15K 12Gbps SAS 2.5" G3HS HDD	2
ATC8	8GB TruDDR4 Memory (1Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	8
A5RP	Flex System CN4052 2-port 10Gb Virtual Fabric Adapter	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5RV	Flex System CN4052 Virtual Fabric Adapter SW Upgrade (FoD)	1
A1BM	Flex System FC3172 2-port 8Gb FC Adapter	1
A1BQ	Flex System FC5172 2-port 16Gb FC Adapter	1

System x3550 M5

Code	Description	Quantity
8869AC1	Lenovo System x3550 M5	1
ATM3	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB Cache 2400MHz 120W	1
ATMU	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATKQ	x3550 M5 Base Chassis 8x2.5	1
ATKT	x3550 M5 MLK Planar	1
A5AG	System x3550 M5 PCIe Riser 1 (1x LP x16 CPU0)	1
A5AF	System x3550 M5 PCIe Riser 2, 1-2 CPU (LP x16 CPU1 + LP x16 CPU0)	1
A5AY	System x 750W High Efficiency Platinum AC Power Supply	2
6311	2.8m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
ATYV	System x Advanced LCD Light Path Kit	1
ATLK	System x3550 M5 front IO cage Advanced	1
A5AK	System x3550 M5 Slide Kit G4	1
ATL3	System Documentation and Software-US English	1
A59W	System x3550 M5 4x 2.5" HS HDD Kit	1
A59X	System x3550 M5 4x 2.5" HS HDD Kit PLUS	1
A3YZ	ServeRAID M5210 SAS/SATA Controller for System x	1
A3Z2	ServeRAID M5200 Series 2GB Flash/RAID 5 Upgrade	1
5978	Select Storage devices - Lenovo-configured RAID	1
A2K7	Primary Array - RAID 1 (2 drives required)	1
AT84	300GB 15K 12Gbps SAS 2.5" G3HS HDD	2
ATC8	8GB TruDDR4 Memory (1Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	8
AT7S	Emulex VFA5.2 2x10 GbE SFP+ PCIe Adapter for System x	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5UV	Emulex VFA5 FCoE/iSCSI SW for PCIe Adapter (FoD)	1
3581	Emulex 8Gb FC Dual-port HBA	1
A2W6	Emulex 16Gb FC Dual-port HBA	1
88Y6854	5m LC-LC fiber cable (networking)	2

System x3650 M5

Code	Description	Quantity
8871AC1	Lenovo System x3650 M5	1
ATET	Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB Cache 2400MHz 120W	1
ATFJ	Addl Intel Xeon Processor E5-2680 v4 14C 2.4GHz 35MB 2400MHz 120W	1
ATDY	2.5" Flexible Base (up to 24x 2.5") w/o Power Supply	1
ATE4	System x3650 M5 Planar BDW	1
A5FN	System x3650 M5 PCIe Riser 1 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
A5R5	System x3650 M5 PCIe Riser 2 (1 x16 FH/FL + 1 x8 FH/HL Slots)	1
A5AY	System x 750W High Efficiency Platinum AC Power Supply	2
6311	2.8m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
ATEC	System x3650 M5 Single Rotor Fan	6
A1ML	Lenovo Integrated Management Module Advanced Upgrade	1
ATE8	System x3650 M5 2.5" Bezel with LCD Light Path	1
ATE6	x3650 M5 Front IO Cage Std. (3x USB, Optional LCD/Optical drive)	1
ATG2	System Documentation and Software-US English	1
A5G6	x3650 M5 8x 2.5" HS HDD Assembly Kit (Single RAID)	1
A5FV	System x Enterprise Slides Kit	1
A3YZ	ServeRAID M5210 SAS/SATA Controller for System x	1
A3Z2	ServeRAID M5200 Series 2GB Flash/RAID 5 Upgrade	1
5978	Select Storage devices - Lenovo-configured RAID	1
A2K7	Primary Array - RAID 1 (2 drives required)	1
AT84	300GB 15K 12Gbps SAS 2.5" G3HS HDD	2
ATC8	8GB TruDDR4 Memory (1Rx4, 1.2V) PC4-19200 CL17 2400MHz LP RDIMM	8
AT7S	Emulex VFA5.2 2x10 GbE SFP+ PCIe Adapter for System x	1
Select extra network connectivity for iSCSI, 8Gb FC, or 16 Gb FC		
A5UV	Emulex VFA5 FCoE/iSCSI SW for PCIe Adapter (FoD)	1
3581	Emulex 8Gb FC Dual-port HBA	1
A2W6	Emulex 16Gb FC Dual-port HBA	1
88Y6854	5m LC-LC fiber cable (networking)	2

5.4 BOM for shared storage

This section contains the bill of materials for shared storage. Table 37 and Table 38 list the BOMs for Lenovo Storage V3700 V2 shared storage.

Table 37: Lenovo Storage V3700 V2 control enclosure

Code	Description	Quantity
6535HC5	Lenovo Storage V3700 V2 XP SFF Control Enclosure	1
AU42	Lenovo Storage V3700 V2 XP SFF Control Enclosure	1
AU7J	Lenovo Storage V3700 V2 XP Easy Tier Key Activation	1
AU79	Lenovo Storage V3700 V2 XP Cache Upgrade	1
AU6L	Lenovo Storage V3700 V2 800GB 2.5" Flash Drive	2
AU6E	Lenovo Storage V3700 V2 600GB 2.5" 15K HDD	22
AU5P	Lenovo Storage V3700 V2 2.8m, 10A/100-250V, C13/IEC 320-C14 Rk Cbl	1
Select network connectivity of 10 GbE iSCSI or 16 Gb FC		
AU4F	Lenovo Storage V3700 V2 2x 4-port 10GbE SFP+ Adapter Cards	1
AU4B	Lenovo Storage V3700 V2 2x 16Gb FC 4 Port Adapter Card, 4x SW SFP ea	1

Table 38: Lenovo Storage V3700 V2 expansion enclosure

Code	Description	Quantity
6535HC8	Lenovo Storage V3700 V2 SFF Expansion Enclosure	1
AU44	Lenovo Storage V3700 V2 SFF Expansion Enclosure	1
AU4P	Lenovo Storage V3700 V2 0.6m 12Gb SAS Cable (mSAS HD)	1
AU5P	Lenovo Storage V3700 V2 2.8m, 10A/100-250V, C13/IEC 320-C14 Rk Cbl	1
AU6L	Lenovo Storage V3700 V2 800GB 2.5" Flash Drive	2
AU6E	Lenovo Storage V3700 V2 600GB 2.5" 15K HDD	22

5.5 BOM for networking

For more information about the number and type of TOR network switches that are needed for different user counts, see the “Networking” section on page 27.

RackSwitch G8052

Code	Description	Quantity
7159G52	Lenovo System Networking RackSwitch G8052 (Rear to Front)	1
6201	1.5m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
3802	1.5m Blue Cat5e Cable	3
A3KP	Lenovo System Networking Adjustable 19" 4 Post Rail Kit	1

RackSwitch G8124E

Code	Description	Quantity
7159BR6	Lenovo System Networking RackSwitch G8124E (Rear to Front)	1
6201	1.5m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
3802	1.5m Blue Cat5e Cable	1
A1DK	Lenovo 19" Flexible 4 Post Rail Kit	1

RackSwitch G8272

Code	Description	Quantity
7159CRW	Lenovo System Networking RackSwitch G8272 (Rear to Front)	1
6201	1.5m, 10A/100-250V, C13 to IEC 320-C14 Rack Power Cable	2
A3KP	Lenovo System Networking Adjustable 19" 4 Post Rail Kit	1
5053	SFP+ SR Transceiver	2
A1DP	1m QSFP+-to-QSFP+ cable	1
A1DM	3m QSFP+ DAC Break Out Cable	0

Lenovo B6505

Code	Description	Quantity
3873AR4	Lenovo B6505, 12 ports activated w/ 8Gb SWL SFPs, 1 PS, Rail Kit	1
00WF812	Lenovo B6505 12-port license w/ 12x 8G SWL SFP+	1
88Y6416	Brocade 8Gb SW SFP+ Optical Transceiver	24
00MN505	Lenovo 3m LC-LC OM3 MMF Cable	24

Lenovo B6510

Code	Description	Quantity
3873BR2	Lenovo B6510, 24 ports activated w/ 8Gb SWL SFPs, 2 PS, Rail Kit	1
00WF808	Lenovo B6510 12-port license w/ 12x 8G SWL SFP+	2
88Y6416	Brocade 8Gb SW SFP+ Optical Transceiver	48
00MN505	Lenovo 3m LC-LC OM3 MMF Cable	24

5.6 BOM for racks

The rack count depends on the deployment model. The number of PDUs assumes a fully-populated rack.

Code	Description	Quantity
93634PX	42U 1100mm Enterprise V2 Dynamic Rack	1
39Y8941	DPI Single Phase C19 Enterprise PDU (without line cord)	6
40K9614	DPI 30a Line Cord (NEMA L6-30P)	6

5.7 BOM for Flex System chassis

The number of Flex System chassis that are needed for different numbers of users depends on the deployment model.

Code	Description	Quantity
8721HC2	Lenovo Flex System Enterprise Chassis w/ CMM2	1
ASQ8	Lenovo Flex System Redundant Chassis Management Module 2	1
EPA8	Flex System Enterprise Chassis HVDC 2500W Power Module Standard	2
EPA9	Flex System Enterprise Chassis HVDC 2500W Power Module	4
6252	2.5 m, 16A/100-240V, C19 to IEC 320-C20 Rack Power Cable	6
A0UA	Flex System Enterprise Chassis 80mm Fan Module	4
ASUS	Lenovo Flex System Enterprise Chassis w/ CMM2	1
3803	3m Blue Cat5e Cable	2
ASUX	System Documentation and Software-US English	1
A1NF	Flex System Console Breakout Cable	1
2306	Rack Installation >1U Component	1
Select network connectivity for 10 GbE, 10 GbE iSCSI, 8 Gb FC, or 16 Gb FC		
ASUU	Lenovo Flex System Fabric EN4093R 10Gb Scalable Switch	2
A1PJ	3m Passive DAC SFP+ Cable	8
ATYX	Lenovo 1M SFP+ to SFP+ Active Optical Cable	1
A0TJ	Lenovo Flex System FC3171 8Gb SAN Pass-thru	2
5075	8 Gb SFP + SW Optical Transceiver	4
ASR8	Lenovo 5m LC-LC OM3 MMF Cable	8
A3DP	Lenovo Flex System FC5022 24-port 16Gb SAN Scalable Switch	2
A22R	Brocade 16Gb SFP + SW Optical Transceiver	2
ASR8	Lenovo 5m LC-LC OM3 MMF Cable	8

Resources

For more information, see the following resources:

- Lenovo Client Virtualization reference architecture
lenovopress.com/tips1275
- Citrix XenDesktop
citrix.com/products/xendesktop
- Citrix XenServer
citrix.com/products/xenserver
- VMware vSphere
vmware.com/products/datacenter-virtualization/vsphere
- Flex System Interoperability Guide
lenovopress.com/redpfsig-flex-system-interoperability-guide
- Lenovo Storage Interoperability Links
lenovopress.com/lp0584-lenovo-storage-interoperability-links

Document history

Version 1.0	30 Jan 2015	<ul style="list-style-type: none">• Conversion to Lenovo format• Added Lenovo thin clients• Added XenServer 6.5 and SMB operational model
Version 1.1	5 May 2015	<ul style="list-style-type: none">• Added performance measurements and recommendations for the Intel E5-2600 v3 processor family and added BOMs for Lenovo M5 series servers.• Added hyper-converged operational model and Atlantis USX.• Added graphics acceleration performance measurements for Citrix XenServer 6.5 pass-through and vGPU modes.
Version 1.2	2 July 2015	<ul style="list-style-type: none">• Added more performance measurements and recommendations for the Intel E5-2600 v3 processor family to include power workers, Hyper-V hypervisor, SMB mode, and Atlantis USX simple hybrid storage acceleration.• Added hyper-converged and vGPU deployment models.
Version 1.3	16 March 2016	<ul style="list-style-type: none">• Minor updates for hardware refreshes.
Version 1.4	27 March 2017	<ul style="list-style-type: none">• Added performance measurements and recommendations for the Intel E5-2600 v4 processor family with ESXi 6.5a and added BOMs for Lenovo M5 “Broadwell” series servers.• Replaced SAN switches with Lenovo B65xx series switches.• Removed older storage and replaced with Lenovo storage.• Replaced Nvidia GRID K1 and K2 GPUs with GRID 2.0 M60.• Removed Atlantis storage.

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