Reference Architecture

EMC INFRASTRUCTURE FOR SUPERIOR END-USER COMPUTING EXPERIENCE

Enabled by the EMC XtremIO All-Flash Array, VMware vSphere 5.0, Citrix XenDesktop 5.6, and Citrix Provisioning Services 6.1

EMC Solutions Group

Abstract

This reference architecture highlights the potential of a state-of-the-art end-user computing deployment based on the EMC® XtremIO™ All-Flash array, enabled by Citrix XenDesktop 5.6, Citrix Provisioning Services 6.1, and VMware vSphere 5.0.

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Document purpose

EMC's commitment to consistently maintain and improve quality is led by the Total Customer Experience (TCE) program, which is driven by Six Sigma methodologies. As a result, EMC has built Customer Integration Labs in its Global Solutions Centers to reflect realworld deployments in which TCE use cases are developed and executed. These use cases provide EMC with an insight into the challenges currently facing its customers.

This document describes the reference architecture of the EMC infrastructure for a superior end-user computing (EUC) experience enabled by the EMC® XtremIO™ All-Flash Array, EMC VNX® series, VMware vSphere 5.0, Citrix XenDesktop 5.6, and Citrix Provisioning Services 6.1, which was tested and validated by the EMC Solutions Group.

Introduction to the EMC XtremIO All-Flash Array

The EMC XtremIO All-Flash Array is designed to maximize the use of flash storage media. Key attributes of the XtremIO platform are:

- Incredibly high levels of I/O performance, particularly for random I/O workloads that are typical in virtualized environments
- Consistently low (sub-millisecond) latency
- True inline data reduction—the ability to remove redundant information in the data path and write only unique data on the storage array, thus lowering the amount of capacity required
- A full suite of enterprise array capabilities, such as integration with VMware through VAAI, N-way active controllers, high availability, strong data protection, and thin provisioning

Furthermore, the XtremIO array is a scale-out design, in which additional performance and capacity are added in a building block approach, with all building blocks forming a single clustered system. The following are some of the benefits of the EMC XtremIO platform:

- **Standards-based enterprise storage system**—The XtremIO system interfaces with vSphere hosts using standard Fibre Channel and iSCSI block interfaces, making it drop-in compatible. The system supports complete high-availability features, including support for native VMware multipath I/O, protection against failed SSDs, non-disruptive software and firmware upgrades, no single point of failure (SPOF), and hot-swappable components.
- **Realtime, inline data reduction**—The XtremIO storage system deduplicates desktop images in real time, allowing a massive number of virtual desktops to reside in a small and economical amount of flash capacity. Furthermore, data reduction on the XtremIO array does not adversely affect Input/Output per Second (IOPS) or latency performance; rather it enhances the performance of the end-user computing environment.
- **Scale-out design**—A single X-Brick is the fundamental building block of a scaled out XtremIO clustered system. Virtual desktop deployments can start small (about 1,000 desktops) and grow to nearly any scale required by simply configuring a larger XtremIO cluster. The system expands capacity and

performance linearly as building blocks are added, making EUC sizing and management of future growth extremely simple.

- **VAAI integration**——The XtremIO array is fully integrated with vSphere through vStorage APIs for Array Integration (VAAI). All API commands are supported, including ATS, Clone Blocks/Full Copy/XCOPY, Zero Blocks/Write Same, Thin Provisioning, and Block Delete. This, in combination with the array's inline data reduction and in-memory metadata management, enables nearly instantaneous virtual machine provisioning and cloning and the ability to use large volume sizes for management simplicity.
- **Massive performance**– The XtremIO array is designed to handle very high, sustained levels of small, random, mixed read and write I/O as is typical in virtual desktops, and to do so with consistent extraordinarily low latency.
- **Ease of use**– The XtremIO storage system requires only a few basic setup steps that can be completed in minutes and absolutely no tuning or ongoing administration in order to achieve and maintain high performance levels. In fact, the XtremIO system can be taken from shipping box to deployment readiness in less than an hour.
- **Data center economics**—2,000 or more desktops are easily supported on an X-Brick, requiring just a few rack units of space and approximately 750 W of power.

Solution purpose

The purpose of this reference architecture is to highlight the potential of a state-of-the-art EUC deployment based on XtremIO All-Flash array technology, to build a replica of a common customer end-user computing environment, and to validate the environment for performance, scalability, functionality, and user experience, as measured by concurrent IOPS delivered per desktop. EUC is an I/O intensive application and historically has been challenging to design and deploy successfully, especially at scale. The XtremIO array makes EUC simple in a number of ways, but the three key benefits are:

- As an all-flash array, XtremIO delivers extraordinarily high levels of small random I/O, which is prevalent in EUC. This enhances the virtual desktop user experience through rapid operating system and application response times and eliminates the need to specially prepare desktop images to lower the amount of I/O they drive to the underlying storage.
- With inline data reduction, the XtremIO array is able to fit very high numbers of virtual desktops into a minimal footprint in flash, which makes an all-flash solution economically attractive and drives highly efficient data center operational metrics.
- The XtremIO array leverages several unique capabilities simultaneously to deliver provisioning speeds previously impossible. Rolling out new desktops at scale can be done quickly and easily in a production environment without affecting the user experience on existing live desktops.

Most customers choose to deploy the virtual desktop virtual machines on XtremIO, while maintaining user data (which does not have the same high I/O requirements) on a separate NAS storage system. In this reference architecture, an EMC VNX5500™

platform with multiprotocol support provides Common Internet File System (CIFS)-based storage for the user data.

This reference architecture validates the performance of the solution and provides guidelines to build similar solutions. This document is not intended to be a comprehensive guide to every aspect of this solution.

Business challenge

User experience (how responsively the virtual desktop performs) is critical to successful EUC project rollouts. Today, user experience expectations are increasingly being set based on devices such as ultrabooks and tablets that use flash memory. For example, the rapid application response time of a modern ultrabook notebook computer is due in large part to its use of a SSD. Knowledge workers accustomed to working with an ultrabook that easily peaks over 2,000 IOPS may have performance problems using a virtual desktop that only delivers between 7 and 25 IOPS (the common planning assumption range in previous EUC reference architectures). This can lead to calls to the help desk from unhappy users complaining that performance is unacceptably slow. A modern EUC deployment must deliver a better-than-local desktop user experience, a better cost per desktop relative to a physical machine, and enable IT to continue using existing desktop management tools and applications.

EUC exacerbates this need for higher desktop IOPS by centrally serving potentially tens of thousands of virtual operating systems and applications running concurrently. EUC also introduces its own unique challenges such as boot storms and login storms, which have peak IOPS requirements that often exceed the typical operational parameters of storage arrays. The reasons listed above combined with the desire to build an economical solution have led to sub-par EUC infrastructures, such as those that under size storage and downgrade desktop functionality by disabling various software components, which results in a less desirable user experience.

By using the XtremIO storage system as the foundation for EUC deployments, several unique advantages are created that cannot be achieved with any other EUC deployment architecture:

- **Complete flexibility in EUC deployments**—Administrators can use persistent desktops, non-persistent desktops, or any combination thereof without regard to underlying I/O performance or excessive capacity consumption. The XtremIO platform allows administrators the flexibility to simply do what is right for their business because there is no inherent advantage or disadvantage in performance or cost with either deployment method or any combination of deployment methods.
- **Superior EUC user experience**—Every desktop in an XtremIO deployment gets an all-SSD experience with reliable and massive I/O potential both in sustained IOPS and the ability to burst to much higher levels as dictated by demanding applications such as Microsoft Outlook, desktop search, and antivirus scanning. There is no need for de-featuring desktops anymore, and users can run on fully functional desktops. Even during scale testing, every simulated application operation was completed in half or less of the acceptable user experience boundaries. This performance was superior by a wide margin to any previously tested shared storage array.
- **Lowest cost per virtual desktop**—XtremIO EUC deployments are surprisingly affordable. Due to XtremIO's inline data reduction and massive performance

density, the cost per desktop is lower than with other EUC solutions, allowing virtual desktops to be deployed for less than their physical desktop counterparts.

- **Rapid provisioning and rollout** –XtremIO is simple to set up and requires no tuning, any EUC deployment model can be chosen at will, and complex planning is eliminated. EUC deployments can be designed and rolled out quickly with assured success.
- **No need for third-party tools**—XtremIO solves all I/O related EUC deployment challenges. There is no need for additional caching or host-based deduplication schemes, or any other point solutions that increase expense and complexity.
- **No change to desktop administration**—Whatever methods administrators are using to manage their existing physical desktops can be directly applied to the EUC deployment when XtremIO is used. No changes to software updates, operating system patching, antivirus scanning, or other procedures need to be made in order to lighten the I/O load on shared storage. Rather, administrators can confidently rely on XtremIO's high performance levels to deliver.
- **No change to desktop features**–Virtual desktop best practices currently dictate dozens of changes to the desktop image to reduce the I/O load on the shared storage. None of these changes are required with XtremIO, allowing the desktop to remain fully functional while maintaining a strong user experience.

Solution benefits

This solution aids in the design and successful deployment of virtual desktops on Citrix XenDesktop 5.6 and Citrix Provisioning Services 6.1. This solution gives the ultimate in performance, while at the same time delivering a highly attractive cost per desktop—not just for storage, but for the overall infrastructure.

Desktop virtualization enables organizations to exploit additional benefits such as:

- Increased security by centralizing business-critical information
- Increased compliance as information is moved from endpoints into the data center
- Simplified and centralized management of desktops

Customers will realize:

- A user experience that is superior to that of a physical desktop equipped with a dedicated SSD.
- Increased control and security of their global, mobile desktop environment, typically their most at-risk environment.
- Better end-user productivity with a more consistent environment.
- Simplified management with the environment contained in the data center.
- Better support of service-level agreements and compliance initiatives.
- Lower operational and maintenance costs.

Solution architecture

Architecture diagram

This document provides a summary and characterization of the tests performed to validate the EMC infrastructure for a superior EUC experience enabled by the EMC XtremIO All-Flash Array, EMC VNX Series, VMware vSphere5.0, Citrix XenDesktop 5.6, and Citrix Provisioning Services 6.1. It involves building a 2,500-seat Citrix XenDesktop environment on XtremIO and integrating the new features of this platform to provide a high performance, compelling, and cost-effective EUC platform. An optional VNX 5500 was used to provide CIFS services for user data and profile storage.

Figure 1 depicts the overall physical architecture of the solution.

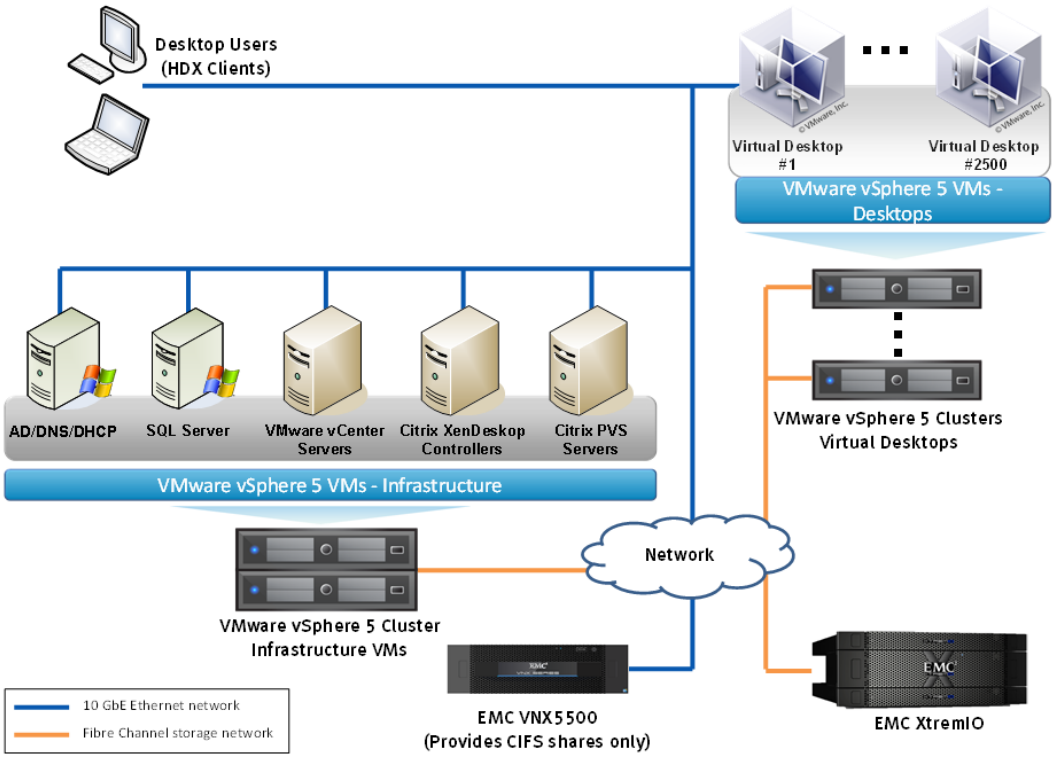

Figure 1. Physical architecture

Reference architecture overview

The reference architecture consists of the following components.

- **EMC XtremIO platform**—Provides storage for Windows 7 virtual machine image files by using FC connections to vSphere hosts.
- **EMC VNX5500 platform**—Provides storage by using IP (NAS) connections for CIFS-based shares hosting user data.
- **VMware vSphere 5.0 server**—A two-node VMware vSphere 5.0 cluster is used to host infrastructure virtual machines. Three additional VMware vSphere 5.0 clusters are used to host 2,500 virtual desktops.

- **VMware vCenter Server 5.0**—Provides a scalable and extensible platform that forms the foundation for virtualization management for the VMware vSphere 5.0 clusters.
- **Citrix XenDesktop 5.6 controller**—Three Citrix XenDesktop 5.6 controllers provide redundant virtual desktop delivery, authenticate users, manage the assembly of users' virtual desktop environments, and broker connections between users and their virtual desktops. In this reference architecture, the controllers are installed on Windows Server 2008 R2 and hosted as virtual machines running on vSphere hosts.
- **Citrix Provisioning Services 6.1 servers**—Five Provisioning Services 6.1 servers are used to provide a redundant software-streaming technology to enable virtual desktops to be provisioned and re-provisioned in real time from a single shared-disk image. In this reference architecture, the Citrix Provisioning Services (PVS) servers are installed on Windows Server 2008 R2 and hosted as virtual machines running on vSphere hosts. Each PVS server is configured with four virtual CPUs, 20 GB of RAM, and sufficient additional disk space to host the master virtual desktop vDisk.
- **Virtual desktops**—Citrix Provisioning Services creates 2,500 virtual desktops running Windows 7.
- **Cisco Nexus 5020 switches**—Two Cisco Nexus 5020 switches are used to provide high port density, wire-speed performance, and extremely low latency that meet the growing demand for a 10-gigabit Ethernet network.
- **Microsoft Windows 2008 R2 domain controller and Domain Name System (DNS) server**—The Windows 2008 R2 domain controller provides Active Directory services to manage the identities and relationships that constitute the Windows environment for the virtual desktops. The DNS component of the Windows network infrastructure is also installed on this server, which is hosted as a virtual machine on a VMware vSphere 5.0 server.
- **Microsoft Windows 2008 R2 dynamic host configuration protocol (DHCP) server**—Centrally manages the IP address scheme for virtual desktops. This service is hosted on the same virtual machine as the domain controller and DNS server.
- **Microsoft SQL Server 2008 R2**—The Citrix XenDesktop Controllers, Citrix Provisioning Servers, and VMware vCenter Server require database services to store configuration details. Microsoft SQL Server 2008 is used for this purpose. This server is hosted as a virtual machine on a VMware vSphere5.0 server.
- **10-gigabit IP network**—The Ethernet network infrastructure provides 10-gigabit connectivity to the VNX storage. The 10-gigabit infrastructure allows guest virtual machines on the vSphere servers to access CIFS datastores on VNX5500 with high bandwidth and low latency.

XtremIO network layout overview

Figure 2 shows the 8 Gbps Fibre Channel connectivity between the Cisco Nexus 5020 switches and the EMC XtremIO array. In this solution, the 8 Gbps Fibre Channel ports on Cisco Nexus 5020 switches are used to extend Fibre Channel connectivity to the vSphere hosts.

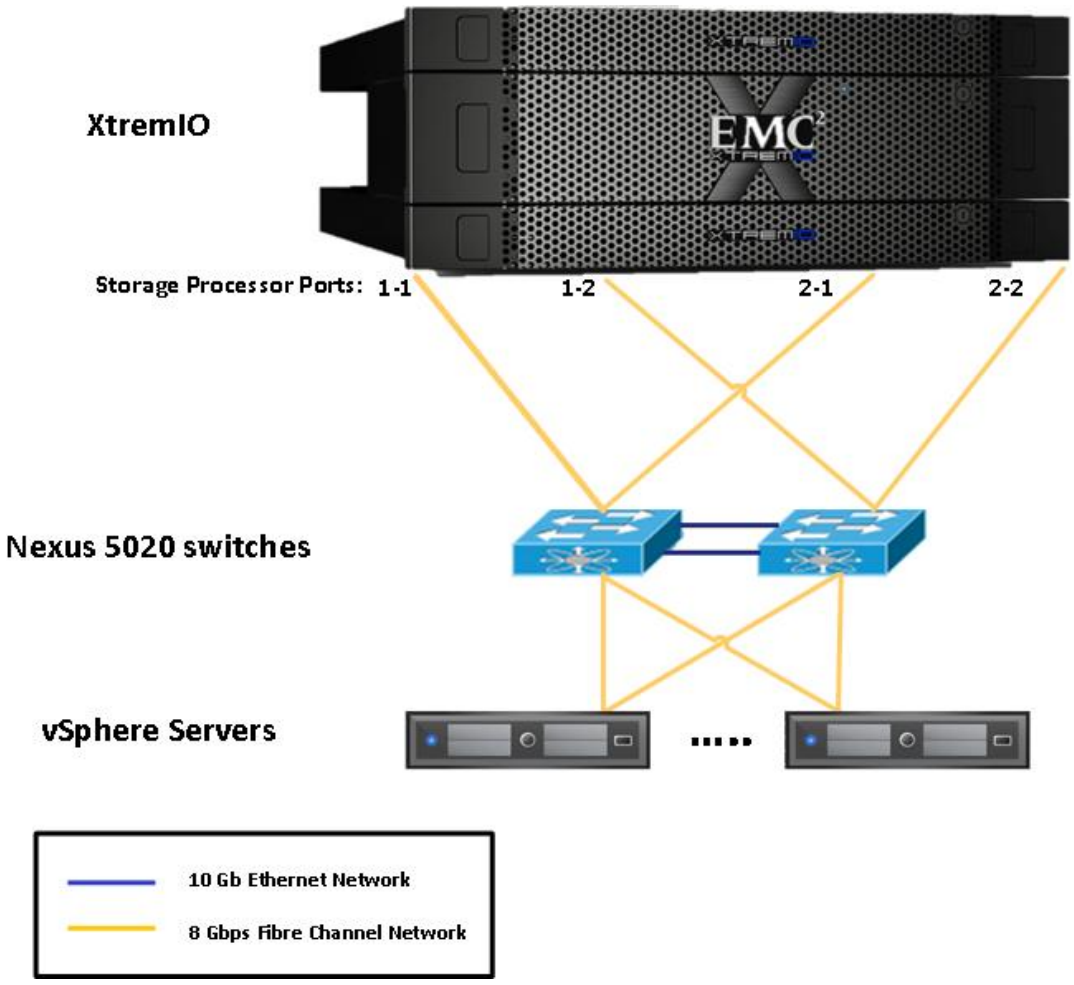

Figure 2. Network layout diagram

XtremIO storage layout overview

The EMC XtremIO array is configured with the following LUNs for desktop and infrastructure storage:

- Twenty 1.25 TB LUNs for desktop storage. Each LUN is used to store 125 desktops. XtremIO supports the VAAI ATS primitive, thereby enhancing desktop performance.
- One 2 TB LUN for infrastructure server storage.

Table 1 lists the storage requirements of the PVS virtual desktops.

Table 1. Storage requirements

Item	Capacity (GB)	Number of items	Total capacity (GB)
Single provisioned vDisk	16	1	16
Personal vDisk (PVD)	9 per PVD	2,500	22,500
Write cache	3 per write cache	2,500	7,500
Total			**30,016 GB**

The virtual disk that hosts the PVS Personal vDisk file is provisioned in a thick format by the PVS platform. The vdbench test file is stored on this disk to allow it to persist when the desktops are restarted between tests. The virtual disk that hosts the PVS write cache is provisioned in a thin format. The write caches achieve an optimal footprint on XtremIO by virtue of XtremIO's true inline data reduction, thus enabling customers to provision thousands of XenDesktops very efficiently on XtremIO.

Figure 3 shows the LUN configuration in the EMC XtremIO user interface, as well as the LUN Mapping for one of the two Initiator Groups. Initiator Groups are composed of vSphere host FC World Wide Names (WWNs), and in the example each group contains the WWNs of the hosts in the indicated vSphere cluster.

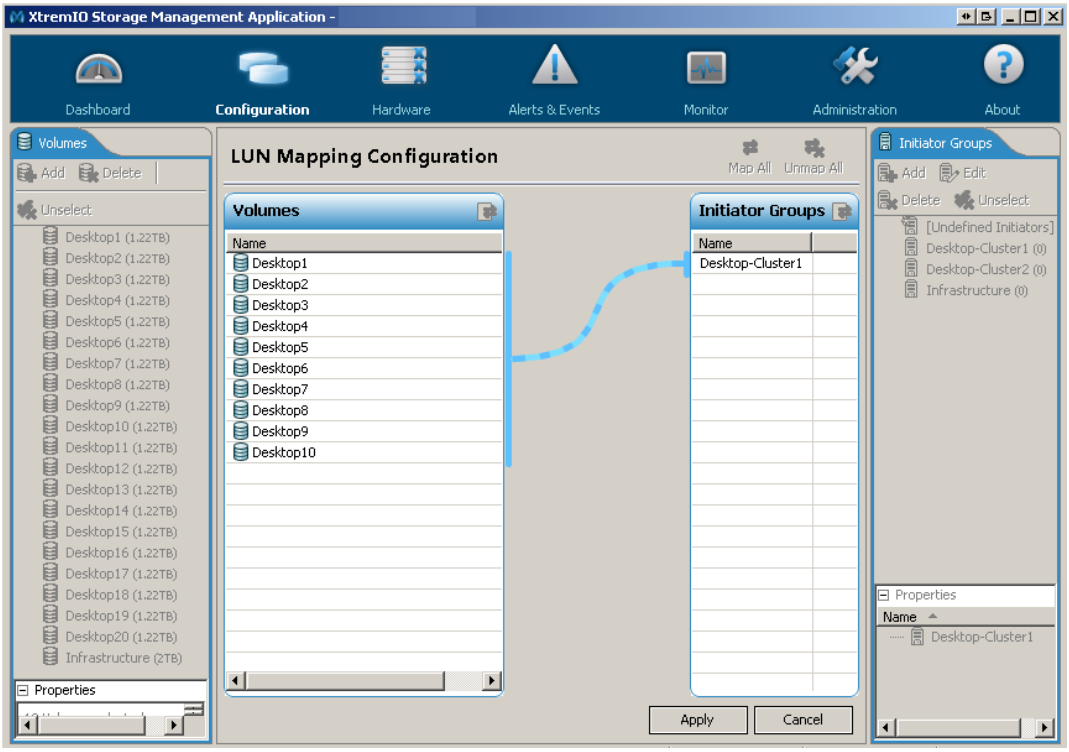

Figure 3. EMC XtremIO LUN configuration and zoning

VNX shared file systems

Virtual desktops use four shared file systems—two for user profiles and two to redirect user storage that resides in home directories. In general, redirecting users' data out of the base image to VNX for File enables centralized administration, backup, and recovery, and makes the desktops more stateless. Each file system is exported to the environment through a CIFS share.

Host network configuration

All Ethernet network interfaces on the vSphere servers in this solution use 10 Gb connections. All virtual desktops are assigned IP addresses by using a DHCP server. The Intel-based servers use two onboard 10 GbE Ethernet controllers and two 4 Gb FC controllers.

Figure 4 shows the vSwitch configuration in vCenter Server.

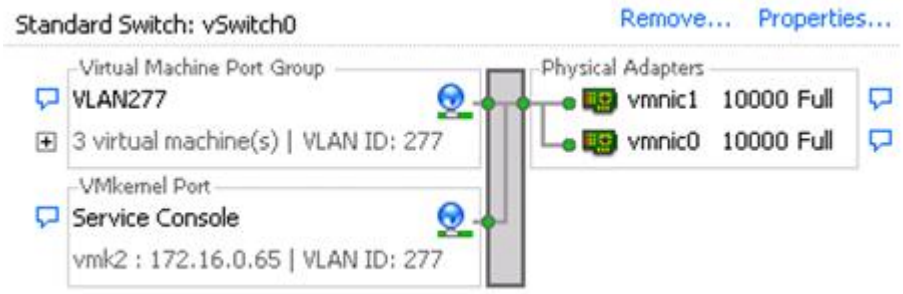

Figure 4. vSwitch configuration in vCenter Server

Table 2 lists the port groups configured on vSwitch0.

Table 2. Port groups configured on vSwitch0

Virtual switch	Configured port groups	Used for
vSwitch0	Service console	VMkernel port for vSphere host management
vSwitch0	VLAN277	Network connection for virtual desktops and LAN traffic

Key components

Introduction

This section briefly describes the key components of this solution:

- EMC XtremIO All-Flash Array
- Citrix XenDesktop 5.6
- Citrix Personal vDisk
- Citrix Profile Management
- Citrix Provisioning Services 6.1
- VMware vSphere 5.0
- EMC Virtual Storage Integrator for VMware vSphere
- EMC VNX series

Hardware and software resources provides more information about the components that make up the solution.

EMC XtremIO All-Flash Array

The EMC XtremIO All-Flash Array is a scale-out clustered design, in which additional capacity and performance can be configured to meet any requirement. Each cluster building block is itself a high-availability, high-performance, fully active/active storage system with no SPOF. With multiple building blocks forming a cluster, XtremIO automatically stays in balance so all desktops benefit from the entire performance potential of the cluster at all times.

The XtremIO storage cluster is managed by XtremIO Operating System (XIOS), XtremIO's powerful operating system. XIOS ensures that the system remains balanced and always delivers the highest levels of performance without any administrator intervention.

- XIOS ensures that all solid state drives (SSDs) in the system are evenly loaded, providing both the highest possible performance as well as endurance that stands up to demanding workloads for the entire life of the array.
- XIOS eliminates the need to perform the complex configuration steps found on traditional arrays. There is no need to set RAID levels, determine drive group sizes, set stripe widths, set caching policies, build aggregates, or do any other such configuration.
- With XIOS, every volume is automatically and optimally configured at all times. I/O performance on existing volumes and data sets automatically increases with large cluster sizes. Every volume is capable of receiving the full performance potential of the entire XtremIO system.

Citrix XenDesktop 5.6

Citrix XenDesktop delivers Windows desktops as an on-demand service to any user, any device, anywhere. Powered by Citrix HDX technologies, XenDesktop quickly and securely delivers any type of virtual desktop or any type of Windows, web, or software-as-a-service (SaaS) application to any of the latest PCs, Macs, tablets, smart phones, laptops, and thin clients with a high-definition user experience.

Citrix FlexCast delivery technology enables IT to optimize the performance, security, and cost of virtual desktops for any type of user, including task workers, mobile workers, power users, and contractors. XenDesktop helps IT rapidly adapt to business initiatives by simplifying desktop delivery and enabling user self-service. The open, scalable, and proven architecture simplifies management, support, and integration.

Citrix Personal vDisk

Citrix XenDesktop 5.6 introduces the Personal vDisk feature, which allows users to preserve customization settings and user installed applications in a pool-based desktop. This is accomplished by redirecting the changes from the user's pooled virtual machine to a separate disk called personal vDisk. During runtime, the content of the personal vDisk is blended with the content from the base virtual machine to provide a unified experience to the end user. The personal vDisk data is preserved during the restart and refresh operations.

Citrix Profile Management

Citrix Profile Manager 4.1 preserves user profiles and dynamically synchronizes them with a remote profile repository. Citrix Profile Manager does not require the configuration of Windows roaming profiles, eliminating the need to use Active Directory to manage Citrix user profiles.

Citrix Profile Manager provides the following benefits over traditional Windows roaming profiles:

- With Citrix Profile Manager, a user's remote profile is dynamically downloaded when the user logs in to a XenDesktop desktop. XenDesktop downloads persona information only when the user needs it.
- The combination of Citrix Profile Manager and pooled desktops provides the experience of a dedicated desktop, while potentially minimizing the amount of storage required in an organization.

Citrix Provisioning Services 6.1

Citrix Provisioning Services (PVS) takes a very different approach from traditional desktop imaging solutions by fundamentally changing the relationship between hardware and the software that runs on it. By streaming a single shared-disk image (using vDisk) instead of copying images to individual machines, PVS enables organizations to reduce the number of disk images that they manage. As the number of machines continues to grow, PVS provides the efficiency of a centralized management with the benefits of distributed processing.

As machines stream the disk data dynamically in real time from a single shared-disk image, the machine image consistency is ensured. In addition, the configuration, applications and even OS of large pools of machines can change completely during the restart operation.

VMware vSphere 5.0

VMware vSphere 5.0 is the market-leading virtualization platform that is used across thousands of IT environments around the world. VMware vSphere 5.0 can transform or virtualize computer hardware resources including CPU, RAM, hard disks, and network controllers to create a fully functional virtual machine that runs its own operating system and application just like a physical computer.

The high-availability features of VMware vSphere 5.0, along with Distributed Resource Scheduler (DRS) and Storage vMotion, enable seamless migration of virtual desktops from one vSphere server to another with minimal or no impact to the customer.

EMC Virtual Storage Integrator for VMware vSphere

EMC Virtual Storage Integrator (VSI) for VMware vSphere is a plug-in to the vSphere Client that provides a single management interface to manage EMC storage within the vSphere environment. Features can be added and removed from VSI independently, which provides flexibility to customize VSI user environments. The features are managed by using the VSI Feature Manager. VSI provides a unified user experience that enables new features to be introduced rapidly in response to changing customer requirements.

The following features were used during the validation testing:

- Storage Viewer (SV)—Extends the vSphere client to facilitate the discovery and identification of EMC VNX storage devices that are allocated to VMware vSphere hosts and virtual machines. SV presents the underlying storage details to the virtual datacenter administrator, merging the data of several different storage mapping tools into a few seamless vSphere client views.
- Unified Storage Management—Simplifies storage administration of the EMC VNX platforms. It enables VMware administrators to provision new network file system (NFS) and virtual machine file system (VMFS) datastores and raw device mapping (RDM) volumes seamlessly within the vSphere client.

The EMC VSI for VMware vSphere product guides available on the EMC Online Support website provide more information.

EMC VNX series

The EMC VNX series is a dedicated network server optimized for file and block access that delivers high-end features in a scalable and easy-to-use package.

The VNX series delivers a single-box block and file solution, which offers a centralized point of management for distributed environments. This makes it possible to dynamically grow, share, and cost-effectively manage multiprotocol file systems and provide multiprotocol block access. Administrators can take advantage of the simultaneous support for NFS and CIFS protocols by enabling Windows and Linux/UNIX clients to share files by using the sophisticated file-locking mechanism of VNX for file and VNX for block for high-bandwidth or for latency-sensitive applications.

High availability and failover

Introduction

This solution provides a highly available virtual desktop infrastructure. Each component is configured to provide a robust and scalable solution for the host layer, connectivity layer, and storage layer.

Storage layer

The EMC XtremIO array delivers the best in reliability and availability with completely redundant components and the ability to tolerate any component failure without loss of service. Fault protection includes (but is not limited to):

- Dual power supplies in controllers and disk array enclosures (DAEs) to support loss of a power supply, while keeping the controller/DAE in service
- Redundant active/active controllers to support controller failures
- Redundant SAS interconnect modules in the DAEs
- Redundant inter-controller communication links
- Multiple host connections with multipath capabilities to survive path failures
- XtremIO Data Protection (XDP) to tolerate SSD failures
- Multiple techniques to ensure initial and ongoing data integrity

Host layer

The application hosts have redundant power supplies and network connections to reduce the impact of component failures in the vSphere servers. VMware high availability (HA) is configured on the cluster to help recover virtual desktops quickly in case of a complete host failure.

Validated environment profile

Profile characteristics

Table 3 provides the environment profile used to validate the solution.

Table 3. Profile characteristics

Profile characteristic		Value
Number of virtual desktops		2,500
Virtual desktop OS		Windows 7 Enterprise SP1 (32-bit)
CPU per virtual desktop		1 vCPU
Number of virtual desktops per CPU core		7.81
RAM per virtual desktop		1 GB
Average storage available for each virtual desktop		2 GB
Average IOPS per virtual desktop at steady state		Varied based on test configuration
Average peak IOPS per virtual desktop during boot storm		40
Number of datastores used to store PVS desktops		20
Number of virtual desktops per datastore		125
Disk and RAID type for datastores		• 400 GB eMLC SSD drives • EMC XtremIO proprietary data protection XDP that delivers RAID 6-like data protection but better than the performance of RAID 10
Disk and RAID type for CIFS shares to host user profiles and home directories		RAID 6, 2 TB, 7,200 rpm, 3.5-in NL-SAS disks
Number of VMware clusters		4
Number of vSphere servers in each cluster		6
Number of virtual desktops in each cluster		833
Citrix PVS Server resources (each)	vCPUs	4
	RAM	20 GB
	Total disk space	64 GB

Hardware and software resources

Hardware resources

Table 4 lists the hardware used to validate the solution.

Table 4. Hardware details

Hardware	Quantity	Configuration	Notes
EMC XtremIO	1	1 x X-Brick • 25 x 400 GB eMLC SSD drives	Shared storage for virtual desktops and infrastructure servers.
EMC VNX5500	1	2 x Data Movers (active/passive) 3 x DAEs configured with: • 6 x 300 GB, 15k rpm 3.5-inch SAS disks • 34 x 2 TB, 7,200 rpm 3.5-inch NL-SAS disks	Optional VNX shared storage for user home directories and profiles.
Intel-based servers	20	• Memory: 144 GB of RAM • CPU: 2 x Intel Xeon E7-2870 with 2.40 GHz deca-core processors • Internal storage: 1 x 146 GB internal SAS disk • External storage: XtremIO (FC) • NIC: Dual-port 10 GbE adapter • FC HBA: Dual-port 8 Gbps adapter	18 servers—vSphere desktop clusters 1 to 3. 2 servers—vSphere cluster to host infrastructure virtual machines.
Cisco Nexus 5020	4	40 x 10 Gb ports	Redundant LAN A/B configuration

Software resources

Table 5 lists the software used to validate the solution.

Table 5. Solution software

Software	Configuration
XtremIO (FC-connected shared storage for vSphere datastores)	
XtremIO XIOS Operating System	Release 1.05
VNX5500 (CIFS file systems)	
VNX OE for File	Release 7.0.40.0
VNX OE for Block	Release 31 (05.31.000.5.502)
VSI for VMware vSphere: Unified Storage Management	Version 5.0.0.61
VSI for VMware vSphere: Storage Viewer	Version 5.0
Cisco Nexus	
Cisco Nexus 5020	Version 4.2(1)N1(1)
vSphere servers	
vSphere	5.0.0 (474610)
vCenter Server	
OS	Windows 2008 R2 SP1
Citrix XenDesktop	
XenDesktop Controller	5.6
Citrix Provisioning Services	
Provisioning Services	6.1
Virtual desktops **Note:** This software is used to generate the test load.	
OS	MS Windows 7 Enterprise SP1 (32-bit)
VMware tools	8.6.0 build-425873
Microsoft Office	Office Enterprise 2007 (Version 12.0.6562.5003)
Internet Explorer	8.0.7601.17514
Adobe Reader	9.1.0
McAfee Virus Scan	8.7 Enterprise
Adobe Flash Player	11
Bullzip PDF Printer	6.0.0.865
Login VSI (EUC workload generator)	3.7 Professional Edition

Test results

Introduction

The EMC Solutions Group performed several tests to assess how the EMC XtremIO array performed during periods of heavy load. The tools used included:

- Login Virtual Session Index (VSI)—Used to simulate user workloads.
- Vdbench—Used within each Login VSI desktop session to generate additional I/Os. Vdbench complements Login VSI to create a real-life knowledge worker workload, heavy in random I/Os, to the storage subsystem.

This section provides a more detailed description of each of these tools.

Login VSI

VSI version 3.7 was used to run a user load on the desktops. VSI provided the guidance to gauge the maximum number of users that a desktop environment can support. The Login VSI workload is categorized as light, medium, heavy, multimedia, core, and random (also known as workload mashup). A medium workload that was selected for this testing had the following characteristics:

- The workload emulated a medium knowledge worker who used Microsoft Office Suite, Internet Explorer, Adobe Acrobat Reader, Bullzip PDF Printer, and 7-zip.
- After a session started, the medium workload repeated every 12 minutes.
- The response time was measured every two minutes during each loop.
- The medium workload opened up to five applications simultaneously.
- The type rate was 160 ms for each character.
- Approximately two minutes of idle time was included to simulate real world users.

Each loop of the medium workload used the following applications:

- Microsoft Outlook 2007—Browsed 10 email messages.
- Microsoft Internet Explorer (IE)—On one instance of IE, the BBC.co.uk website was opened, another instance browsed Wired.com, Lonelyplanet.com, and another instance opened a flash-based 480p video file.
- Microsoft Word 2007—One instance of Microsoft Word 2007 was used to measure the response time, while another instance was used to edit a document.
- Bullzip PDF Printer and Adobe Acrobat Reader—Printed the Word document to PDF and reviewed.
- Microsoft Excel 2007—Opened a very large Excel worksheet and performed random operations.
- Microsoft PowerPoint 2007—Reviewed and edited a presentation.
- 7-zip—Using the command line version, the output of the session was zipped.

For additional information about Login VSI, visit the Login VSI website.

Vdbench

Vdbench is an open source workload generator that can be used to generate a sustained and consistent I/O rate based on the parameters that you provide. Vdbench was launched within each Login VSI session by adding the required parameters to the Login VSI user login script. Several different I/O rates and read/write ratios were tested in order to assess the performance of the EMC XtremIO array under a variety of conditions. This is a very important test parameter that was introduced to complement Login VSI and stress the storage subsystem by mimicking real-life heavy knowledge worker activity.

For additional information about Vdbench, visit http://sourceforge.net/projects/vdbench.

I/O mix

The EMC Solutions Group deliberately chose a range of write-heavy I/O to mimic the workload of knowledge workers, who typically create content and run write-heavy desktop applications. Furthermore, any shared storage solution like XtremIO will naturally receive a write heavy workload in PVS deployments, since the PVS servers act as a read cache. In this solution, the PVS write cache is stored on shared LUNs hosted on the EMC XtremIO array.

Test results

The following is a summary of the test results, measured on a per-desktop basis. For each I/O rate and write percentage listed, the Login VSI test passed and vSphere datastore latencies remained below one millisecond. The IOPS were measured during the Login VSI steady state period, which is when all desktops have logged in and are executing the test at the same time. These tests results do not represent the only I/O rates and read/write ratios that the EMC XtremIO array will support, but merely the results of the tests that were performed.

The graphs in Figure 5 through Figure 8 show the total I/O served by the EMC XtremIO array during the test and the ESXi datastore latency measured using ESXTOP within one of the desktop vSphere hosts. The ratio of reads to writes is also provided. Each graph shows the increase in I/O as each additional desktop is logged in. During this period, Login VSI logged in a new user session approximately once every 1.4 seconds.

IMPORTANT: The test results that follow were generated on a single XtremIO X-Brick (the minimum system configuration). As a scale-out clustered design, higher performance supporting larger numbers of virtual desktops (beyond the 2,500 tested here) is simply a matter of specifying a larger XtremIO cluster.

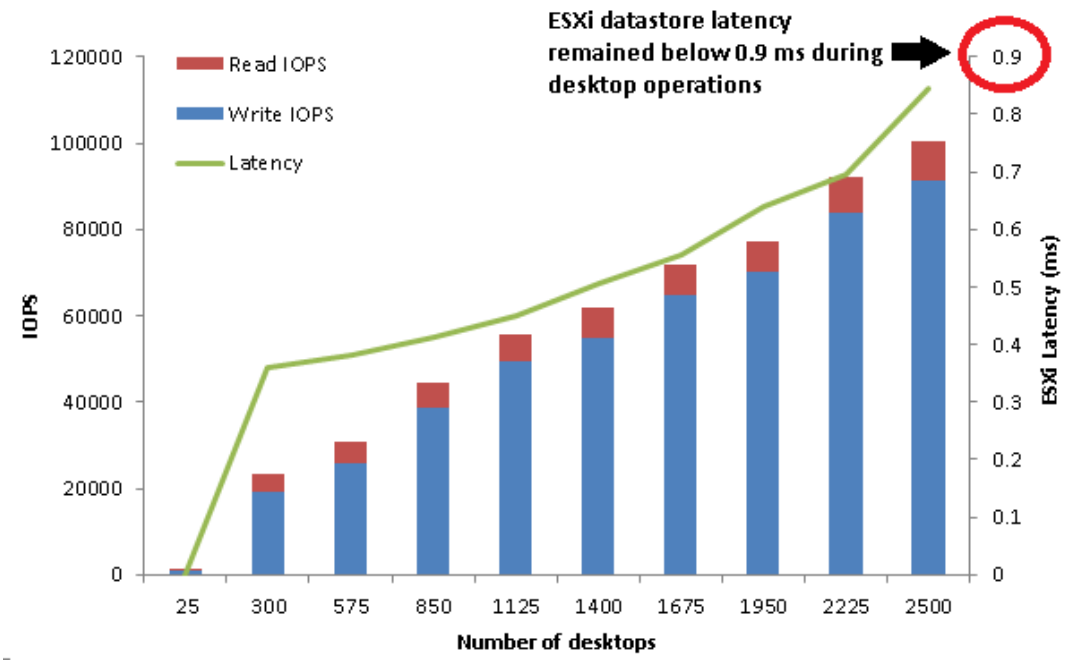

Figure 5. Test 1: 39.6 IOPS per desktop at 92 percent writes

During this test the desktops generated an average of 39.6 IOPS each, of which 92 percent were writes. vSphere datastore latency remained below 0.9 ms during desktop operations.

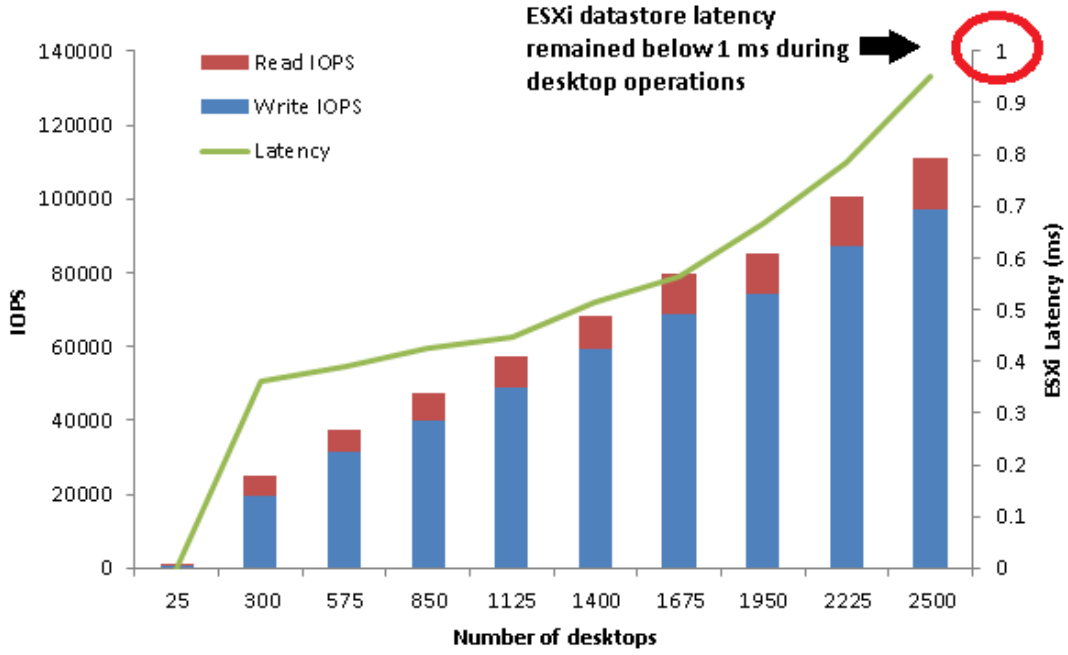

Figure 6. Test 2: 44.0 IOPS per desktop at 85percent writes

During this test the desktops generated an average of 44.0 IOPS each, of which 85percent were writes. vSphere datastore latency remained below 1 ms during desktop operations.

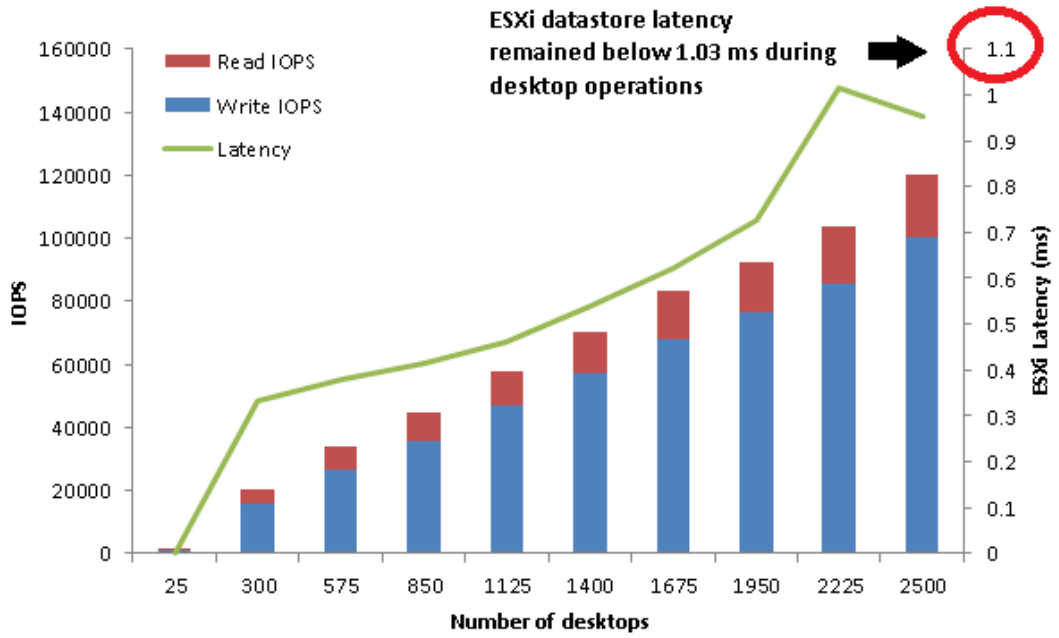

Figure 7. Test 3: 47.4 IOPS per desktop at 82percent writes

During this test the desktops generated an average of 47.4 IOPS each, of which 82percent were writes. vSphere datastore latency remained below 1.03 ms during desktop operations.

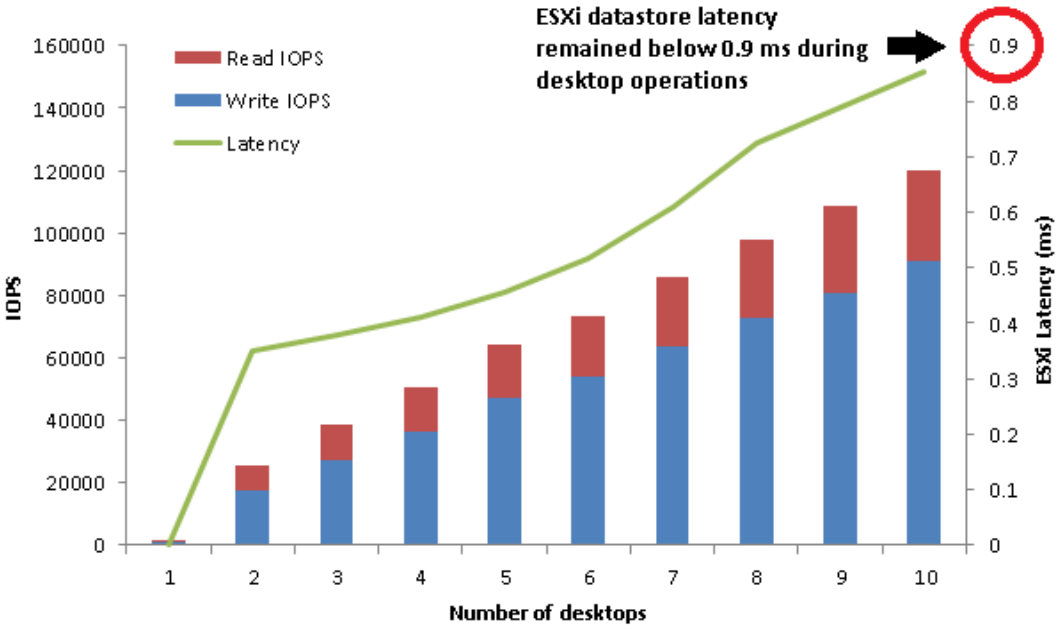

Figure 8. Test 4: 47.4 IOPS per desktop at 75percent writes

During this test the desktops generated an average of 47.4 IOPS each, of which 75percent were writes. vSphere datastore latency remained below 0.9 ms during desktop operations.

The significant conclusion from these test runs is that even in the worst case, XtremIO delivers desktop performance that far surpasses the typical EUC planning assumptions. In a world of flash-based devices such as ultrabooks, tablets, and smartphones, XtremIO's performance allows the EUC user experience to match or exceed modern computing devices.

Ease of administration

The EMC XtremIO array is easily configured, enabling new volumes to be created and associated with clients in just three simple steps:

1. Create an initiator group containing the clients that need access to the array, as shown in Figure 9.

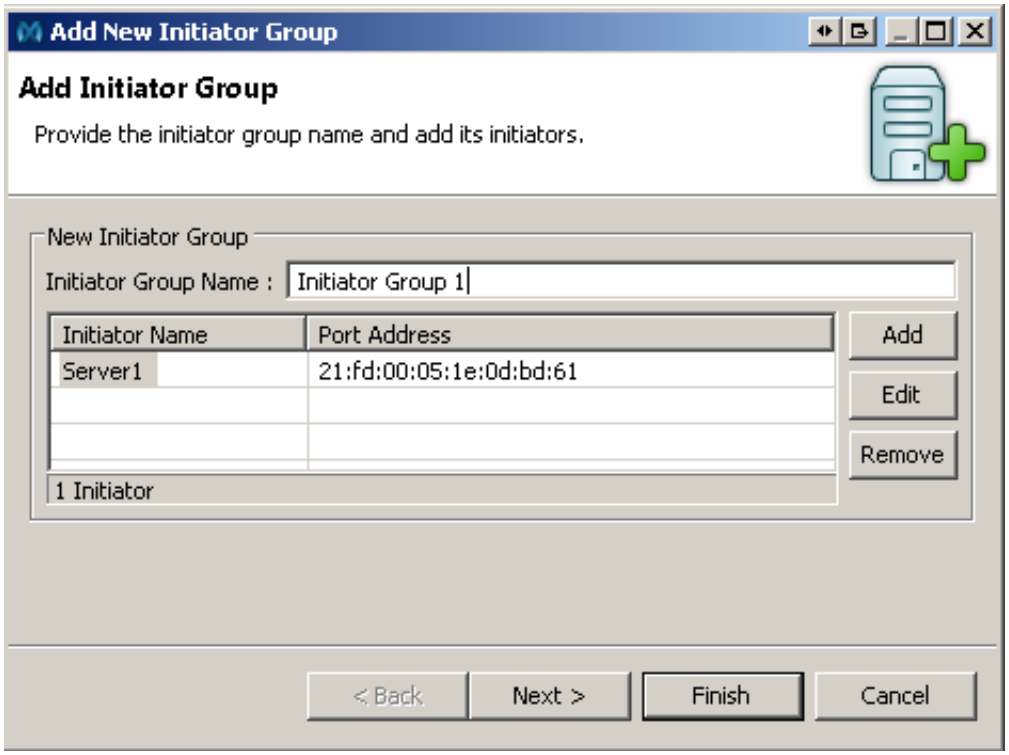

Figure 9. Create an Initiator Group

2. Create a volume of the required size, as shown in Figure 10.

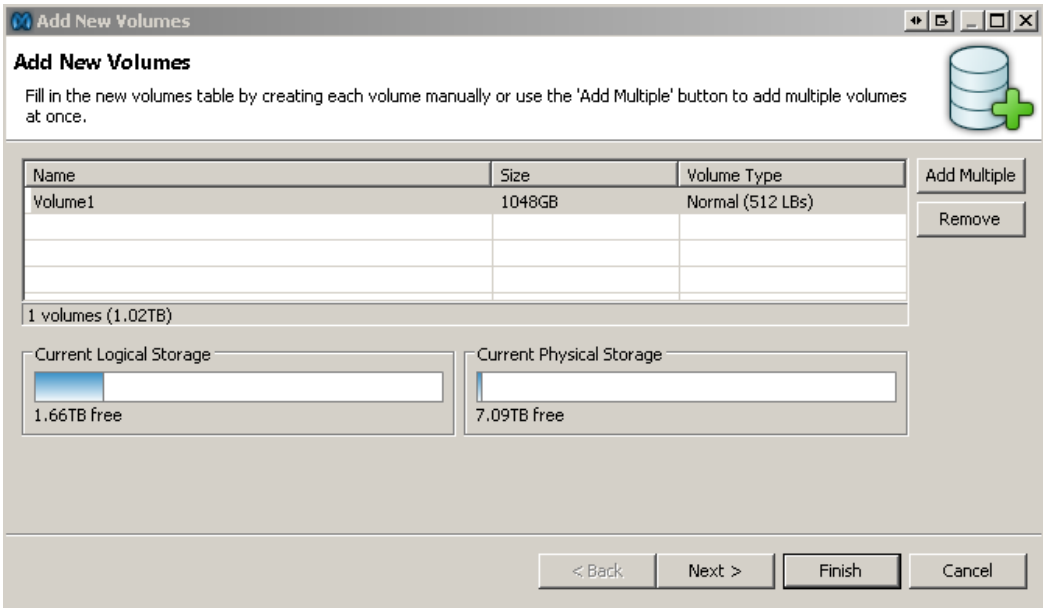

Figure 10. Create a volume

3. Follow the steps shown in Figure 11: Select the volume (1) and initiator group (2), click Map All (3), and then click Apply (4). The volume is now available to the hosts in the selected initiator group.

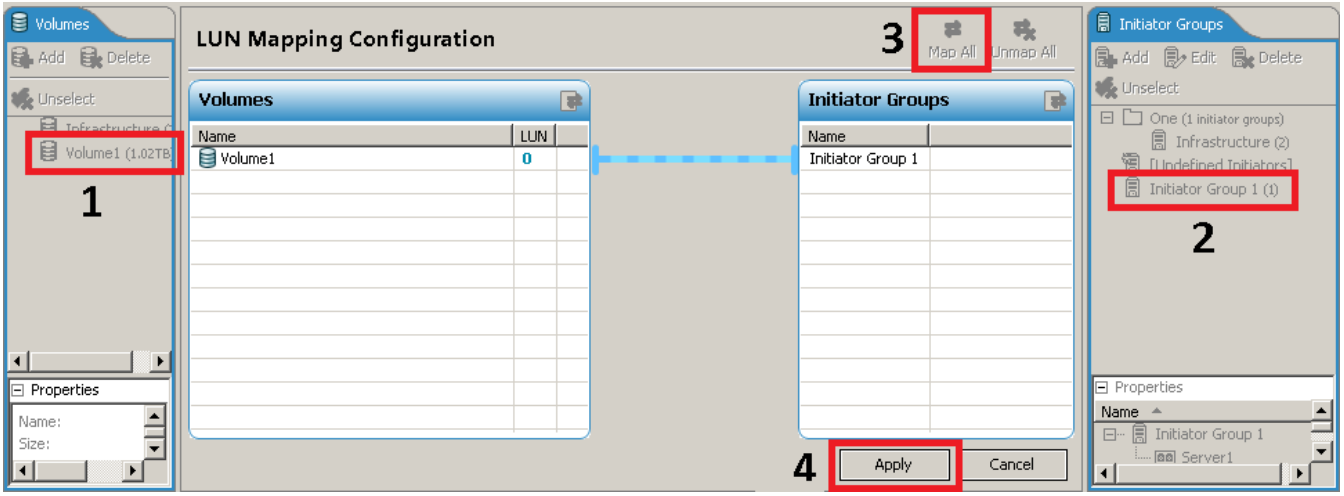

Figure 11. Map the Volume

Deduplication benefits

During the testing, the EMC XtremIO array required an average of only 400 MB of disk space per virtual desktop. This represents a space savings of over 90percent compared to an array without deduplication capabilities.

During the testing, the Vdbench software created a unique 6 GB file on each virtual desktop, which adversely affects the deduplication rate observed on the array. Due to this, it is important to remember that actual deduplication ratios will vary from one environment to the next.

Boot storms

A boot storm was performed to observe the performance of the array when all desktops are powered on at the same time. The architecture of PVS generates a unique I/O pattern, compared to traditional full clone or linked clone virtual desktops, because a significant amount of the desktop image is read over the network from RAM on the PVS servers, rather than from the storage array.

During the boot storm operation, over 100,000 IOPS were observed on average and vSphere datastore latency reached a peak of 60.4 ms. The boot storm operation for 2,500 desktops concluded in approximately 9 minutes, as shown in Figure 12.

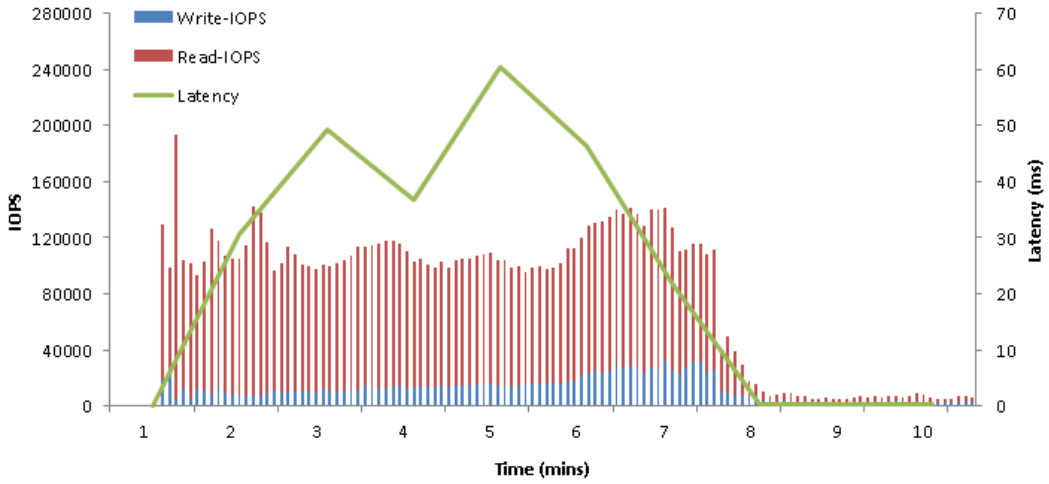

Figure 12. Boot storm IOPS and Latency

Test summary

The testing revealed the following:

- Based on the test results, the EMC XtremIO array is capable of delivering outstanding user experience to each virtual desktop user by servicing I/O at sub-millisecond latency at high I/O levels for 2,500 PVS desktops across a wide variety of desktop workloads.
- As the IOPS read/write ratio changes, there is virtually no change in the EMC XtremIO's responsiveness. The EMC XtremIO array does not require any system level post process garbage collection, nor does XtremIO exclusively lock SSDs being written to—both commonly implemented in all-flash arrays. As a result XtremIO is able to provide consistent performance for any mix of R/W IOPS.
- There is no degradation in the user experience of the virtual desktops over time as they fill up and must overwrite existing capacity in the array. Citrix XenDesktop stakeholders (including end users, storage administrators, virtualization administrators, and desktop administrators) benefit from XtremIO's predictable, consistent performance over time.
- The testing also reveals that while the 2,500 PVS desktops are running, each X-Brick can easily support additional concurrent workloads because the aggregate demand from the virtual desktops are well below each X-Brick's rated capacity of 150,000 50 percent read to 50 percent write 4K random IOPS.

Notes:

- Benchmark results are highly dependent upon workload, specific application requirements, and system design and implementation. Relative system performance will vary as a result of these and other factors. Therefore, this workload should not be used as a substitute for a specific customer application benchmark when critical capacity planning and/or product evaluation decisions are contemplated.
- All performance data contained in this report was obtained in a rigorously controlled environment. Results obtained in other operating environments may vary significantly.
- EMC Corporation does not warrant or represent that a user can or will achieve similar performance expressed in transactions per minute.

Conclusion

Summary

The features of the EMC XtremIO All-Flash array enable XenDesktop environments to achieve high levels of performance, scale as needed, be easier to administer, and require less overall infrastructure resources.

The performance capabilities of the EMC XtremIO array enable virtual desktop application response times to mirror the "SSD" experience of the most modern physical desktops, even if it the virtual desktop was not optimized to minimize the I/O footprint as is required with some storage solutions.

The performance capabilities of the EMC XtremIO array also enable virtual desktops to power on and off or suspend and resume much more quickly than when using non-all-flash arrays. This allows organizations to potentially reduce virtual desktop infrastructure resource utilization by powering off or suspending desktops when they are not needed.

The deduplication capabilities of the EMC XtremIO array further reduce the storage required for each PVS virtual desktop, particularly for the Citrix XenDesktop Personal vDisks, which are created for each desktop and provisioned in a thick format. This allows the storage cost per desktop to be very attractive, even though it is 100 percent flash.

This reference architecture provides a blueprint of a validated Citrix XenDesktop 5.6 virtualization solution enabled by an EMC XtremIO All-Flash array and the VMware vSphere 5.0 virtualization platform. The solution is able to support and scale to thousands of virtual desktops.

Findings

By using the XtremIO storage system as the foundation for Citrix XenDesktop deployments, you gain the following unique advantages that cannot be achieved with any other XenDesktop deployment architecture.

Superior XenDesktop user experience

Test results showed that every desktop in an XtremIO deployment gets reliable and massive I/O potential both in sustained IOPS and the ability to burst to much higher levels as dictated by demanding applications such as Microsoft Outlook, desktop search, and antivirus scanning. During the 2,500 desktop scale testing, every Login VSI simulated application operation was completed much quicker than the acceptable user experience boundaries. This performance is superior by a wide margin to all other all-flash shared storage arrays.

Lowest cost per virtual desktop

XtremIO XenDesktop deployments are surprisingly affordable. Due to XtremIO's inline data reduction and massive performance density, the cost per desktop is lower than with other XenDesktop solutions, allowing XenDesktop virtual desktops to be deployed for less than their physical desktop counterparts.

Rapid provisioning and rollout

Since XtremIO is simple to set up and requires no tuning, and because any XenDesktop deployment model (PVS, Machine Creation Services (MCS), or any

combination thereof) can be chosen at will, complex planning is eliminated. XenDesktop deployments can be designed and rolled out quickly with assured success.

No need for third-party tools

XtremIO solves all I/O related XenDesktop deployment challenges. There is no need for additional caching or host-based deduplication schemes or any other point solutions that increase expense and complexity.

No change to desktop administration

Whatever methods administrators are using to manage their existing physical desktops can be directly applied to the XenDesktop deployment when XtremIO is used. No changes to software updates, operating system patching, antivirus scanning or other procedures need to be made in order to lighten the I/O load on shared storage. Rather, administrators can confidently rely on XtremIO's high performance levels to deliver.

No change to desktop setup

XenDesktop best practices currently dictate dozens of changes to the desktop image in order to reduce the I/O load on shared storage. None of these changes are required with XtremIO, allowing the desktop to remain fully functional while maintaining a strong user experience.

References

EMC documentation

The following documents, located on the EMC Online Support website, provide additional and relevant information. Access to these documents depends on your login credentials. If you do not have access to a document, contact your EMC representative:

- *EMC Infrastructure for Virtual Desktops Enabled by EMC VNX Series (NFS), Cisco UCS, Citrix XenDesktop 5.5 (PVS), XenApp 6.5, and XenServer 6—Proven Solution Guide*
- *EMC Infrastructure for Virtual Desktops Enabled by EMC VNX Series (NFS), Cisco UCS, Citrix XenDesktop 5.5 (PVS), XenApp 6.5, and XenServer 6—Reference Architecture*
- *EMC Infrastructure for Citrix XenDesktop 5.6 (MCS): VNX (NFS), vSphere 5.0, and Citrix Profile Manager 4.1—Proven Solution Guide*
- *EMC Infrastructure for Citrix XenDesktop 5.6 (MCS): VNX (NFS), vSphere 5.0, and Citrix Profile Manager 4.1—Reference Architecture*

Other documentation

Documentation related to the other components of this solution is available at the respective vendor websites:

- For Citrix documentation, visit the Citrix website.
- For VMware documentation, visit the VMware website.