Reference Architecture: Lenovo Client Virtualization (LCV) with ThinkSystem Servers

Last update: 10 June 2019
Version 1.3

Base Reference Architecture document for all LCV solutions

Describes Lenovo clients, servers, storage, and networking hardware used in LCV solutions

LCV covers both virtual desktops and hosted desktops

Contains system performance considerations and performance testing methodology and tools

Mike Perks
Pawan Sharma
# Table of Contents

1 Introduction .................................................................................................................. 1

2 Business problem and business value ........................................................................... 2

3 Requirements .................................................................................................................. 3

4 Architectural overview .................................................................................................. 6

5 Component model .......................................................................................................... 7

   5.1 Management services .................................................................................................. 10

   5.2 Support services ......................................................................................................... 11

   5.2.1 Lenovo Thin Client Manager ................................................................................... 11

   5.2.2 Chromebook management console ........................................................................... 12

   5.3 Storage ......................................................................................................................... 14

   5.4 Virtual desktop image assignment models ................................................................. 15

   5.5 Networking model ....................................................................................................... 17

   5.6 User virtualization ....................................................................................................... 18

   5.6.1 User folders ............................................................................................................... 18

   5.6.2 User profiles ............................................................................................................. 18

6 Operational model ......................................................................................................... 20

   6.1 Clients ......................................................................................................................... 20

   6.1.1 ThinkCentre M625q thin client ................................................................................ 20

   6.1.2 ThinkCentre M715q thin client ................................................................................ 21

   6.1.3 Lenovo 14e Chromebook ......................................................................................... 21

   6.2 Servers ......................................................................................................................... 22

   6.2.1 Bladed Servers using Lenovo Flex System ............................................................... 22

   6.2.2 Lenovo ThinkSystem SN550 compute node ............................................................. 23

   6.2.3 Lenovo ThinkSystem SR630 rack server ................................................................ 23

   6.2.4 Lenovo ThinkSystem SR650 rack server ................................................................ 24

   6.2.5 Lenovo ThinkSystem SD530 server ....................................................................... 24

   6.3 Graphics Adapters .................................................................................................... 25

   6.4 Shared storage .......................................................................................................... 25

   6.4.1 Lenovo ThinkSystem DM5000F storage array ....................................................... 25
1 Introduction

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

Lenovo Client Virtualization (LCV) is Lenovo’s answer to client virtualization and integration needs. It offers robust virtual desktop and virtual application solutions, infrastructure, and services that are designed to make the deployment of virtual desktops easier as it is based on a reference architecture approach. As such, LCV supports a wide range of hardware, hypervisors, and software platforms from multiple vendors, which provides a high degree of flexibility and customization choices. LCV helps offer a more cost-effective, manageable, virtual desktop, and virtual application environment for a wide range of customer sizes, user types, and industry segments.

This document describes the business problem that is solved by client virtualization, the business benefits of using a client virtualization solution that is based on LCV, and the details of the logical architecture of LCV. The actual mapping of the LCV logical architecture to the vendor-specific solution implementations is described in the corresponding reference architecture documents for those solutions.

Concerns about endpoint management, desktop backup, multisite deployments, and data replication are outside the scope of this document.
2 Business problem and business value

Today’s IT staff are faced with ever-rising costs, increased complexity of maintaining remote user workstations, growing needs to avoid security exposures (such as virus attacks), the lack of centralized management, and the need for flexibility and global availability of compute resources.

The Lenovo Client Virtualization (LCV) solution uses server-based desktop virtualization and server-based computing (client virtualization) to solve these business problems. Client virtualization is an enterprise architecture that stores user data, user profiles, and application data files on centralized servers. This approach extends the robust server security and manageability down to the user resources. Client virtualization also provides users with anywhere, anytime, secure access to data and applications from any device. This includes popular mobile devices, such as tablets and cell phones.

Client virtualization consists of server hosted virtual machines (VMs) that are running desktop operating systems in the central data center location, delivering a graphical representation (screen updates) to remotely connected users, and allowing local user input (keyboard/mouse/touch) to their virtual desktops or virtual applications. In a traditional desktop model, a user has the entire compute environment (OS, processing power, memory, and hard disk) placed in front of the user. In the case of client virtualization, a lightweight endpoint device is used with minimal need for processing power and little or no storage to access the user’s desktop that is processed on remote hardware.

A server-based approach to enterprise desktop management compared to traditional desktop environments includes the following advantages:

- Rapid desktop deployment, including updates, patches, and security enhancements
- Overall cost savings in desktop support, a centralized approach to client OS management, and reduced client machine energy consumption
- Unified management and reporting through a single administrator console
- Easy accessibility through various endpoint devices (for example, notebooks, tablets, and thin clients) locally and remotely
- User and application virtualization that disaggregates resources for balanced network workloads while maintaining a consistent look and feel for the user
- Ability to use centralized data center resources and processes for backup and recovery
- Horizontal scalability, in which up to tens of thousands of endpoint devices can be handled through a central point
- Improved data security through centralization of sensitive data behind data center firewalls and security protection
- Compliance with regulatory norms for information protection, such as HIPAA and Sarbanes-Oxley (SOX) security standards
3 Requirements

A simplified use case model that shows the major actors and operations in the LCV solution is shown below.

![Use case model for Lenovo Client Virtualization](image)

**Figure 1: Use case model for Lenovo Client Virtualization**

The following functional and non-functional requirements are needed for typical deployments:

- **User experience:**
  - Connects from any mainstream client OS, such as Microsoft® Windows®, Linux®, and Mac OS
  - Connects from any mainstream thin or zero clients, such as mobile devices and zero clients
  - Allows customer applications to run properly on the virtual system
  - Includes a universal printer driver
  - Dynamically adjusts for changes in endpoint printer/scanner configuration
  - Dynamically adjusts for changes in endpoint monitor configuration, including multiple monitors
  - Masks the effect of network latency on user-initiated actions
  - Supports common Universal Serial Bus (USB) devices
  - Supports playback of multimedia content
  - Provides audio and video resource utilization tuning and control
  - Supports boot and reboot storms
  - Includes on-demand Windows endpoint client software, (that is, clicking a link starts an application)
  - Provides self-service virtual workplace and application provisioning
  - Provides self-service user image and file recovery / rollback

- **Service advertising and connection brokerage:**
  - Broker cluster scales to 10,000 virtual desktops and allows for multiples thereof
  - Provides a web-based connection interface
  - Supports industry-standard remote display protocols
  - Enables session reconnection from current or new endpoints
- Maintains user experience across multiple delivery models
- Integrates with application and profile virtualization

**Networking and connectivity:**
- Integrates with enterprise application delivery controllers that provide high-speed load balancing and content switching for user sessions
- Integrates with virtual private network (VPN) appliances, access gateway, or both
- Provides network separation using mechanisms such as virtual LANs (VLANs)
- Provides centralized management of networking parameters for thin clients
- Offers traceability mapping between virtual workplace/user and external IP
- Supports low-bandwidth and high-latency wide area network (WAN) connections
- Supports WAN acceleration devices, which reduce WAN bandwidth and latency requirements

**Storage and provisioning:**
- Integrates with storage provisioning features for the server virtualization platform
- Supports thin provisioning
- Manages disconnected virtual desktop synchronization

**Management and performance tooling:**
- Requires application deployment or publishing is done for user groups
- Must have built-in fully automated customization for applications or offer tools to achieve this customization
- Supports multiple concurrent administrators or connections
- Offers policy-based management
- Includes user, virtual desktop, and client endpoint search capabilities
- Provides flexible management of virtual desktop OS and application updates
- Includes command-line interface (CLI) and scripting support
- Includes real-time and historical data management
- Monitors application for traffic analysis
- Offers planning and migration tools
- Allows for virtual desktop provisioning
- Provides a management console
- Enables virtual desktop pooling and resource prioritization
- Suspends or shuts down idle virtual desktop instances or sessions

**Security:**
- Offers directory service integration
- Provides role-based access controls
- Ensures that client and management traffic is secured
- Allows for security logging and auditing of administrative actions
- Supports standard remote-access authentication protocols
- Considers vendor-provided hardening guidelines
- Offers configuration file and virtual desktop image integrity checking
- Includes multi-factor authentication for users, client endpoints, and management server
- Provides antivirus and antispyware software integration
- Allows for USB device access restrictions
- Offers granular desktop access control
- Patches deployment

- **Business continuity:**
  - Provides no single points of failure
  - Provides failure detection, isolation, and recovery
  - Allows for live migration of virtual workplace instance/sessions
  - Offers client connection failure notification and automatic reconnection
  - Provides session failure notification and automatic restart
  - Allows for resource prioritization

The following sections describe the reference architecture that meets all of these business needs and their functional and non-functional requirements.
4 Architectural overview

Figure 2 provides an architectural overview of the LCV solution, which consists of the following components:

- **Clients**: End-points for users, which can be laptops, tablets, and other mobile devices, thin clients, or workstations.
- **Choice of middleware and connection broker**: Representing the main three software solutions: VMware Horizon, Citrix XenDesktop, and Microsoft® Windows® Server 2012
- **Hypervisors**: Includes VMware ESXi, Citrix XenServer, and Microsoft Hyper-V.
- **Server building blocks**: Includes Lenovo Flex System® and ThinkSystem servers
- **Storage**: Includes Lenovo ThinkSystem DM5000F storage array and hyper-converged storage using local drives in servers

![Diagram of LCV solution](image-url)
LCV offers flexibility through a choice of solution elements. There are standard components, such as connection brokers, provisioning servers, and administrator consoles that make up and define the LCV architecture. This section describes these required components.

Different organizations have different guidelines for the amount of personalization that is permitted on user desktops. Some organizations allow users to customize to the extent that users are permitted to install applications; others allow minor changes, such as screensavers, desktop wall papers, and still others do not allow any changes to the standard image at all.

This set of policies can be applied to an environment in a similar manner. Users can be allowed to have their own dedicated virtual desktops or be required to use a standard desktop image, and can make minor modifications (if any). Eliminating modifications to a virtual desktop environment allows images to be shareable across multiple users, which allows a virtual desktop image to be stateless.

The LCV architecture allows for dedicated and stateless desktop images. However, a key design decision is to favor stateless desktop images whenever possible, as this reduces the shared storage requirements by using local solid-state drive (SSD) storage instead of large-scale, shared storage arrays for the performance-intensive I/O operations that occur in most environments. This can greatly improve performance as well as saving significant storage costs.

Figure 3 on page 8 shows a layered component model for the LCV solution. Conceptually, there are four logical layers: end-user clients, middleware (including management services), hypervisors that are running, and shared storage.

The following main components are shown in Figure 3:

- **Administrator GUIs**
  The middleware infrastructure is configured, managed, and monitored by using administrator graphical user interfaces (GUIs), which can be browser’s interfaces or thick-client applications. The administrator GUIs usually interact with one or more of the management services.

- **Management services**
  The middleware consists of several different management services for provisioning desktops, connection to desktops, management of desktops, and licensing. Data about the infrastructure is usually held in one or more management databases in shared storage. For more information, see page 10.

- **Client devices**
  Users can access their virtual desktop, published desktop, or published application from any device that is supported by the respective desktop virtualization solution, including company notebooks, home PCs, thin-client devices, or tablets. Customers can repurpose existing desktops (which is typical for many deployments) or **green-field** with thin- or zero-client devices. Lenovo offers a variety of client devices from tablets and phones to workstations and thin-clients. For more information about Lenovo thin-clients, see “Clients” on page 20.
Figure 3: Component model for LCV

- Hypervisor: The hypervisor for each server is responsible for running multiple VMs and sharing the resources of that server (processor, memory, and local storage) between the VMs.

- Accelerator VM: Accelerator VMs are optional. They often provide some means of improving the performance of the user VMs by using storage or compute acceleration. There are instances in which this acceleration functionality is deployed as an extension to the hypervisor.

- Dedicated virtual desktops: These desktops hold user configuration information that is dedicated to each individual user.

- Stateless virtual desktops: These desktops share a standard image across multiple users. Stateless desktops require local storage to keep any modified state that is discarded when the desktop is ended for the current user.

- Hosted desktops and applications: Hosted desktops are published desktops in which each user is sharing a VM. A hosted application provides access to a single published application without first needing a hosted or virtual desktop.
- **Local SSD storage**: Local SSD storage can be used as a local cache for stateless virtual desktops. Any changes can be discarded after a user logs off.

- **Shared storage**: Shared storage is used to hold all of the data that can be shared across servers, including the VM images themselves, deltas (changes) to dedicated VM images, user profile information, user data files, and management databases. For more information about the types of data in shared storage, see page 11.

- **Support Services**: Support services are outside the definition of LCV. Generally, these are services that are in the organization. For more information about support services, see page 10.

- **Administrator GUIs for support services**: The support services often include administrator GUIs to configure, manage, and monitor these services. More information about these GUIs is outside the scope of the LCV solution.

- **Web protocols**: Web protocols, such as Hypertext Transfer Protocol (HTTP) and Hypertext Transfer Protocol Secure (HTTPS), are used between the administrator GUIs or client devices and the management services.

- **Display protocols**: The virtual desktop image is streamed to the client device by using a display protocol. Depending on the solution, the choice of protocols available are: Remote Desktop Protocol (RDP), PC-over-IP (PCoIP), Independent Computing Architecture (ICA), and Simple Protocol for Independent Computing Environments (SPICE). The agent in the desktop takes display information and sends it to the agent in the client device. The agent in the client device displays the information appropriately and captures keyboard and gesture input, which is then transmitted back to the agent in the desktop.

- **Management protocols**: The protocols that are used between the management services and hypervisor or desktop agents often are vendor-specific and might not have a public specification.

- **Storage protocols**: Data can be read or written to shared storage by using many different protocols. File I/O is typically done with Common Internet File System (CIFS) or Network File System (NFS) into a network-attached storage (NAS). Other types of data, such as databases and VM images, are accessed by using block I/O that uses Fibre Channel into a storage area network (SAN).

- **Support service protocols**: The protocols for desktops to access support services are different and might not have a public specification.
5.1 Management services

Management services are provided by the vendor solution for creating desktops; provisioning desktops, connection to desktops, maintenance and management of desktops, and licensing. In many cases, these management services can be installed as desktops and thus do not need separate stand-alone servers. In some cases, such as large-scale deployments, the use of bare-metal management servers is required. Other scenarios include situations where a management service must manipulate specifics on the underlying server.

The following management services can be provided by a vendor:

- **Web server** The web server is often the first point of contact for a client that wants to access a desktop or virtual application. The user provides the credentials, which are verified in the directory, and then the user might be presented with one or more types of virtual desktops to which the user can connect. The web server must be highly available.

- **Connection broker** User requests for virtual desktops are sent from the web server to the connection broker. After a user is authenticated, it directs the client to its assigned virtual desktop that is running in a VM. If a desktop is not available, the connection broker works with the provisioning services to have the desktop ready and available. The connection broker plays no further role after the agent in the desktop and the agents in the client are communicating with each other. The connection broker must be highly available.

- **Provisioning services** Provisioning services is responsible for creating VM for virtual desktops or virtualized applications. This can be done on demand from the connection broker or ahead of time so that a pool is ready and waiting to which users can connect. Provisioning services use VM repository and VM deltas in shared storage to create the appropriate VM. Provisioning services must be highly available and might require many instances as this service type has the heaviest workload, especially at the start of a day when every user wants to get started with a virtual desktop.

- **VM manager** The VM manager is responsible for managing the state of a VM after it is created by provisioning services. Desktops can be returned to an idle state or deleted after a user disconnects from the desktop. The VM manager must be highly available.

- **VM Manager DB server** The VM manager database server is responsible for storing and retrieving the metadata about desktops and their state. The VM manager database server must be highly available.

- **License server** The License server is used to verify licensing of the infrastructure, including management services. Often, a grace period is allowed so that this service does not need to be highly available.
Other services
The infrastructure from vendors might include other services that often provide a differentiated function, such as event or performance monitoring.

For manageability, virtual desktops are usually divided into pools, which are created for the following reasons:

- Each unique desktop image must have its own pool.
- Desktops can be used with different sets of applications for different user groups. For example, accounting, engineering, and sales can be divided into separate pools.
- Stateless and dedicated desktops must be in separate pools.
- Management services limit the number of desktops they control within one instance. Therefore, multiple pools with the same VM image might be needed.

5.2 Support services

Support services such as a directory service, DNS server, DHCP server, and OS licensing server may already exist in the organization and can be reused. In some cases, these support services are VMs that can be run under a hypervisor and do not need separate stand-alone servers. For large-scale deployments, Lenovo recommends that these services are redundant by using the high-availability functionality built into the respective services.

- Directory
  The most-often used directory service is Microsoft Active Directory Server which provides authentication for both virtual desktop machine accounts and user access to the virtual desktops. Microsoft Active Directory has built-in high availability features, such as multi-master replication. Other directory servers and protocols also can be used, such as Samba or standards-compliant Lightweight Directory Access Protocol (LDAP) clients for higher integration into UNIX®-like server environments.

- DNS
  Domain name server (DNS) services are required to resolve fully qualified domain names (FQDNs). DNS servers must have high availability.

- DHCP
  When a new virtual desktop is started, it requests an address from Dynamic Host Configuration Protocol (DHCP). The DHCP system that is used within the organization must be designed for high availability. The most common methods for redundant DHCP are to use split scopes or to cluster DHCP servers.

- OS licensing
  The Windows operating system in the virtual desktop or management services must be licensed by using Microsoft Volume Licensing.

5.2.1 Lenovo Thin Client Manager

The Lenovo Thin-client Manager (LTM) is used to manage and support Lenovo thin-client devices individually or in groups. For more information about Lenovo ThinkCentre thin client devices, see “Clients” on page 20.

LTM is delivered as a virtual appliance that can be installed into any of the supported hypervisors: VMware ESXi, Microsoft Hyper-V, or Citrix XenServer. The LTM is a web-based console that allows IT administrators to perform the following tasks:
- Install new software, updates, and patches
- Create and manage user profile settings
- Manage terminal settings
- Capture and restore images (cloning)
- Manage inventory

The LTM supports a variety of Lenovo third party thin clients. Figure 4 shows an example of the LTM.

![LTM example](image)

**Figure 4: LTM example**

### 5.2.2 Chromebook management console

The Google Chromebook management console is used to manage and support Lenovo ThinkPad Chromebook devices individually or in groups. For more information about Lenovo ThinkPad client devices, see "Clients" on page 20.

Figure 5 is an example screenshot of the Chromebook management console.
The Chromebook management console has the following features:

- **Create user groups:** Apply policies, apps, and settings to different sets of users.
- **Pre-install and block apps:** Blacklist, whitelist, or pre-install apps, extensions and URLs.
- **Track assets:** Assign devices to specific employees and get configuration and usage reports.
- **Manage user access:** Control who uses your Chrome devices: prevent outside users from logging in, disable Guest Mode, or designate specific types of users for your devices.
- **Configure network access:** Set network and proxy settings to make it easy for users to get up and running and ensure they’re protected by web filters and firewalls.
- **Customize user features:** Modify user settings like bookmark and app sync across computers and apply custom Chrome desktop themes.

Figure 6 is an example screenshot of Chromebook device management.
5.3 Storage

Storage is required for persistent or non-persistent access of all the databases, VM images, user files, and other data that is needed for a deployment. This storage can be shared and accessed by using Ethernet or fibre networking or can be cached in some way in locally attached storage, such as flash. The types of data and methods that are used to store data vary by vendor solution and can include the following types:

- **Management databases**: Management databases hold information that is related to the configuration of the infrastructure or some kind of activities logging.
- **VM repository**: The VM repository contains master virtual desktop images. A history of changes to the images can also be kept. Backups of these images should also be stored separately.
- **VM deltas**: Changes to virtual desktop images that are made by users must be kept. Because keeping a separate copy of every user’s image is wasteful, most infrastructures have a way to store only the changes (or deltas).
• User profiles

By using Microsoft Roaming Profile (MSRP), users anywhere on the network can access their profile information. However, MSRP has several functional and performance disadvantages. Some implementations attempt to eliminate these problems with their own custom profile solution. For more information, see “User virtualization” section on page 18.

• User data files

User data files are often made available by using a shared drive letter. The hidden AppData folder, which contains files and settings for individual applications, is sometimes stored separately with the VM image.

5.4 Virtual desktop image assignment models

When virtual desktop solutions are designed, it is important to understand the relationship between the user and the virtual desktop image (the image assignment model). When a physical desktop computer (desktop PC or a notebook) is used, there is a one-to-one relationship between a user and the physical computer. As a natural evolution, most deployments initially used the same approach for the device management. With this design, users have a dedicated (persistent) virtual desktop instance and log into the same virtual desktop image when they connect. The dedicated desktop model is best for users who need to install more applications, store data locally, and retain the ability to work offline.

Although this approach aligns most closely to the way people approached desktops for a long time, it also prevents them from making full use of some of the following most important aspects and opportunities of desktop virtualization:

• Administration aspects
• Data management aspects
• Cost aspects (predominantly requirement of external storage)

From an administrator’s point of view, dedicated desktops have many drawbacks. All of the desktop images are unique and often are large, grow quickly in size, and must be updated and patched individually as they have no common base image. There is often no separation between the operating system and user data. Also, data backup is critical (as the image is unique to each user) and often entails the backup of large data sets. More importantly, high availability must be considered as the user needs to connect to the same image, even if a host fails, which is impossible if it is hosted locally. Therefore, dedicated desktops require access to expensive shared storage.

Stateless (which is also referred to as pooled, floating, or non-persistent) desktops are allocated to users temporarily. After the user logs off, changes to the image often are discarded (reset) and the desktop becomes available for the next user or a desktop is created for the next user session. A persistent user experience (that is, the ability to personalize the desktop and save data) is achieved through user profile management, folder redirection, difference data collection, and similar approaches. Also, specific individual applications can be provided to stateless desktops by using application virtualization technologies.

A stateless approach is based on a logical separation of operating system, application, and user layers that unlock the full benefits of desktop virtualization, if architected properly. It means that a common base image can be used for all users in the same pool. This image can also be updated centrally. If the image is corrupt or becomes unavailable, the user simply connects to another image in the pool, which uses the high-availability features of connection brokers rather than providing high availability through a storage-hungry VM failover.
approach. Backup is simplified because only a small subset of the overall data (profile information and saved data) must be archived.

As a result of these attributes, the stateless approach inherently enables the use of local storage instead of shared storage (with only a fraction of the data on distributed storage; for example, profile and user data), which helps to directly reduce the cost per desktop. The only potential restriction to storing this state locally is that a desktop cannot be moved from one server to another (motion) without restarting the VM – live migration. Motion is often used to maintain a live server by moving all of the desktops to another server. If the maintenance is not needed immediately, the server can be put into maintenance mode so that no new desktops are placed on the server. When the last desktop is closed, the server can be taken offline and have maintenance applied. If this live migration of servers is required, a stateless desktop can be still used, but all of the data is on shared storage with a corresponding increase in the performance requirements of shared storage.

For dedicated virtual desktops, it is also a good practice to separate out user profile and user data files from the VM images and VM deltas and differences. This separation makes it easier to refresh the VM images and reset the VM deltas when they get too large. Also, because dedicated and stateless virtual desktops access user profiles and user data files in the same way, it is easier to migrate from dedicated to stateless desktops.

This distinction between dedicated and stateless desktops and the use of local storage instead of shared storage is one of the key differentiators for the LCV solution. The stateless approach addresses a common practical inhibitor to virtual desktops (which is shared storage cost) and reduces networking requirements, and improves overall user performance and manageability. The approaches are compared in Table 1.

Table 1: Comparison of stateless and dedicated desktops

<table>
<thead>
<tr>
<th>Approach</th>
<th>Local storage</th>
<th>Live migration</th>
<th>Shared storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stateless</td>
<td>High IOPS (using SSD)</td>
<td>Not supported</td>
<td>Low IOPS</td>
</tr>
<tr>
<td>Stateless with motion</td>
<td>Not Used</td>
<td>Supported</td>
<td>High IOPS</td>
</tr>
<tr>
<td>Dedicated</td>
<td>Not Used</td>
<td>Supported</td>
<td>High IOPS</td>
</tr>
</tbody>
</table>

The dedicated and stateless approaches are supported by the LCV solution and can be used in the same environment. The exact mix of dedicated to stateless desktops depends on user requirements and customer policies.
5.5 Networking model

The LCV solution includes many different kinds of networking protocols. For simplification, the LCV network is divided into the following VLANs:

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

A 10-Gb network infrastructure is used to provide the required bandwidth and performance for these three VLANs. The storage VLAN requires the maximum bandwidth. As an alternative, shared storage can be attached by using 8 Gbps or 16 Gbps Fibre Channel SAN or by using Fibre Channel over Ethernet (FCoE).

A 1Gigabit Ethernet (GbE) network can also be used for certain solutions that are aimed at a small number of users (fewer than 600).

The LCV networking model is shown in Figure 7 with the different VLANs and storage networking.

![Figure 7: Network model for LCV](image)

Not shown in Figure 7 is a separate IT administration network that is used for systems management of nodes (power-up, reboot), optional Preboot Execution Environment (PXE) boot of hypervisors, and shared storage management. A separate 1 GbE network is used for the IT administration network.
5.6 User virtualization

User virtualization means independently managing all aspects of the user’s desktop environment by decoupling a user’s profile, settings, and data from the operating system and storing that data centrally. In fact, user virtualization can be performed with standard physical desktops as a first step towards client virtualization.

Within an environment, 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.

5.6.1 User folders

User folder redirection to a shared directory is easy to perform by using Microsoft Active Directory services and is well-documented. The most common folder that is redirected is the user’s home directory.

5.6.2 User profiles

User profile data for the purposes of this example is everything user-specific, not including the user’s home directory. The following types of user profiles are available:

- **None**: Each user’s desktop contains the profile, which is difficult to manage and recover from if an error occurs. This profile is not recommended.

- **Mandatory**: Mandatory profiles are used in locked-down environments where users are not allowed to perform tasks, such as changing the font, setting a personalized background, and so on. Every user receives the same, standard desktop. This profile is not a common scenario because most users demand some level of customization to their desktops.

- **Roaming**: Roaming profiles allow users to personalize the desktop experience. When a user moves from one desktop to another, the profile moves with that user.

- **Terminal services**: Terminal services profiles are used with application virtualization. It allows users to save their application-specific customization between logins so it does not need to be redone every time they log in to a virtualization application.

- **Hybrid**: Combines the Mandatory and Roaming profiles, which can speed up the user login process.

There are several potential problems with profiles that need careful planning and a software solution that eliminates or reduces the effect of these problems. The following main problems can occur:

- **Corruption**: Over a period of time, profiles can become corrupted. It might be as a result of the last write wins scenario, a driver installation that malfunctioned, or a bad sector on the disk. If the profile cannot be repaired, it might be restored from a backup. If this solution does not resolve the problem, the profile must be deleted and the user must start over, which often results in an unhappy user.
• Last write wins  In many environments, a user might have a roaming profile and multiple terminal service profiles for each virtualized application that they use. If the user logs in to several applications and virtual desktops at the same time, it is possible that the profile changes that are saved with a virtual desktop overwrite the profile changes for a virtualized application. To a user, it appears that the virtual application changes were not saved.

• Slow logins  There are several factors that can affect the login time, including the size of the profile, the network latency of accessing the profile from a different location, not using folder redirection, and disk fragmentation. Slow logins can also result from the number and type of Active Directory policies, each of which is applied in a serial fashion. By implementing a dedicated resource domain, only the required Active Directory policies are moved to the resource domain and applied at login time.

The standard solution for profiles is to use MSRP. However, MSRP does not scale well. In small environments with less than 600 users, MSRP can be fine. MSRP should be used with folder redirection to reduce what is stored in the profile because the smaller the profile the better the performance. Left unchecked, profiles can grow large and substantially increase user login type. MSRP can also have problems with data corruption and errors from last-write-wins scenarios.

Because of the problems with MSRP, various third-party user environment management (UEM) products were created, including some from vendors. Ruben Spruijt produced a well-written white paper that compares different UEM products that is titled “UEM Smackdown” (for more information and instruction about how to download the whitepaper, see goo.gl/uYZRr). Lenovo recommends evaluating an UEM solution for larger deployments.
6 Operational model

The operational model for LCV depends upon the middleware that is used. For more information about vendor-specific reference architecture documents, see “Resources” section on page 48.

Instead of describing a particular operational model, this section describes the Lenovo hardware that you can use for implementing LCV.

6.1 Clients

Lenovo offers various user devices, including laptops, desktops, all-in-ones, tablets, and phones. Any of these devices can be used as an end-point for client virtualization. In particular, Lenovo ThinkCentre thin clients and Chromebooks require virtually zero maintenance, can be managed remotely from the data center, and connect to different vendor platforms.

6.1.1 ThinkCentre M625q thin client

The ThinkCentre M625q Thin Client is a great solution for businesses looking for a quiet, compact thin client that can be deployed anywhere and balances cost, performance, and low power consumption. It supports up to 2 independent monitors and 4K resolution content, and has plenty of ports for robust connectivity and speedy data transfer.

The ThinkCentre M625q tiny thin client uses an AMD A9 series APU with Windows 10 Pro 64-bit. There is built-in support for Citrix® Receiver and VMware® Horizon.

The ThinkCentre M625q can be managed centrally using the Lenovo Thin Client Manager (see page 11). For more information, see psref.lenovo.com/syspool/Sys/PDF/ThinkCentre/ThinkCentre%20M625%20Tiny/M625q%20Tiny.pdf.

Figure 8: Lenovo ThinkCentre M625q tiny desktop

The ThinkCentre M625q tiny thin client is for customers that:

- need a perfect mix of space manageability, and exceptional cost-effectiveness,
- need reliable performance through features like the innovative intelligent cooling engine and keyboard power-on,
- need strong security and good total cost of ownership (TC0).
- need a tiny footprint, measuring a mere 179mm x 34.5mm with a VESA mount.

The ThinkCentre M625q can be managed centrally using the Lenovo Thin Client Manager (see page 11). For more information, see psref.lenovo.com/syspool/Sys/PDF/ThinkCentre/ThinkCentre%20M625%20Tiny/M625q%20Tiny.pdf.
6.1.2 ThinkCentre M715q thin client

The ThinkCentre M715q thin client is a great solution for businesses looking for a rugged, compact thin client that can be deployed anywhere and balances cost, performance, and low power consumption. It supports up to 3 independent monitors and 4K resolution content, and has plenty of ports for robust connectivity and speedy data transfer.

The ThinkCentre M715q thin client is built to military specifications, and can withstand punishing treatment – humid environments, extreme temperatures, sustained vibration, dust, fungus, and solar radiation.

The ThinkCentre M715q tiny thin client uses an AMD A6, A10, or A12 series APU with Windows 10 Pro 64-bit. There is built-in support for Citrix® Receiver and VMware® Horizon.

Figure 9: Lenovo ThinkCentre M715q Tiny Desktop

The ThinkCentre M715q thin client is for customers that:

- need ultimate flexibility with a pure thin client running from a server and the ability to run local applications as well,
- use high-performance video, 3D designs and other performance hungry applications,
- need highly secure desktops that are unquestionably reliable,
- need to maximize productivity while minimizing TCO,
- need a tiny footprint, measuring a mere 179mm x 34.5mm with a VESA mount.

The ThinkCentre M715q can be managed centrally using the Lenovo Thin Client Manager (see page 11).

For more information, see
psref.lenovo.com/syspool/Sys/PDF/ThinkCentre/ThinkCentre%20M715q%20Tiny/M715q%20Tiny.pdf

6.1.3 Lenovo 14e Chromebook

The Lenovo 14e Chromebook is directed towards business users, teachers, and students.

Figure 10: Lenovo 14e Chromebook
Features of the Lenovo 14e Chromebook include:

- 7th Generation AMD® A4-9120C dual-core processor.
- Thin and light design with all-day battery life of 10 hours.
- Rugged construction and tested to military specifications such as high pressure, humidity, vibration, high temperature, temperature shock, low pressure, low temperature, solar radiation, fungus, and dust.
- Integrated webcam, speakers, and microphone.
- Integrated wireless networking, Bluetooth, USB ports and USB type-C ports.
- Optional high-density 1920x1080 In-Plane Switching (IPS) display.

The Lenovo Chromebook 14e can be managed centrally using the Chromebook management console (see page 12). For more information, see psref.lenovo.com/Product/Lenovo_Laptops/Lenovo_14e_Chromebook.

6.2 Servers

You can use various Lenovo server platforms to implement LCV, including a modular blade-based system or traditional rack-based servers.

6.2.1 Bladed Servers using Lenovo Flex System

Flex System is a Lenovo enterprise-class platform that is specifically created to meet the demands of a virtualized data center and help clients establish a highly secure, private cloud environment. The Flex System includes the following features:

- Greatest choice for clients in processor type and OS platform (all in the same chassis) that is managed from a single point of control.
- The Flex System networking delivers 50% latency improvement through node-to-node (east-west) traffic rather than routing everything through the top-of-rack (ToR) switch (north-south).

Flex System is anchored by the Flex System Enterprise Chassis which enables high-speed performance with integrated servers and networking. Furthermore, its flexible design can meet the needs of varying workloads with independently scalable IT resource pools for higher utilization and lower cost per workload.

Figure 11 shows the front and rear of the Flex Chassis with fourteen ThinkSystem SN550 compute nodes in the front and two 10 Gbe switches in the rear with power supplies and fans.
For more information, see the following websites:

- Lenovo Flex System Enterprise Chassis: lenovopress.com/tips0863

### 6.2.2 Lenovo ThinkSystem SN550 compute node

The Lenovo ThinkSystem SN550 compute node (as shown in Figure 12) is a high-performance server that offers enhanced security, efficiency, and reliability features to handle business-critical workloads. The blade server incorporates Intel Xeon Processor Scalable Family of processors. The processors feature up to 28 cores each and includes industry-leading two-socket memory capacity that features Lenovo TruDDR4™ memory up to 1.5 TB.

For more information, see this website: lenovopress.com/lp0637

### 6.2.3 Lenovo ThinkSystem SR630 rack server

Lenovo ThinkSystem SR630 (as shown in Figure 13) is an ideal 2-socket 1U rack server for small businesses up to large enterprises that need industry-leading reliability, management, and security, as well as maximizing performance and flexibility for future growth. The SR630 server is designed to handle a wide range of workloads, such as databases, virtualization and cloud computing, virtual desktop infrastructure (VDI),
infrastructure security, systems management, enterprise applications, collaboration/email, streaming media, web, and HPC. The ThinkSystem SR630 offers up to twelve 2.5-inch hot-swappable SAS/SATA HDDs or SSDs together with up to 4 on-board NVMe PCIe ports that allow direct connections to the U.2 NVMe PCIe SSDs.

Figure 13: Lenovo ThinkSystem SR630

For more information, see this website: lenovopress.com/lp0643

6.2.4 Lenovo ThinkSystem SR650 rack server

Lenovo ThinkSystem SR650 (as shown in Figure 14) is similar to the SR630 but in a 2U form factor.

Figure 14: Lenovo ThinkSystem SR650

The key differences compared to the SR630 server are more expansion slots and chassis to support up to twenty-four 2.5-inch or fourteen 3.5-inch hot-swappable SAS/SATA HDDs or SSDs together with up to 8 on-board NVMe PCIe ports that allow direct connections to the U.2 NVMe PCIe SSDs. The ThinkSystem SR650 server also supports up to two NVIDIA GPUs for graphics acceleration.

For more information, see this website: lenovopress.com/lp0644

6.2.5 Lenovo ThinkSystem SD530 server

Lenovo ThinkSystem SD530 server is an ultra-dense and economical two-socket server in a 0.5U rack form factor. Four SD530 servers installed in the ThinkSystem D2 Enclosure provides an ideal high-density 2U four-node (2U4N) platform for enterprise, cloud, and VDI workloads (as shown in Figure 15). Each ThinkSystem SD530 server offers up to six 2.5-inch hot-swappable SAS/SATA HDDs or SSDs together with up to 2 on-board NVMe PCIe ports that allow direct connections to the U.2 NVMe PCIe SSDs.

2U4N systems have gained popularity in a variety of data centers, from large enterprises to service providers, because their small footprint, inherent density, and low total cost of ownership (TCO) make them ideal for building solution-based appliances at a low cost.
6.3 Graphics Adapters

The Lenovo ThinkSystem SR650 server supports up to two NVIDIA graphics adapters, which enable rich graphics in virtualized environments. See lenovopress.com/lp0768-thinksystem-gpu-summary for more details on supported GPUs.

The ThinkSystem NVIDIA Tesla P40 GPU is a dual-slot 10.5-inch PCIe 3.0 card based on a high-end NVIDIA Pascal graphics processing unit (GPU) with 24GB GDDR5 memory. It uses a passive heat sink for cooling and has a 250 W maximum power limit. It supports 18 virtual GPU profiles for different use cases and up to 24 users per GPU, or 48 users per SR650 server.

The ThinkSystem NVIDIA Tesla M10 GPU is a dual-slot 10.5 inch PCI Express 3.0 graphics card with four mid-range NVIDIA Maxwell graphics processing units (GPUs) with 32 GB GDDR5 memory (8 GB per GPU). The board is passively cooled and has a 225 W maximum power limit. It supports 12 virtual GPU profiles for different use cases and up to 32 users per GPU, or 64 users per SR650 server.

The NVIDIA software needs to be licensed for Windows or Linux. See the following for more details: images.nvidia.com/content/grid/pdf/161207-GRID-Packaging-and-Licensing-Guide.pdf.

6.4 Shared storage

Lenovo Client Virtualization can use a range of shared storage solutions including Lenovo ThinkSystem DM5000F and DM7000F storage arrays.

6.4.1 Lenovo ThinkSystem DM5000F storage array

Lenovo ThinkSystem DM5000F is a unified, all flash entry-level storage system that is designed to provide performance, simplicity, capacity, security, and high availability for medium to large businesses. Powered by the ONTAP software, ThinkSystem DM5000F delivers enterprise-class storage management capabilities with a wide choice of host connectivity options and enhanced data management features. The ThinkSystem DM5000F is a perfect fit for a wide range of enterprise workloads, including big data and analytics, artificial intelligence, engineering and design, enterprise applications, and other storage I/O-intensive applications.

ThinkSystem DM5000F models (as shown in Figure 16) are 2U rack-mount controller enclosures that include two controllers, 64 GB RAM and 8 GB battery-backed NVRAM (32 GB RAM and 4 GB NVRAM per
controller), and 24 SFF hot-swap drive bays (2U24 form factor). Controllers provide universal 1/10 GbE NAS/iSCSI or 8/16 Gb Fibre Channel (FC) ports for host connectivity.

A single ThinkSystem DM5000F Storage Array scales up to 144 solid-state drives (SSDs) with the attachment of Lenovo ThinkSystem DM240S 2U24 SFF Expansion Enclosures. Up to 12 DM5000F Storage Arrays can be combined into a clustered system in a NAS environment, or up to 6 DM5000F Storage Arrays can be combined into a clustered system in a SAN environment.

![Figure 16: Lenovo DM5000F storage array](image)

**Figure 16: Lenovo DM5000F storage array**

The ThinkSystem DM5000F offers the following key features and benefits:

- All-flash array capabilities to meet the demand for higher speed storage and provide higher IOPs and bandwidth with lower power usage and total cost of ownership than hybrid or HDD-based solutions.
- Improved performance and data protection with RAID-DP and RAID-TEC, as well as support for traditional RAID 4.
- Flexible host connectivity to match diverse client needs with support for unified NAS and SAN storage protocols, including 1/10 GbE NAS and iSCSI, and 8/16 Gb Fibre Channel connectivity.
- 12 Gb SAS drive-side connectivity with multipathing with up to 24x 2.5-inch small form factor (SFF) drives in the 2U24 SFF enclosures.
- Rich set of standard storage management functions available at no extra cost, including snapshots, volume copy, quality of service, thin provisioning, compression, deduplication, encryption, disk-based backup, application- and virtual machine-aware backup, quick data recovery, and asynchronous mirroring.
- Optional WORM (write once, read many) (SnapLock) licensed function to reinforce permanence and integrity of stored data and to ensure compliance with applicable regulations.
- Intuitive, web-based GUI for easy system setup and management.
- Lenovo XClarity support for centralized systems management of Lenovo x86 servers, switches, and storage, which provides automated agent-less discovery, inventory, monitoring, and additional platform-specific functions across multiple systems.
- Designed for high availability with redundant hot-swap components, including controllers and I/O modules, power supplies, and non-disruptive firmware upgrades.

For more information, see this website: lenovopress.com/lp0911.
6.4.2 Lenovo ThinkSystem DM7000F storage array

Lenovo ThinkSystem DM7000F is a scalable, unified, all flash mid-range storage system that is designed to provide high performance, simplicity, capacity, security, and high availability for medium to large businesses. Powered by the ONTAP software, ThinkSystem DM7000F delivers enterprise-class storage management capabilities with a wide choice of host connectivity options, flexible drive configurations, and enhanced data management features, including support for NVMe over Fabrics. The ThinkSystem DM7000F is a perfect fit for a wide range of enterprise workloads, including big data and analytics, artificial intelligence, engineering and design, hybrid clouds, and other storage I/O-intensive applications.

ThinkSystem DM7000F models (as shown in Figure 17) are 3U rack-mount controller enclosures that include two controllers, and 256 GB RAM and 16 GB battery-backed NVRAM (128 GB RAM and 8 GB NVRAM per controller). Universal 1/10 GbE NAS/iSCSI or 4/8/16 Gb Fibre Channel (FC) ports and 1/10 GbE RJ-45 ports provide base host connectivity, with an option for additional 1/10 GbE or 40 GbE NAS/iSCSI, or 8/16/32 Gb FC connections with the adapter cards.

A single ThinkSystem DM7000F Storage Array scales up to 384 SFF solid-state drives (SSDs) with the attachment of Lenovo ThinkSystem DM240S 2U24 SFF Expansion Enclosures. Up to 12 DM7000F Storage Arrays can be combined into a clustered system in a NAS environment, or up to 6 DM7000F Storage Arrays can be combined into a clustered system in a SAN environment.

Figure 17: Lenovo DM7000F storage array

The ThinkSystem DM7000F offers the same key features and benefits as the DM5000F but with the following enhancements:

- Support for NVMe over Fabrics to help achieve up to two times higher performance at a half of the latency.
- Additional support for 40 GbE NAS and iSCSI, and 32 Gb Fibre Channel connectivity.

For more information, see this website: lenovopress.com/lp0912.

6.5 10 GbE networking

The standard network for the LCV solution is 10 GbE and it needs to transport several VLANs. Lenovo Virtual Fabric provides a fast, flexible, and reliable I/O solution. This new and innovative solution that is based on Emulex adapters and specific Lenovo switches is different than other virtual network interface card (NIC)
solutions in that it establishes dedicated pipes between the adapter and the switch. This solution is built on industry standards and provides maximum performance in both directions. Lenovo Virtual Fabric also allows for advanced levels of security and higher levels of availability per virtual NIC by using virtual pipes, which isolate vNICs from each other.

For more information about network switches, see this website: shop.lenovo.com/us/en/systems/networking/.

6.5.1 Emulex 10 GbE adapters

The Emulex Virtual Fabric Adapter 5.2 (VFA5.2) Network Adapter Family for ThinkSystem builds on the foundation of previous generations of Emulex VFAs by delivering performance enhancements and new features that reduce complexity and cost and improve performance. These adapters are available as slotless mezzanine cards for Flex System SN550 and the ThinkSystem rack servers. An optional upgrade provides iSCSI and FCoE capability. The Emulex card takes a 10 Gb port and splits it into four vNICs. This configuration allows each vNIC or virtual channel to be 100 Mb - 10 Gb in increments of 100 Mb. The total of all four vNICs cannot exceed 10 Gb.

For more information, see this website: lenovopress.com/lp0052.pdf

6.5.2 Lenovo ThinkSystem NE1032 RackSwitch

The Lenovo ThinkSystem NE1032 RackSwitch (as shown in Figure 18) 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.

Figure 18: Lenovo ThinkSystem NE1032 RackSwitch

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

6.5.3 Lenovo RackSwitch G8272

The Lenovo RackSwitch G8272 that uses 10Gb SFP+ and 40Gb QSFP+ Ethernet technology 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 19), 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. The G8272 supports the newest protocols, including Data Center Bridging/Converged Enhanced Ethernet (DCB/CEE) for Fibre Channel over Ethernet.
(FCoE), iSCSI and network-attached storage (NAS).

**Figure 19: Lenovo RackSwitch G8272**

The RackSwitch G8272 supports Lenovo Virtual Fabric, which helps clients significantly reduce cost and complexity that are related to I/O requirements of many virtualization deployments. Virtual Fabric helps reduce the number of multiple I/O adapters to a single dual-port 10 Gb adapter and the number of cables and required upstream switch ports.

By using Virtual Fabric, you can carve a dual-port 10 Gb server adapter into eight virtual network ports (vPorts) and create dedicated virtual pipes between the adapter and switch for optimal performance, higher availability, and improved security. With Virtual Fabric, you can make dynamic changes and allocate bandwidth per vPort so that you can adjust it over time without downtime.

For more information, see this website: [lenovopress.com/tips1267.html](http://lenovopress.com/tips1267.html)

### 6.5.4 Flex System Fabric EN4091 Pass-thru Module

The Flex System EN4091 10 GbE Pass-thru Module offers easy connectivity of the Flex System Enterprise Chassis to any external network infrastructure. This unmanaged device enables direct connectivity of the compute node in the chassis to an external top-of-rack data center switch. This module can function at 1 GbE and 10 GbE speeds. It has 14 internal 10 Gb links and 14 external 10 Gb SFP+ uplinks.

### 6.5.5 Flex System Fabric EN4093R 10 Gb Scalable Switch

The Flex System Fabric EN4093R 10 Gb Scalable Switch (as shown in Figure 20) offers easy connectivity of the Flex System Enterprise Chassis to any external network infrastructure. By default, the CN4093 switch supports 14 10 GbE internal ports, 2 external 10 GbE SFP+ ports, and 6 external Omni Ports. More ports can be enabled, including up to 28 l internal ports, 2 external 40 GbE QSFP+ uplink ports, and 6 external Omni Ports. The switch offers full Layer 2/3 switching, FCoE Full Fabric, can help clients migrate to a 10 Gb or 40 Gb Ethernet infrastructure, and offers virtualization features such as Virtual Fabric.

**Figure 20: Flex System Fabric EN4093R 10 Gb Scalable Switch**

For more information, see this website: [lenovopress.com/tips0864.html](http://lenovopress.com/tips0864.html)
6.5.6 Flex System Fabric CN4093 10 Gb Converged Scalable Switch

The Flex System Fabric CN4093 10Gb Converged Scalable Switch (as shown in Figure 21) offers easy connectivity of the Flex System Enterprise Chassis to any external network infrastructure. The switch offers full Layer 2/3 switching and FCoE Full Fabric and Fibre Channel NPV Gateway operations to deliver a truly converged integrated solution. It is designed to install within the I/O module bays of the Flex System Enterprise Chassis. The switch can help clients migrate to a 10 Gb or 40 Gb converged Ethernet infrastructure and offers virtualization features, such as Virtual Fabric.

![Flex System Fabric CN4093 10 Gb Converged Scalable Switch](image)

Figure 21: Flex System Fabric CN4093 10 Gb Converged Scalable Switch

For more information, see this website: [lenovopress.com/tips0910.html](http://lenovopress.com/tips0910.html)

6.6 1 GbE networking

A separate 1 Gb Ethernet network is used for administration and management of the various hardware servers, storage and other components. Lenovo has a variety of top of rack switches to support 1 GbE networks. For more information about network switches, see this website: [shop.lenovo.com/us/en/systems/networking/](http://shop.lenovo.com/us/en/systems/networking/).

6.6.1 Lenovo RackSwitch G8052

The Lenovo System Networking RackSwitch G8052 (as shown in Figure 22) 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 4 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.

![Lenovo RackSwitch G8052](image)

Figure 22: Lenovo RackSwitch G8052

For more information, see this website: [lenovopress.com/tips0813.html](http://lenovopress.com/tips0813.html)
7 System performance considerations

The following main factors affect the performance of client virtualization:

- User Profiles
- Processor and memory
- Graphics Acceleration
- High availability for management VMs
- Storage
- Networking

A well-designed deployment is balanced with respect to these six factors and should not unduly stress one of these factors to the detriment of the overall solution.

Equally important is the elimination of single points of failure in the infrastructure architecture and the ability to failover if an individual piece of hardware or software is no longer functional. The cost of the infrastructure might increase if it must cope with multiple points of failure. The performance design of the system should be unaffected in the failover scenario, which means that extra performance capacity is built into the system for the normal case.

This section describes considerations for these factors in a general way. Detailed performance results and recommendations are found in each of the vendor-specific reference architectures. The vendor-specific recommendations are also followed in terms of optimizing the Windows desktops for the specific environment of hypervisor, connection broker, and storage technology.

For all production deployments, Lenovo recommends an assessment and a proof of concept or pilot deployment to validate the actual performance against the expected performance. Actual user workload in production environments can vary greatly and might be because of lighter or heavier user tasks, the effect of antivirus solutions, more load that is generated by application virtualization, profile management solutions, or operational tasks, such as patching or indexing.

There are four well-known phases when considering the performance of an implementation: boot, login, steady state, and logoff.

The boot phase is when all of the desktops are booted and made ready for users. Desktops are booted when the system is first initialized and Lenovo recommends restarting the desktops once a week. Staggering the reboots reduces the effect of this so-called “boot storm.” Any image-recompose, refresh operations, or other maintenance that requires the restart of all virtual desktops must be performed during maintenance windows or off-peak hours to minimize the IOP effect on the storage system.

The login phase occurs when users log in to the desktops. The so-called “login storm” occurs when all of the employees come to work and first log in to their desktops at the beginning of the day. The measurements from the login storm are used in the vendor-specific reference architectures as the peak IOP rate. This peak assumes that a new user logs into a server every 30 seconds. The load on the storage system is the currently logged on users in a steady state and all of the new users, one per server that are logging on.

The steady state phase occurs after the log in is complete and the users are performing the normal work. The
steady state phase is typically the longest phase. The IOP measurements from this phase must not be used as a basis for a deployment because they often are too small and do not adequately represent the daily peak at login.

The logoff phase is when users log out from their desktop and a new desktop VM is restarted. If there are many simultaneous log out operations, this phase is similar to the boot phase and can be I/O intense. The logoff phase must be managed appropriately to avoid refresh operation affecting the system performance. For example, you can set timeouts that delay the logout after the user disconnects, which delays the refresh operation or scripts the refresh (for example, at night time) instead of refreshing the image automatically on logoff.

The login and logoff pattern of a specific environment can influence the system usage if it significantly deviates from the baseline assumptions that are described here, such as users logging into their desktops in intervals shorter than 30 seconds.

### 7.1 User Profiles

Because there is a wide range of users and user requirements, it is natural to classify users into classes or profiles that represent the workloads that are performed by each user. In the Reference Architectures for LCV, users are classified into the following profiles:

- Office Worker
- Knowledge Worker
- Power Worker
- Designer/Engineer

The Office Worker profile is for users who do not need many resources, typically run a few applications, and often need only stateless virtual desktops or a few shared applications. Office Workers do not use applications that need graphics acceleration. Examples of Office Workers can include call center workers or hospital staff (nurses).

The Knowledge Worker profile is for users who require a reasonable amount of resources, typically run a range of office applications, and might need dedicated or stateless virtual desktops, depending on the environment. Knowledge workers might need some graphics acceleration for certain applications, such as Google Earth, Photoshop, or 3D viewing but not all of the time. There are many examples of Knowledge Workers and this group represents the largest proportion of users.

The Power Worker profile is for users who require more resources than the average user and might run long-running compute or I/O-intensive applications. Power Workers are likely to require dedicated virtual desktops. This class of user might also require extensive use of graphics accelerations for some applications, such as medium computer-aided drawing (CAD), computer-aided engineering (CAE) visualization, or multi-display financial applications.

The Designer/Engineer profile is for users who have the highest demand for compute, storage, and graphics acceleration. This class of user uses high-end CAD, petrochemical seismic time reversal, reservoir analysis, or other HPC visualization applications, such as weather or life sciences.

Table 2 lists the four user profiles and their typical requirements on for virtual desktops, virtual machine (VM) memory, virtual CPUs (vCPUs), display resolution, and GPU equivalent.
### Table 2: Summary of User Profiles

<table>
<thead>
<tr>
<th>User Profile</th>
<th>Virtual Desktop</th>
<th>VM memory</th>
<th>vCPUs</th>
<th>Resolution</th>
<th>Displays</th>
<th>GPU equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Worker</td>
<td>Stateless</td>
<td>2 – 3 GB</td>
<td>1</td>
<td>1280 x 720</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>Knowledge Worker</td>
<td>Stateless or Dedicated</td>
<td>3 – 4 GB</td>
<td>2</td>
<td>1920 x 1080</td>
<td>1</td>
<td>Quadro K600 or K2000</td>
</tr>
<tr>
<td>Power Worker</td>
<td>Dedicated</td>
<td>4 – 8 GB</td>
<td>3</td>
<td>2560 x 1600</td>
<td>1 or 2</td>
<td>Quadro K4000</td>
</tr>
<tr>
<td>Designer/Engineer</td>
<td>Dedicated</td>
<td>8 – 16 GB</td>
<td>4 or more</td>
<td>2560 x 1600</td>
<td>Up to 4</td>
<td>Quadro K5000</td>
</tr>
</tbody>
</table>

### 7.2 Processor and memory for user desktops

The number of desktops that can be run on a specific server depends upon the available system memory and compute power of the processors. For a cost-effective solution, the maximum number of users should be put on each server without wasting processor resource or memory, notwithstanding the extra buffer that is needed for failover if a server fails.

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.

Some hypervisors implement schemes to better manage the memory for each desktop with the ultimate aim of allowing more desktops to share a server. For example, memory blocks that are the same are shared between desktops. This sharing can reduce the total memory needed. However, no good calculators exist to understand the savings. Ultimately, it might require testing to determine the best VM size for a specific workload.

To simplify matters, the easiest solution is still to divide the system memory by the average VM size after taking into account the average hypervisor memory of 4 GB. For example, a server with 256 GB of memory can host up to 125 desktops, each with 2 GB of memory.

If one or more servers fail, the users on that server must be transferred over to the remaining servers, which increases the number of desktops per server. Therefore, for production purposes, the number of users on each server must be low enough to allow for headroom in memory and processor to support these extra desktops and still keep processor usage under 100%. This best practice avoids overcommitting on the processors, which can be worse than overcommitting on memory. The redundancy that is required for failover is dependent on the system environment and a 5-to-1 ratio is recommended for most circumstances.
7.3 Graphics Acceleration

There is an increasing need for GPUs to provide graphics acceleration for virtual desktops and shared desktops. It is not recommended to mix users on a server where some need graphics acceleration and some do not. It is also recommended that servers with different specifications for graphics acceleration are kept in separate pools so that the users can be directed to the most appropriate server. For example, designers might use ThinkSystem SR650 servers with NVidia P40 GPUs and office workers with no requirement for graphics acceleration use ThinkSystem SR630 servers.

Table 3 lists the three options for the use of a GPU for graphics acceleration. The best option for a particular application, user, or environment depends upon the performance characteristics and there is no single prescriptive choice.

**Table 3: Summary of options for virtual desktop graphical acceleration**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dedicated GPU</th>
<th>Shared GPU</th>
<th>GPU hardware virtualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance/cost per user</td>
<td>Best performance</td>
<td>Low cost per user</td>
<td>Flexible choice of cost per user and performance.</td>
</tr>
<tr>
<td>Guaranteed GPU performance</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Supports motion (live migration of VMs)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>All versions of 3D APIs supported</td>
<td>All</td>
<td>Limited</td>
<td>All</td>
</tr>
<tr>
<td>(DirectX and OpenGL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended for Designer/Engineer</td>
<td>Yes</td>
<td>No</td>
<td>Possibly</td>
</tr>
<tr>
<td>Recommended for Power Worker</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Recommended for Knowledge Worker</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The number of users for the dedicated GPU and the GPU virtualization options is limited by the GPU rather than the CPU, which implies that less system memory is needed for the VMs. For example, a designer might need a large 32 GB VM; however, because there are only four VMs per server, 192 GB of memory is sufficient. Similarly, 192 GB of memory can be used for 32 knowledge workers and each still has a 5 GB VM.
7.3.1 Dedicated GPU

With desktop PCs and workstations, a user has complete and sole access to a GPU. In a virtual desktop environment, the same pattern can be used where a user has access to a dedicated GPU. Naturally, this limits the number of users on a server to the number of GPUs available on that server. For example a Lenovo ThinkSystem SR650 has a capacity of two GPUs.

The dedicated GPU option as depicted in Figure 23 requires support from the hypervisor and is most often used by designers, engineers, or scientists who need the best possible performance.

For the case of hosted desktops, it is also possible to dedicate a GPU to the whole VM and all of the hosted users can share the GPU resource. Note that there may be GPU resource contention and the severity depends on the hypervisor and OS in the VM.
7.3.2 Shared GPU

Some hypervisors support a GPU sharing mode which is a form of software virtualization of a GPU. The number of users is limited by the processor, memory, and GPU usage in the server.

At any particular time, multiple users might be trying to access the GPU at the same time. This means that there can be choppy performance because each user is essentially vying for dedicated use of the GPU. For this reason, GPU sharing is not generally recommended.

Figure 24: Shared GPU (example with VMware ESXi)

7.3.3 Hardware virtualization of GPU

With hardware virtualization of a GPU, the hardware resources in the GPU are partitioned and each user only has access to their partition. The NVIDIA GRID GPUs were specifically designed to manage this partitioning and ensure each user can have simultaneous, unimpeded access to their assigned partition. The NVIDIA vGPU manager can assign up to eight users per GPU chip. See Figure 25 for details and also the following website: docs.nvidia.com/grid/latest/grid-vgpu-user-guide.
Figure 25: Virtual GPU

Each physical GPU can support several different types of virtual GPU. Virtual GPU profiles have been defined which have a fixed amount of frame buffer, number of supported display heads, and maximum resolutions. Because the number of users for a given profile is fixed, the maximum number of users is also fixed.

The profiles are grouped into different series according to the different classes of workload at which they are targeted. Each series is identified by the last letter of the vGPU type name.

- Q-series virtual GPU types are targeted at designers and power users. These profiles require certification of applications. These users were probably already using a graphics workstation with an included GPU.
- B-series virtual GPU types are targeted at power users (and knowledge workers).
- A-series virtual GPU types are targeted at virtual application users.

NVIDIA requires a license for virtual GPUs. See the following website for further information on licensing models, pricing, and packaging: images.nvidia.com/content/grid/pdf/161207-GRID-Packaging-and-Licensing-Guide.pdf.

The GPU usage requirements determine which profile to use. Table 4 below lists the virtual GPU profiles for the NVIDIA P40 GPU.
### Table 4: Virtual GPU profiles for NVidia P40 GPU

<table>
<thead>
<tr>
<th>Virtual GPU Profile</th>
<th>Intended Use Case</th>
<th>Frame Buffer (Mbytes)</th>
<th>Virtual Display Heads</th>
<th>Maximum Resolution per Display Head</th>
<th>Maximum vGPUs per Board</th>
<th>Required License Edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>P40-24Q</td>
<td>Designer</td>
<td>24576</td>
<td>4</td>
<td>4096x2160</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P40-12Q</td>
<td>Designer</td>
<td>12288</td>
<td>4</td>
<td>4096x2160</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>P40-8Q</td>
<td>Designer</td>
<td>8192</td>
<td>4</td>
<td>4096x2160</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>P40-6Q</td>
<td>Designer</td>
<td>6144</td>
<td>4</td>
<td>4096x2160</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>P40-4Q</td>
<td>Designer</td>
<td>4096</td>
<td>4</td>
<td>4096x2160</td>
<td>6</td>
<td>Quadro vDWS</td>
</tr>
<tr>
<td>P40-3Q</td>
<td>Designer</td>
<td>3072</td>
<td>4</td>
<td>4096x2160</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>P40-2Q</td>
<td>Power User, Designer</td>
<td>2048</td>
<td>4</td>
<td>4096x2160</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>P40-1Q</td>
<td>Power User, Designer</td>
<td>1024</td>
<td>2</td>
<td>4096x2160</td>
<td>24</td>
<td>GRID Virtual PC or Quadro vDWS</td>
</tr>
<tr>
<td>P40-2B</td>
<td>Power User</td>
<td>2048</td>
<td>2</td>
<td>4096x2160</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>P40-1B</td>
<td>Power User</td>
<td>1024</td>
<td>4</td>
<td>2560x1600</td>
<td>24</td>
<td>GRID Virtual Application</td>
</tr>
<tr>
<td>P40-24A</td>
<td>Virtual Application User</td>
<td>24576</td>
<td>1</td>
<td>1280x1024</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P40-12A</td>
<td>Virtual Application User</td>
<td>12288</td>
<td>1</td>
<td>1280x1024</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>P40-8A</td>
<td>Virtual Application User</td>
<td>8192</td>
<td>1</td>
<td>1280x1024</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>P40-6A</td>
<td>Virtual Application User</td>
<td>6144</td>
<td>1</td>
<td>1280x1024</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>P40-4A</td>
<td>Virtual Application User</td>
<td>4096</td>
<td>1</td>
<td>1280x1024</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>P40-3A</td>
<td>Virtual Application User</td>
<td>3072</td>
<td>1</td>
<td>1280x1024</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>P40-2A</td>
<td>Virtual Application User</td>
<td>2048</td>
<td>1</td>
<td>1280x1024</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>P40-1A</td>
<td>Virtual Application User</td>
<td>1024</td>
<td>1</td>
<td>1280x1024</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 below lists the virtual GPU profiles for the NVIDIA M10 GPU.

### Table 5: Virtual GPU profiles for NVidia M10 GPU

<table>
<thead>
<tr>
<th>Virtual GPU Type</th>
<th>Intended Use Case</th>
<th>Frame Buffer (Mbytes)</th>
<th>Virtual Display Heads</th>
<th>Maximum Resolution per Display Head</th>
<th>Maximum vGPUs per Board</th>
<th>Required License Edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>M10-8Q</td>
<td>Designer</td>
<td>8192</td>
<td>4</td>
<td>4096x2160</td>
<td>4</td>
<td>Quadro vDWS</td>
</tr>
<tr>
<td>M10-4Q</td>
<td>Designer</td>
<td>4096</td>
<td>4</td>
<td>4096x2160</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>M10-2Q</td>
<td>Power User, Designer</td>
<td>2048</td>
<td>4</td>
<td>4096x2160</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>M10-1Q</td>
<td>Power User, Designer</td>
<td>1024</td>
<td>2</td>
<td>4096x2160</td>
<td>32</td>
<td>GRID Virtual PC or Quadro vDWS</td>
</tr>
<tr>
<td>M10-0Q</td>
<td>Power User, Designer</td>
<td>512</td>
<td>2</td>
<td>2560x1600</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>M10-2B</td>
<td>Power User</td>
<td>2048</td>
<td>2</td>
<td>4096x2160</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>M10-1B</td>
<td>Power User</td>
<td>1024</td>
<td>4</td>
<td>2560x1600</td>
<td>32</td>
<td>GRID Virtual PC or Quadro vDWS</td>
</tr>
<tr>
<td>M10-0B</td>
<td>Power User</td>
<td>512</td>
<td>2</td>
<td>2560x1600</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>M10-8A</td>
<td>Virtual Application User</td>
<td>8192</td>
<td>1</td>
<td>1280x1024</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>M10-4A</td>
<td>Virtual Application User</td>
<td>4096</td>
<td>1</td>
<td>1280x1024</td>
<td>8</td>
<td>GRID Virtual Application</td>
</tr>
<tr>
<td>M10-2A</td>
<td>Virtual Application User</td>
<td>2048</td>
<td>1</td>
<td>1280x1024</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>M10-1A</td>
<td>Virtual Application User</td>
<td>1024</td>
<td>1</td>
<td>1280x1024</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>
7.4 High availability for management VMs

In addition to user desktops, there are many different VMs that are needed for managing the environment. The size and type of management VMs that are required depends on the individual vendor solution. In all cases, it is a best practice to use at least two separate servers for these VMs so that there is failover from one of these servers to the other. It also makes sense that these management VM servers are configured the same as the servers for user desktops so that they can be used interchangeably. For example, a server that is running user virtual desktops can be co-opted to run management VMs while a management server is down, which maintains high availability for the management services.

7.5 Storage

Client virtualization can be an intensive workload for storage in terms of IOPS and the amount of data to be stored, which translate to a high cost per user. Therefore, there are different solutions to reduce the IOPS and the amount of stored data. The storage infrastructure is highly dependent on the individual situation and depends on technical and unique organizational criteria.

The most significant performance optimization is to use stateless desktops and, where possible, local SSDs to cache data locally. This configuration helps reduce cost because server SSDs are less expensive than storage SSDs and network traffic is reduced. For more information, see “Virtual desktop image assignment models” section on page 15.

Other optimizations that can be performed locally at each server are storage read/write caches and de-duplication that reduce data transfers to and from shared storage. These software-based caches can provide significant advantages at the cost of extra RAM in each server.

For shared storage, the most important performance criterion is the ability to service I/O operations from all of the desktops. The required performance for a desktop logon is at least 50% more than that needed for a steady state condition. At logon, the I/O operations consist mainly of reads. At logout, profile changes are written back to disk by using the chosen profiling tool (see “User profiles” section on page 18). Third-party alternatives to MSRP tend to load profile information on demand and store changes in regular intervals, which flattens the IOPS requirement at the cost of making the data a little larger.

An understanding of the read-write ratio is important because caching algorithms often address reads only and that writes often have a larger effect on the disk subsystem because of RAID penalties (writing the redundancy information). Desktop virtualization often requires 75% or more writes, which has another effect on the number of IOPS. For example, a single 15k rpm drive of 175 IOPS in a RAID 10 array with a two times write penalty is actually worth only 100 IOPS (25 read and 75 write).

The simplest and most transparent storage optimization is a RAM or flash memory-based read-only cache in the shared storage device. As indicated before, this has only limited usefulness at logon time when there are reads.

Tiering of shared storage so that different types of I/O transactions go to different types of storage is helpful. Frequently read data, such as VM base images, can be explicitly placed into a separate RAID 1 or RAID 10 array of SSDs. SSDs can also be used as a general read/write cache so that the frequently used data is stored transparently on SSDs. Some amount of learning might be required to train this SSD cache in shared storage.
Data compression and data de-duplication are other possibilities for reducing the amount of data to be stored at the cost of processing power at the server or in the shared storage device. Both of these techniques might also destroy the original meaning of the data, which can make it harder to perform backups or data replication to other sites.

As an alternative to spinning disks and SSDs, all flash memory storage systems solve the IOPS problem but are costly, even for small storage sizes. These flash storage systems tend to be used with other storage devices or optimizations (such as compression or de-duplication) to somewhat improve the cost per user.

RAID also is an important factor when storage is considered. For temporary data that is stored on local SSDs as required by stateless desktops, RAID 0 provides the best performance and capacity. The decision is not so clear for other types of data that need redundancy. It is often a trade-off between drive capacity and drive performance.

With stateless desktops and local SSDs, the remainder of the I/O for folders and profile data tends to be capacity-bound, which means the limit on the disk capacity you need rather than the disk performance. This factor allows the use of a RAID 5 or RAID 50 array for the best compromise on disk storage and disk performance. However, for dedicated desktops, the I/O tends to be performance bound and more drives are needed to give the required IOPS, which often provides more capacity than needed. In this case, RAID 10 is the best option. Some storage systems offer custom RAID levels, which might offer a better compromise than standard RAID levels.

7.6 Networking

There are three types of networking transactions: user, management, and storage.

7.6.1 User and management networking

Regardless of the type of virtual desktop, published desktop, or published application that is implemented, the network plays a critical role, especially for remote and branch office users. If the network bandwidth is not planned properly, users might experience poor performance with their virtual desktop. Therefore, the user experience can degrade as the latency increases and the bandwidth decreases.

Proper network planning must be based on the type of work users are performing and the overall network topology. The bandwidth requirements of delivering a full Windows desktop might be higher than the bandwidth that is required for delivering few applications. This condition exists because a full Windows desktop provides a richer experience with more multimedia and graphical content and is idle less often than when a user is accessing only a few applications.

To better determine user bandwidth requirements of the user VLAN, the user’s activity must be assessed. Estimating bandwidth for office-based applications might result in inadequate performance if users also print and access multimedia content. The percentage of time a user spends working with Microsoft Office based applications, browsing the Internet, accessing videos, and being idle can help in determining the overall required bandwidth. Table 6 lists the bandwidth estimates for different types of workload.
### Table 6. Typical user workload bandwidth estimates

<table>
<thead>
<tr>
<th>Activity</th>
<th>Bandwidth per user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office-based</td>
<td>50 kbps</td>
</tr>
<tr>
<td>Internet</td>
<td>80 kbps</td>
</tr>
<tr>
<td>Printing</td>
<td>600 kbps</td>
</tr>
<tr>
<td>Flash video</td>
<td>200 kbps</td>
</tr>
<tr>
<td>Standard WMV video</td>
<td>500 kbps</td>
</tr>
<tr>
<td>High-definition WMV Video</td>
<td>2000 kbps</td>
</tr>
<tr>
<td>Idle</td>
<td>Based on active application</td>
</tr>
</tbody>
</table>

By estimating the percentage of time for each activity, an overall estimate of average required bandwidth per user can be obtained. Caution must be taken when the average value is used. By averaging out the bandwidth requirements across an entire day and across many users, there might be a lack of bandwidth if many users have a large burst in traffic at the same time. Based on the expected user habits, it is advisable to include bandwidth burst calculations for unexpected bursts of traffic.

Assuming an average bandwidth requirement of 100 - 200 kbps, then 10,000 users need a bandwidth of 1 – 2 Gbps on the user VLAN. The management VLAN is used much less and a general guideline is 0.5 Gbps. The user VLAN and management VLAN can be provided by a single dual-port Emulex 10GbE Virtual Fabric Adapter.

To support networking failover, it is recommended that some kind of link aggregation is used, such as Link Aggregation Control Protocol (LACP). For smaller environments, this configuration might be too complex and it can be sufficient to have spare switch.

#### 7.6.2 Storage networking

The shared storage can be connected to the server nodes in various ways. The four most common ways are 10 GbE file, Internet Small Computer System Interface (iSCSI) that uses 10 GbE, 8 or 16 Gbps Fibre Channel, and FCoE that uses 10 GbE.

The storage network requires the most bandwidth and lowest latency compared to the user and management networks. It is suggested that at least four (and possibly eight) network connections are used going into a shared storage device. Half of the connections go into each storage controller and each storage controller is connected to two different network switches to provide redundancy. This connection strategy provides the best performance if a storage controller or a network fails. If a storage controller and a network fail, there is at least one network connection to handle the load. Redundancy is provided by LACP for 10 GbE networking and dual-zoning fabrics for Fibre Channel.
8 Performance testing

This appendix describes Lenovo’s performance testing methodology, test environment, and tools that were used to verify client virtualization performance for different hardware and software infrastructures. The tests for each of the solutions were conducted in partnership with the product vendors at Lenovo lab facilities.

The lab setup consisted of various ThinkSystem and Flex System servers, combined with a 10 GbE and SAN networking infrastructure and storage products. The individual virtual desktop solutions were installed on top of the described infrastructure. Architecture validation testing was performed by using the test methodology that is described in the following section.

8.1 Performance testing methodology

The key to any successful performance test is to understand what is being measured and how to interpret the results. Client virtualization is a performance-intensive workload that can stress all parts of the system, including processors, memory, storage, networking, and the software infrastructure. To successfully measure the performance, each of these attributes must be stressed in turn to determine its limits.

To understand processor performance and how many desktops can be serviced by processors, the VM server should have access to copious local memory (384 GB or more) and shared storage. The desktop memory size is kept small to fit as many desktops as possible into the local server (1 GB or 1.5 GB). Variables include the use of processors of different clock speeds, different number of cores, or a different number of processors. Only one server is needed per processor performance test as scaling for servers often is linear.

To understand memory performance and how many desktops can be serviced, the VM server should have fast processors and access to sufficient shared storage. Variables include the use of different amounts of memory and desktops with different memory requirements. Only one server is needed per processor performance test as scaling for servers is usually linear.

To understand storage performance and the number of IOPS from a specific storage configuration, the storage configuration is artificially constrained to a smaller array of drives. Variables include the use of different storage technologies local and shared, different speeds of drives, and different RAID levels. Depending on the amount of storage that is allocated, one or more servers might be needed to drive the storage to capacity. It is also advisable to test different storage sizes to verify linear scalability.

To understand networking performance, the network is artificially constrained, where possible. Variables include the use of different networking technologies, different network speeds, and different display protocols, such as RDP, PCoIP, and ICA. This performance test is the most difficult to verify and often many servers are needed to drive the network to capacity.

Performance testing of the software infrastructure was not explicitly performed because this testing is the responsibility of the vendor. Implicit testing was performed as part of other tests, which is also true for validation testing. Potential errors and problems were reported to the vendor as they were found during testing.

The following primary performance metrics were captured by Lenovo’s testing:

- Processor Throughout the testing, the VSImax often was triggered by processor constraints. For more information, see “Login VSI” section on page 44.
- **Memory**  Monitored aspects of memory that is related behavior, such as memory ballooning and swapping that can have a significant effect on the overall system performance.

- **IOPS**  Where appropriate, separate data stores were created for the different storage types (for example, replicas and linked clones) to determine IOPS distribution.

- **Disk latency**  This latency is seen at the device driver level and includes the roundtrip time between the host bus adapter (HBA) and the storage. The *esxtop* command returns the DAVG/cmd metric (average driver milliseconds/command), which provides a good indicator of performance of the backend storage. For more information, see “VMware Esxtop” section on page 46.

- **Network traffic**  Estimate of network bandwidth requirements.

### 8.2 Performance test environment

The performance test environment consists of the following parts:

- Test framework that is used to generate test workload and capture the test results
- Hardware and software configuration that is being tested

Each part is connected by common networking and common services, such as Active Directory, DHCP, DNS, and WINS. Figure 26 shows an example test environment for a Flex System Enterprise Chassis that is connected to shared storage by using 10 GbE iSCSI or a SAN network switch.

*Figure 26: Example test environment*
8.3 Performance test tools

Performance test tools are needed to generate user loads and to monitor and measure the system performance under a particular load. Several different tools were used, including Login Virtual Session Indexer (VSI), and esxtop. It is a good practice to perform multiple runs to verify the consistency of results.

8.3.1 Login VSI

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 (client virtualization). 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 can be used for the following purposes:

- Benchmarking: Make the correct decisions about different infrastructure options that are based on tests.
- Load-testing: Gain insight in the maximum capacity of your current (or future) hardware environment.
- Capacity planning: Decide exactly what infrastructure is needed to offer users an optimal performing desktop.
- Change Impact Analysis: Test and predict the performance effect of every intended modification before its implementation.

Login VSI measures the capacities of virtualized infrastructures by simulating typical (and atypical) user workloads and application usage. Table 7 lists the Login VSI 4.1 workloads.

<table>
<thead>
<tr>
<th>Workload Name</th>
<th>Login VSI Version</th>
<th>Apps Open</th>
<th>CPU Usage</th>
<th>Disk Reads</th>
<th>Disk Writes</th>
<th>IOPS</th>
<th>Memory</th>
<th>vCPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office worker</td>
<td>4.1</td>
<td>5-8</td>
<td>82%</td>
<td>90%</td>
<td>101%</td>
<td>8.1</td>
<td>1.5GB</td>
<td>1vCPU</td>
</tr>
<tr>
<td>Knowledge worker</td>
<td>4.1</td>
<td>5-9</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>8.5</td>
<td>1.5GB</td>
<td>2vCPU</td>
</tr>
<tr>
<td>Power worker</td>
<td>4.1</td>
<td>8-12</td>
<td>119%</td>
<td>133%</td>
<td>123%</td>
<td>10.8</td>
<td>2GB</td>
<td>2vCPU+</td>
</tr>
</tbody>
</table>

The user profiles for the LCV reference architecture and documented in section 7.1 are deliberately named to match these Login VSI workloads.

The VSImax score parameter (the number to indicate user density) is used to determine the performance of a particular system configuration and determine the influence of changes when Login VSI test is rerun on a modified system. Figure 27 shows an example output of the Login VSI Analyzer showing VSImax.
The following parameters and rules are used for Login VSI tests:

- User login interval: 30 seconds (some tests were ran at 15 seconds intervals).
- Workload: Office Worker or Knowledge Worker for most tests.
- 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.

### 8.3.2 Heaven Benchmark

Heaven Benchmark is a GPU-intensive benchmark that stresses graphics cards. Its features include:

- Benchmarking presets for convenient comparison of results
- Support for DirectX 9, DirectX 11 and OpenGL 4.0
- Comprehensive use of hardware tessellation, with adjustable settings
- Support for multi-monitor configurations
- Various stereo 3D modes
- GPU temperature and clock monitoring
- Command line automation support
- Highly customizable reports in CSV format

The Heaven benchmark is used to measure the graphics performance of GPUs by providing an easy to understand frames per second measurement. The following parameters are used to compare the results and
give an indication of the expected relative performance:

- Virtual desktop infrastructure including hypervisor type
- Graphics acceleration option (dedicated, shared or hardware virtualization) – see Table 3 on page 34
- vGPU profile if hardware virtualization is selected – see Table 4 on page 38
- Display resolution
- Image quality (high or ultra)
- Image tessellation (normal or extreme)
- Anti-aliasing (none, 2x, 4x, 8x)

Because the Heaven benchmark is GPU-intensive and places a load similar to a Designer/Engineer user, the results need to be put in context and are best used to compare the relative performance of different scenarios.

### 8.3.3 VMware Esxtop

IOPS distribution and latency are the two most important metrics to be considered in the analysis of storage system. The VMware tool esxtop was used to capture this information for those test scenarios that use the VMware ESXi hypervisor. For more information about interpreting esxtop statistics, see this website:


The esxtop tool was used to capture the results from a test run. Figure 28 shows the command that was used to pipe the esxtop data to a file.

```
% esxtop -h
          [-d delay] [-n iterations]
          [-export-entity entity-file] [-import-entity entity-file]
          -b prints this help menu.
          -v prints version.
          -h enables batch mode.
          -l lists the esxtop objects to those available in the first snapshot.
          -s enables secure mode.
          -a show all statistics.
          -c sets the esxtop configuration file, which by default is .esxtop50rc
          -R enables replay mode.
          -d sets the delay between updates in seconds.
          -n runs esxtop for only n iterations.
          --------------- Experimental Features ---------------
          -export-entity writes the entity ids into a file, which can be modified
          to select interesting entities.
          -import-entity reads the file of selected entities. If this option
          is used, esxtop only shows the data for the selected entities.
```

**Figure 28: esxtop command line and usage**

The esxtop data file is then opened by using Microsoft Performance Monitor, as shown in Figure 29.
Figure 29: Example Microsoft Performance Monitor output from esxtop

The test results for booted desktops often are split into three standard phases (login, steady state, and logoff) to provide a more comprehensive insight into the IOPS patterns across an average user’s desktop session. The maximum and average data points for all relevant performance aspects are extracted and collated into tables for the vendor-specific reference architecture documents.

A value of 20 milliseconds often is considered the threshold for acceptable disk latency. The I/O latency can be verified by comparing the DAVG/cmd metric with the corresponding data from the storage system. If the two measurements are close, the storage array might be faulty or misconfigured. If not, the DAVG/cmd metric should be compared with corresponding data from points in between the storage system and the ESXi Server, such as the FC switches. If this intermediate data also matches DAVG/cmd values, it is likely that the storage is under-configured for the application.
Resources

For more information, see the following resources:

- Reference architecture for Lenovo Client Virtualization with Citrix XenDesktop and ThinkSystem Servers
  
  lenovopress.com/lp0664

- Reference architecture for Lenovo Client Virtualization with VMware Horizon and ThinkSystem Servers
  
  lenovopress.com/lp0663

- Lenovo servers
  
  shop.lenovo.com/us/en/systems/servers/

- Lenovo storage
  
  shop.lenovo.com/us/en/systems/storage/

- Lenovo network switches
  
  shop.lenovo.com/us/en/systems/networking/
Document History

Version 1.0 5 September 2017
- Initial version

Version 1.1 8 January 2018
- Replaced Lenovo RackSwitch G8124E with Lenovo ThinkSystem NE1032 switch
- Added NVidia M10 GPU
- Removed fibre channel switches and SAN networking

Version 1.2 20 June 2018
- Added NVidia P40 GPU

Version 1.3 10 June 2019
- Updated Lenovo thin client devices
Trademarks and special notices

© Copyright Lenovo 2019.

References in this document to Lenovo products or services do not imply that Lenovo intends to make them available in every country.

Lenovo, the Lenovo logo, ThinkCentre, ThinkVision, ThinkVantage, ThinkPlus and Rescue and Recovery are trademarks of Lenovo.

IBM, the IBM logo, and ibm.com are trademarks or registered trademarks of International Business Machines Corporation in the United States, other countries, or both.

Microsoft, Windows, Windows NT, and the Windows logo are trademarks of Microsoft Corporation in the United States, other countries, or both.

Intel, Intel Inside (logos), MMX, and Pentium are trademarks of Intel Corporation in the United States, other countries, or both.

Other company, product, or service names may be trademarks or service marks of others.

Information is provided "AS IS" without warranty of any kind.

All customer examples described are presented as illustrations of how those customers have used Lenovo products and the results they may have achieved. Actual environmental costs and performance characteristics may vary by customer.

Information concerning non-Lenovo products was obtained from a supplier of these products, published announcement material, or other publicly available sources and does not constitute an endorsement of such products by Lenovo. Sources for non-Lenovo list prices and performance numbers are taken from publicly available information, including vendor announcements and vendor worldwide homepages. Lenovo has not tested these products and cannot confirm the accuracy of performance, capability, or any other claims related to non-Lenovo products. Questions on the capability of non-Lenovo products should be addressed to the supplier of those products.

All statements regarding Lenovo future direction and intent are subject to change or withdrawal without notice, and represent goals and objectives only. Contact your local Lenovo office or Lenovo authorized reseller for the full text of the specific Statement of Direction.

Some information addresses anticipated future capabilities. Such information is not intended as a definitive statement of a commitment to specific levels of performance, function or delivery schedules with respect to any future products. Such commitments are only made in Lenovo product announcements. The information is presented here to communicate Lenovo’s current investment and development activities as a good faith effort to help with our customers’ future planning.

Performance is based on measurements and projections using standard Lenovo benchmarks in a controlled environment. The actual throughput or performance that any user will experience will vary depending upon considerations such as the amount of multiprogramming in the user’s job stream, the I/O configuration, the storage configuration, and the workload processed. Therefore, no assurance can be given that an individual user will achieve throughput or performance improvements equivalent to the ratios stated here.

Photographs shown are of engineering prototypes. Changes may be incorporated in production models.

Any references in this information to non-Lenovo websites are provided for convenience only and do not in any manner serve as an endorsement of those websites. The materials at those websites are not part of the materials for this Lenovo product and use of those websites is at your own risk.