



Simplifying enterprise desktop deployment and management using Dell EqualLogic storage and VMware View:

A highly scalable, end-to-end client virtualization framework

Dell and VMware have created the Virtual Remote Desktop reference configuration based on Dell™ PowerEdge™ servers, Dell EqualLogic™ PS Series storage arrays, Dell PowerConnect™ network switches, and VMware® View™ client virtualization software. This flexible, highly scalable building-block configuration was jointly developed, tested, and validated by Dell and VMware engineers as a baseline for sizing virtual desktop deployments to meet specific organizational goals—helping to reduce cost and complexity through centralized control and delivery of computing assets.

As enterprise computing environments become increasingly distributed and mobile, administrators are compelled to find cost-effective ways to gain control over an expanding variety of client desktops, laptops, and handheld units. Exploring alternatives to simplify management of the enterprise client environment is high on the agenda for many reasons, including escalating maintenance and support expenses, frequent security patches, and software upgrades, as well as an explosion of remote and mobile user devices. Additionally, heightened concerns surrounding data security and confidentiality—often related to specific regulations and standards—have made centralization imperative for organizations in many industries. With IT operations widely deploying server virtualization and benefiting from IT consolidation, a logical

next step is to extend the capital expenditure (capex) and operating expense (opex) savings of virtualization to the desktop.

In keeping with its comprehensive portfolio of customer-focused technologies designed to boost data center efficiency and reduce operating costs, Dell offers a flexible Virtual Remote Desktop (VRD) solution that addresses today's complex computing challenges. The Dell VRD approach—based on VMware View client virtualization infrastructure software deployed across Dell EqualLogic virtualized Internet SCSI (iSCSI) storage, Dell PowerConnect network switches, Dell PowerEdge servers, and Dell OptiPlex™ thin clients, together with the Teradici® PC-over-IP® (PCoIP®) protocol and graphics acceleration—enables IT administrators to centralize the management, data protection, and security of client assets.

The Dell VRD solution also utilizes VMware View Composer image management and storage optimization software to rapidly and easily configure and deploy large numbers of virtual desktops, together with VMware linked clone technology, to maximize performance while minimizing the storage needs of the virtual desktop deployment. Together, VMware software and Dell virtualization-optimized servers and storage provide an efficient platform for desktop virtualization.

To help facilitate deployment of virtualized desktops, Dell and VMware have created an end-to-end framework that addresses a broad range of client needs. The framework leverages a comprehensive Dell portfolio of server, storage, network switch, client device, support, and professional service offerings combined with cutting-edge VMware virtualization technology designed to optimize efficiency and simplify management.

This document describes the results of collaboration by Dell and VMware engineers to create a flexible, highly scalable architecture for virtual desktop deployments using VMware View, PowerEdge servers, PowerConnect network switches, and EqualLogic storage arrays. The configurations presented in this document use a building-block approach for sizing VMware View virtual desktop environments, thereby helping to simplify the purchase, deployment, and scalability of client virtualization solutions for any size IT environment.

Collaborating to provide a comprehensive desktop solution

The long-standing Dell and VMware strategic partnership is designed to deliver customer-focused solutions that help drive efficiencies from desktop to data center and enable organizations of all sizes to reduce costs while planning for growth. The partnership includes tight integration of engineering, professional services, and sales, resulting in seamlessly designed, integrated, and pre-tested solutions. The partnership also has resulted in the co-development of reference architectures—validated configurations—designed to accelerate deployment time and provide end-to-end solutions for organizations looking to benefit fully from the advantages of virtualization technology.

As an extension of this partnership, Dell now offers VMware View as an option for Dell VRD technology that can be easily delivered by the Dell services organization. VMware View 4 provides a wide range of capabilities, including:

- **Simplifying and automating desktop management:** VMware View enables administrators to manage all desktops centrally and provision desktops instantly to users, departments, or offices. Administrators can create instant clones from a standard image and dynamic pools of desktops.
- **Reducing costs:** VMware View helps reduce the overall cost of desktop computing by centralizing management, administration, and resources; and by removing IT infrastructure from remote offices.
- **Enhancing security:** Because all data is maintained within the corporate firewall, VMware View helps minimize risk and data loss. Built-in Secure Sockets Layer (SSL) encryption provides secure tunneling to virtual desktops from unmanaged devices or untrusted networks.
- **Increasing business agility and user flexibility:** VMware View accommodates changing business needs, such as adding new desktop users or groups of users, while providing a consistent experience to every user from any network point.
- **Providing business continuity and disaster recovery:** Built on the cutting-edge VMware vSphere™ virtualization platform and cloud OS, VMware View allows administrators to easily extend features such as high availability and fault tolerance to desktops without the need to add clustering technologies. Desktop backup and recovery can be automated as a business process in the data center.

Additionally, Dell EqualLogic storage integration with VMware vStorage for Array Integration (VAAI) enables virtual remote desktops to be highly efficient. For example, EqualLogic firmware version 5.0 is natively integrated with VMware vStorage application programming interfaces (APIs), enabling exceptional storage performance and scalability as well as intelligent data tiering for multitier workloads such as virtual remote desktops running in VMware vSphere virtualization environments. The direct integration of EqualLogic storage and VMware virtualization enables organizations to achieve a cost breakthrough



for desktop virtualization by optimizing data management with linked clones and storage area network (SAN)-based thin-clone technology.

Dell VRD offerings are available through either purchase or lease options. Organizations can purchase a full VMware desktop virtualization solution from Dell—including servers, storage, networking, client devices, professional services, and support. Alternatively, with Dell's acquisition of Perot Systems, organizations can lease desktop virtualization services through the Dell Services – Managed Virtual Client offering with virtual desktops hosted by Dell and offered as a service.

Simplifying enterprise desktop deployment with a building-block approach

Together, Dell and VMware offer an end-to-end virtual computing framework that enables organizations to standardize on a common platform and a tested architecture. The Dell VRD solution includes OS, application, personalization, and hosted virtual desktop services offerings, providing a cost-effective, automated, and secure solution for managing client platforms. With Dell VRD, organizations can utilize existing VMware investments while extending powerful business continuity, disaster recovery, and cloud delivery features to the desktop infrastructure.

Dell has designed a modular server and storage architecture and tested it for a typical task worker workload profile according to both VMware and Dell best practices. Organizations can use this building-block configuration as a reference for sizing a custom virtual desktop deployment based on their own requirements. The building-block approach helps reduce the time, effort, and complexity of initial sizing exercises, and allows IT staff to focus on deployment using a tested server and storage configuration as the baseline.

Benefits of the Dell and VMware approach to virtualized desktop architectures include:

- **Flexibility:** Dell VRD deployments can be tailored—and scaled up or down—to specific business and organizational requirements.
- **Simplicity:** Dell VRD provides comprehensive specifications for a simple modular architecture including server, storage, and network

components; easy-to-deploy virtualized Dell EqualLogic storage is tightly integrated with VMware infrastructure with intelligent, automated management.

- **Efficiency:** Dell VRD offers a method to quantify the resources required to serve a group of users who have been profiled in terms of application workloads.

Combining Dell Flexible Computing Solutions and VMware View

The Dell Flexible Computing Solutions suite of products and services is designed to centralize the processing and storage resources of a distributed computing environment. Built on a flexible computing architecture foundation, Dell Flexible Computing Solutions help increase control, manageability, and security while helping reduce total cost of ownership and enhance desktop continuity. Dell ProManage™ and Dell IT Consulting Services help organizations to assess their needs, take advantage of hardware technologies, and integrate management tools into their environments.

Additionally, a range of tools facilitate ongoing management. For example, Dell Management Console – Clients and the Dell Distributed Device Manager streamline client management and are designed to be compatible with current and future client products. Also, Dell EqualLogic SAN HeadQuarters (SAN HQ) enables a consolidated view of EqualLogic PS Series SAN usage, networking, and event statistics—both on a real-time and a trend basis—to support planning, troubleshooting, and problem avoidance.

VMware View is a key component of the Dell Flexible Computing architecture. In particular, Dell VRD leverages VMware View in a versatile way that is designed to scale from dozens to thousands of virtual desktops. VMware View enables highly simplified design, deployment, management, and support of Dell Flexible Computing solutions through a single point of contact.

Given today's intense focus on client mobility, VMware and Dell are further enhancing flexibility through capabilities such as the PCoIP protocol. The PCoIP technology built into VMware View 4 is designed to dynamically detect and adapt to end-user network connections, enabling IT organizations to

provide a high-quality desktop experience regardless of user location.

The PCoIP display protocol and graphics acceleration helps deliver virtual desktops efficiently over the network by optimizing low-bandwidth, high-latency connections. PCoIP supports a variety of software and hardware configurations. For example, users can play rich media content, choose from a range of client configurations, and seamlessly access locally attached peripheral devices such as printers, scanners, and mass storage. VMware View with PCoIP offers many advantages, including:

- Consistent, high-performance end-user desktop experience over a local area network (LAN) or wide area network (WAN)
- Multimedia redirect, USB redirect, and multi-monitor configuration support for an exceptional desktop experience
- Desktop access from a wide array of devices, allowing increased availability in virtualized environments
- Use of progressive build technology to display images
- Support for Microsoft® ClearType™ fonts

In addition, the Dell FX100 remote access device offers advanced client mobility. The FX100 provides a high-performance communication platform that uses PCoIP to access full-function virtual desktops running on centralized data center systems. The FX100 works with Dell VRD solutions featuring VMware View to provide a high-quality remote user experience.

Additionally, as organizations migrate to Microsoft Windows® 7, VMware View running on Dell hardware helps to reduce costs and application compatibility issues associated with Windows 7 migrations, extend the life of existing desktop hardware to access virtual Windows desktops, and avoid application conflicts and costly application porting issues.

Using Dell PowerEdge servers and Dell EqualLogic storage for VMware virtualization

Architected for virtual environments, Dell EqualLogic storage arrays bring important benefits to a VMware View–based virtual remote desktop solution. EqualLogic storage arrays feature intelligent

automation for cost-effective storage management, seamless scalability for nondisruptive growth, and comprehensive integration capabilities—enabling organizations to add services such as disaster recovery without increasing costs.

Large-scale consolidation onto Dell PowerEdge server platforms also enhances the overall virtualization environment. Dell is focused on delivering the requisite balance of processor, memory, and I/O to optimize VMware virtualization performance. To that end, PowerEdge servers

“VMware View enables highly simplified design, deployment, management, and support of Dell Flexible Computing solutions through a single point of contact.”

are designed with features that enable rapid virtualization deployment, simplified integration, and low maintenance. For example, organizations can run a large number of desktops on PowerEdge servers with the Intel® Xeon® processor 7500 series and balanced memory architectures. Also, Dell and Intel are working together to optimize the performance, scalability, and availability needed to virtualize mission-critical applications onto VMware virtualized platforms and to increase consolidation ratios across the data center.

Virtualization on industry-standard servers has changed the economics of the data center, driving down total cost of ownership by enabling IT organizations to consolidate multiple applications per server, and to deploy and protect applications in minutes. Together, EqualLogic PS Series iSCSI



storage arrays and PowerEdge servers enable an exceptionally strategic consolidation environment for desktop virtualization with VMware View.

For example, as the deployment of consolidated storage grows, EqualLogic PS Series arrays harness resources to evenly load balance data I/O requests including storage capacity, network bandwidth, and controller cache. EqualLogic PS Series arrays have built-in intelligence, with enterprise data services (for example, snapshot and replication) included at no additional cost. With EqualLogic PS Series arrays, organizations can consolidate their storage to optimize capacity and performance, enhance provisioning, and centralize control. Fully redundant, hot-serviceable components are designed to provide comprehensive data protection, while snapshots and auto-replication enable online backups, instant restore, and straightforward disaster recovery.

Also, in the Dell VRD reference configuration, EqualLogic arrays are directly integrated with VMware vStorage APIs to provide a highly efficient platform for deploying VMware View. In particular, with the launch of EqualLogic firmware version 5.0, Dell delivers comprehensive integration with those APIs aimed at providing advanced performance and scalability of EqualLogic storage as part of VMware vSphere virtualization deployments, including VMware View 4 for virtual desktops.

In fact, vStorage APIs for array integration in EqualLogic firmware version 5.0 with Virtual Machine File System (VMFS) file services have demonstrated the following performance improvements compared to EqualLogic firmware version 4.3 without close API integration by helping to:¹

- Reduce time to complete provisioning scenarios by up to 72 percent
- Reduce time to complete storage migrations using VMware vMotion™ software by up to 72 percent
- Reduce SAN network traffic by up to 95 percent when using XCopy Offload
- Reduce CPU utilization by up to 75 percent when using XCopy Offload

- Improve scalability in VMFS configurations—for example, from 10–12 virtual machines per VMFS volume to up to 64 virtual machines per VMFS volume
- Reduce locking overhead by 76 percent
- Reduce total time to boot multiple virtual machines by 76 percent (key for VMware View and VMware View Composer)—for example, to help improve performance during a “boot storm” at the start of the business day in a virtual desktop environment

VMware vSphere also includes VMware vCompute infrastructure services to efficiently virtualize server resources and vStorage infrastructure services to efficiently virtualize storage resources. vStorage-based functionality enables virtualized storage and centralized management, and vStorage VMFS provides file system services designed to optimize the performance of virtual storage environments. vStorage Thin Provisioning extends the benefits of storage virtualization by allocating capacity as needed—thereby helping clients avoid the overhead and expense of excess storage. Moreover, EqualLogic PS Series SANs use the vSphere virtualization platform and cloud OS together with vStorage APIs to enable exceptionally efficient, integrated data services.

Creating the Virtual Remote Desktop reference architecture

Dell and VMware have designed the Dell Virtual Remote Desktop reference architecture to provide a comprehensive platform for VMware View 4 deployments. It can be tailored to specific organizational sizing requirements while maintaining a straightforward configuration designed to simplify IT while advancing enterprise efficiency.

VMware vSphere 4 provides the foundation for the virtualized infrastructure. The vSphere platform abstracts processor, memory, storage, and networking resources into components that serve multiple virtual machines, enabling optimal hardware utilization and flexibility. VMware View provides unified access to virtual desktops and applications running in a central data center and accessible from a wide variety of devices. VMware View Composer streamlines image management while helping to

¹Based on testing performed by Dell Labs in May 2010 comparing Dell EqualLogic firmware version 4.3 to Dell EqualLogic firmware version 5.0. Actual performance will vary based on configuration, usage, and workload variability.

reduce storage needs through the use of VMware linked clone technology (see Figure 1).

Core infrastructure components for the reference architecture include Dell PowerEdge servers, Dell EqualLogic PS Series iSCSI storage arrays, Dell PowerConnect network switches, and key software components.

Dell PowerEdge servers

The Dell PowerEdge R710 2U rack server is designed to deliver high overall system performance and excellent virtual machine consolidation ratios. It utilizes Intel Core™ i7 quad-core processors at 2.7 GHz and supports a maximum of 144 GB memory. The PowerEdge R710 server has four onboard Gigabit Ethernet (GbE) controllers and up to four PCI Express (PCIe) Gen2 expansion slots. Intel processors help reduce total cost of ownership with advanced virtualization capabilities, enhanced energy efficiency, and innovative systems management.

Dell EqualLogic PS Series iSCSI SAN arrays

Dell EqualLogic PS Series iSCSI SAN arrays are designed to simplify storage deployment by offering high performance, excellent reliability, intelligent automation, and seamless virtualization. The foundation of the VRD storage solution is an EqualLogic PS Series group, which consists of an iSCSI SAN with one or more EqualLogic PS Series SAN arrays (members) connected to an IP network and managed as a single storage pool. Each array has fully redundant hardware and multiple GbE or 10GbE active network connections for maximum bandwidth.

The EqualLogic PS Series architecture simplifies both scale-up and scale-out strategies, and is highly elastic. As members are added to the group, additional capacity is absorbed into the storage pool and immediately shared. Subsequently, data is automatically and transparently load balanced across the pool among different storage types and RAID levels, for automated tiering. EqualLogic PS Series SAN arrays are also able to aggregate GbE or 10GbE for a unified fabric, helping to reduce networking costs.

Dell PowerConnect network switches

The VRD reference architecture uses two Dell PowerConnect 6248 switches to connect the VMware View 4 servers to EqualLogic PS Series

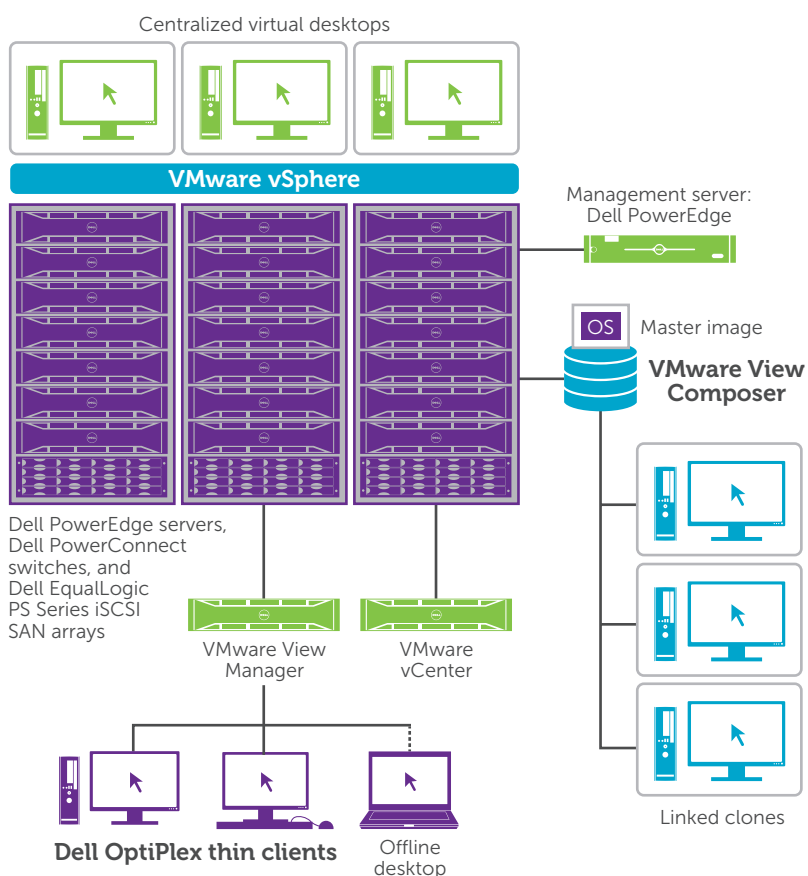


Figure 1. VMware vSphere remote desktop virtualization delivery architecture

SAN arrays. These switches offer 48 ports of 10/100/1000BASE-T wire-speed GbE with advanced security, Layer 3 capabilities, quality of service (QoS), and high-performance stacking features. The PowerConnect 6248 series switches also support up to four 10GbE uplinks for direct connectivity in 10GbE data centers.

Two PowerConnect 8024F switches are used to connect the VMware View 4 servers to an additional EqualLogic array. These high-density, 24-port 10GbE switches are designed for converged Ethernet environments supporting dense virtualization and iSCSI storage. The PowerConnect 8024F switch also provides comprehensive routing features in a compact 1U form factor with data center-friendly front-to-rear cooling.

Software components

VMware View 4 provides a tightly integrated solution built specifically for delivering desktops as



a managed service. VMware View 4 is designed to create simplified, automated desktop workflows that help reduce operational costs and increase control for IT staff. VMware View 4 enables a flexible desktop experience regardless of device, network, or use case.

VMware vSphere 4 builds on the power of the widely deployed VMware Infrastructure virtualization platform to bring the enterprise-class features of data center virtualization to the desktop environment. vSphere 4 extends features such as VMware vMotion, VMware High Availability (HA), VMware Distributed Resource Scheduler (DRS), and VMware Fault Tolerance (FT) technology to the desktop.

Dell EqualLogic SAN HQ provides centralized access to detailed performance and event data, reporting capabilities, and intelligent alerts from the EqualLogic storage array groups. SAN HQ uses Simple Network Management Protocol (SNMP) to collect performance, alarm, and health status data from dozens of array groups that could be spread across multiple locations around the world.

Configuring the reference architecture building block for testing

Dell and VMware established specifications for the various architecture components, including load simulation configuration, user workload profiles, server configuration, networking configuration, and storage configuration.

Load simulation configuration

The testing was designed to simulate the tasks that an average call center worker or typical productivity worker would perform during a workday. The entire test configuration was set up per the VMware Reference Architecture Workload Simulator (RAWC), a tool used to simulate realistic user environments for test purposes. Each virtual machine was configured with the following:

- Microsoft Windows XP Professional with Service Pack 2 (SP2)
- 1 GB RAM
- One 10 GB hard drive
- 1 network interface card (NIC) connected to the applications network
- 1 virtual CPU (vCPU)
- VMware View 4 Agent

- Microsoft Office 2003, with Microsoft Outlook® messaging software configured to use Microsoft Exchange
- McAfee® VirusScan® Enterprise 8.5i for antivirus scanning
- 7-Zip, an open-source Windows utility to create and extract compressed .zip files

User workload profiles

Each virtual machine described previously was equipped to run a workload that simulates typical user behavior, using an application set commonly found and used across a broad array of desktop environments. The workload has a set of randomly executed functions that perform operations on a variety of applications. Several other factors can be implemented to increase the load or adjust the user behavior, such as the number of words per minute that are typed and the delay between applications being launched. The workload configuration used for this validation included Microsoft Outlook; Microsoft Office (Microsoft Word, Microsoft Excel®, and Microsoft PowerPoint® applications); Adobe® Acrobat reader; Microsoft Internet Explorer®; McAfee VirusScan; and 7-Zip.

During the execution of the workload, multiple applications were opened at the same time, and windows were minimized and maximized as the workload progressed, randomly switching between each application. Individual application operations that were randomly performed included:

- **Microsoft Outlook:** Open, minimize, maximize, and close the application, and then send e-mail messages.
- **Microsoft Word:** Open, minimize, close, and write random words and numbers, and then save modifications.
- **Microsoft Excel:** Open, minimize, close, and write random numbers, insert and delete columns and rows, copy and paste formulas, and save modifications.
- **Microsoft PowerPoint:** Open, minimize, close, and conduct a slide show presentation.
- **Adobe Acrobat Reader:** Open, minimize, close, and browse pages in a PDF document.
- **Microsoft Internet Explorer:** Open, minimize, close, and browse Web pages.

- **McAfee antivirus software:** Perform real-time scanning.
- **7-Zip:** Open, close, and compress a large file.

Based on the user-thinking time and words per minute employed for this validation, this workload could be compared to that of a high-end task worker or low-end knowledge worker.

Server configuration

The Dell PowerEdge R710 servers were configured with dual Intel Core i7 quad-core processors at 2.7 GHz with Intel Hyper-Threading Technology enabled, presenting 16 logical CPUs to vSphere. Each server was configured with 48 GB of Double Data Rate 3 (DDR3) 1,333 MHz RAM, and two internal 73 GB, 15,000 rpm Serial Attached SCSI (SAS) drives (mirrored), which were used for vSphere only.

Additionally, each server had four built-in GbE NICs plus an added Intel quad-port GbE card for a total of eight GbE NICs. Four of the NICs were dedicated to software iSCSI—one iSCSI initiator was configured per NIC and all four iSCSI initiators were configured to use round-robin load balancing to each logical unit (LUN) on the array. Two NICs were dedicated for internal networking and management traffic using the vSphere port-based load-balancing feature. The seventh NIC was dedicated to a separate, externally accessible network for testing access, and the eighth NIC was unused.

Each server had vSphere 4.0 Update 1 installed with the latest patches, and the VMware ESX servers were controlled by a separate server that managed the testing. The management server was a PowerEdge R805 server with 10 GbE NICs, 32 GB of RAM, and dual quad-core AMD CPUs.

The management server was configured with virtual machines for the following:

- VMware vCenter™ 4.0 Update 1 software
- VMware View 4.0.1 configured as the connection broker
- Microsoft SQL Server® 2005 database software for vCenter
- Two domain controllers, one running Microsoft Windows Server® 2003 Release 2 (R2) and one running Windows Server 2008 R2, each also configured for domain name system (DNS)

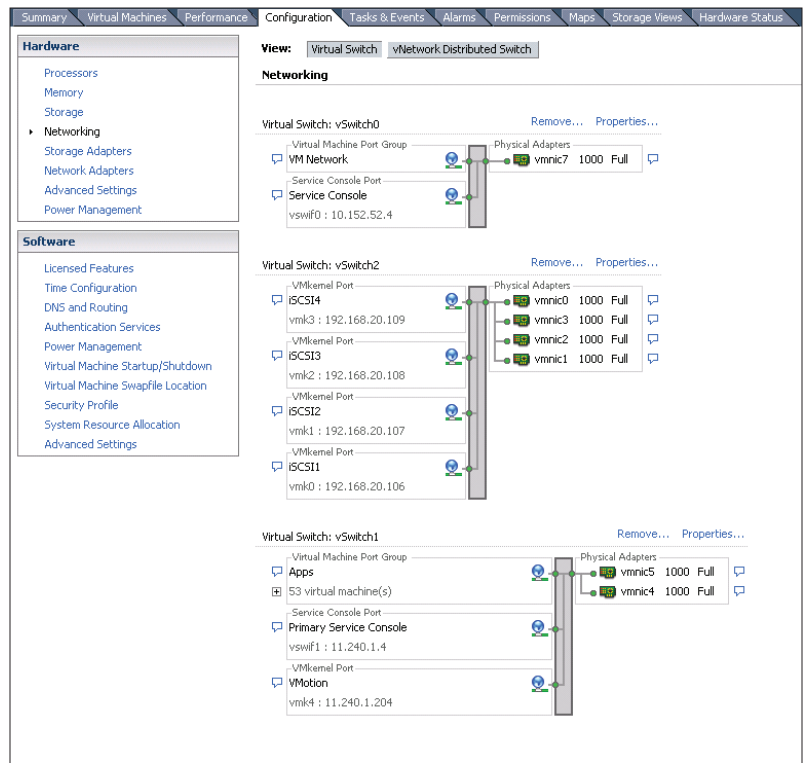


Figure 2. VMware ESX host networking configuration

- A network address translation (NAT) router to allow the virtual machines to access the Internet
- A Microsoft Exchange Server 2003 server for e-mails that were created and sent as part of the test suite

One additional server was used for testing purposes only, allowing remote access to the configuration and running the SAN HQ tool to report on performance.

Networking configuration

The network comprised four Dell PowerConnect 6248 GbE Ethernet switches in full-duplex mode. Two switches were used for iSCSI access by the servers and the array; one switch was used for all the application and testing traffic, and one was used for public access to facilitate testing.

Eight GbE NICs were used to support ESX host networking (see Figure 2). Four GbE NICs supported the SAN and two GbE NICs supported application and client traffic. These NICs were also shared for primary VMware ESX Service Console connection

and VMware vMotion traffic. Additionally, one GbE NIC was used for the secondary service console. One GbE NIC was not used.

For client networking, one-to-one networking was used for physical thin clients. Three physical thin clients were tested: one Dell FX100 Zero Client and two Dell OptiPlex FX160 thin clients. All other virtual clients were connected over the two NICs that are shared for application and client traffic.

Four NICs were used for iSCSI networking (see Figure 3). All four NICs were connected to one vSwitch, with each NIC assigned to a single iSCSI Port Group. There was no teaming of NICs or iSCSI Ports on vSwitch, and the multipathing policy used for each volume was the round-robin method. The configuration utilized four GbE ports on a switch for four active ports on the Dell EqualLogic PS6000XV array and two GbE ports on the EqualLogic PS4000E array. Similarly, four GbE ports on another switch were used as standby ports on the EqualLogic PS6000XV array and two GbE ports were used as standby ports on the EqualLogic PS4000E array. Switches were configured according to EqualLogic best practices. Jumbo frames were enabled, and the Spanning Tree Protocol (STP) was disabled.

Storage configuration

Both EqualLogic PS4000E and EqualLogic PS6000XV virtualized iSCSI SAN arrays were tested. This report describes the configuration and results of the EqualLogic PS4000E array.²

The test used an EqualLogic PS4000E array with sixteen 1 TB Serial ATA (SATA) drives. Two

of the drives were hot spares, and the remaining 14 were configured in RAID-50, the default configuration. Of the approximately 10.5 TB of available space, three 1.7 TB LUNs were created for the virtual machines and the rest of the space was unused. Each LUN could have been smaller, but space was left over for additional virtual machines, overhead space, and snapshots.

Test goal and methodology

PCoIP remote display technology is an important element of the View 4 reference architecture, because it helps deliver a high-quality desktop experience regardless of user location. As part of the reference architecture validation, Dell and VMware engineers verified whether PCoIP required significantly increased CPU time, or significantly slowed other tasks compared with the Remote Desktop Protocol (RDP) that had been used before the introduction of PCoIP in VMware View 4.

To make this determination, the engineers performed two sets of tests. The first set utilized 130 virtual machines and two servers with RDP, and the second set utilized 130 virtual machines and two servers with the PCoIP protocol. The test methodology consisted of sending and receiving e-mail in Microsoft Outlook; creating and using documents in Microsoft Word, Microsoft Excel, and Microsoft PowerPoint; opening and browsing documents using Acrobat Reader; browsing the Web using Microsoft Internet Explorer; compressing several sample files using 7-Zip; and performing a full virus scan of the computer

Figure 3. iSCSI networking configuration

| Device | Speed | Configured | Switch | MAC Address | Observed IP ranges | Wake on LAN Supported |
|---|-----------|------------|----------|-------------------|---------------------------|-----------------------|
| Broadcom Corporation PowerEdge R710 BCM5709 Gigabit Ethernet | | | | | | |
| vmnic3 | 1000 Full | 1000 Full | vSwitch2 | 00:26:89:3c:94:e0 | None | Yes |
| vmnic2 | 1000 Full | 1000 Full | vSwitch2 | 00:26:89:3c:94:d6 | None | Yes |
| vmnic1 | 1000 Full | 1000 Full | vSwitch2 | 00:26:89:3c:94:dc | None | Yes |
| vmnic0 | 1000 Full | 1000 Full | vSwitch2 | 00:26:89:3c:94:da | None | Yes |
| Intel Corporation 82576 Gigabit Network Connection | | | | | | |
| vmnic7 | 1000 Full | 1000 Full | vSwitch0 | 00:1b:21:4f:e7:4d | 10.152.52.1-10.152.52.254 | No |
| vmnic6 | Down | Negotiate | None | 00:1b:21:4f:e7:4e | None | No |
| vmnic5 | 1000 Full | 1000 Full | vSwitch1 | 00:1b:21:4f:e7:49 | 11.240.0.1-11.240.15.254 | No |
| vmnic4 | 1000 Full | 1000 Full | vSwitch1 | 00:1b:21:4f:e7:48 | 11.240.0.1-11.240.15.254 | Yes |
| Intel Corporation 10-Gigabit AF DA Dual Port Server Adapter | | | | | | |
| vmnic9 | Down | Negotiate | None | 00:1b:21:3c:87:c6 | None | No |
| vmnic8 | Down | Negotiate | None | 00:1b:21:3c:87:c7 | None | No |

² For more information and additional details about these tests, visit www.equallogic.com/support.

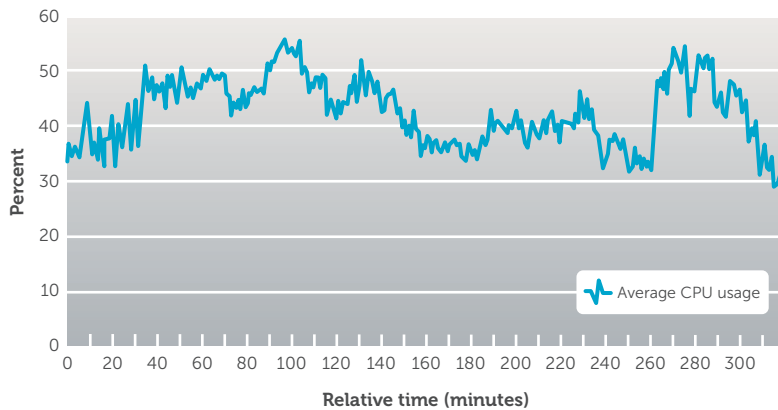


Figure 4. CPU utilization with PCoIP

using McAfee VirusScan software. This battery of tests was repeated three times to help ensure consistent results.

Measurement and analysis tools

Test engineers employed a variety of measurement and analysis tools to evaluate server, virtual machine, SAN, and desktop performance, using VMware vCenter Server to monitor virtual machine and server performance. They utilized the EqualLogic SAN HQ performance monitoring and reporting tool to measure the performance of EqualLogic storage arrays. The Liquidware Labs Stratusphere™ desktop assessment tool was used to monitor desktop application response times.

Summarizing results of the performance tests

Although two sets of tests were run, this document focuses primarily on the test results for the newer PCoIP technology, which are graphically represented in Figures 4–11. For a side-by-side comparison of the PCoIP results and the RDP results, see Tables 1–3 in the section, “Delivering a high-quality user experience with PCoIP.”

VMware vCenter performance statistics

VMware vCenter performance data was collected in vSphere and stored in a Microsoft SQL Server database. Data collected included CPU utilization, memory utilization, ballooning and swapping, network total bandwidth, and disk response times.

The vCenter performance data (see Figures 4–8) shows that the resource utilization increased as the desktop user sessions were started and then settled

to a steady state after all 130 virtual machines were up and running. During the test run, all components—servers, switches, storage—handled the peak and steady-state workloads easily and proved to be a balanced system overall.

CPU utilization values show the average usage over the sampling period as well as the highest, brief spikes (see Figure 4). Average CPU utilization increased from 35 percent to 55 percent as the desktop user sessions were started, and then settled around 40 percent in steady state. There was a brief spike in the system workload after the tests ran for 260 minutes, as evidenced in all performance charts (see Figures 4–10). Most likely, simultaneous virus scans across the user sessions toward the end of the test run caused this increase.

The CPU performance data indicates that there was sufficient unused processor capacity that could have been used to increase the total number of virtual desktops running in the system. However, 130 virtual machines in this configuration (approximately 8 virtual machines per core) were determined to be optimal given the memory utilization (see Figure 5). This number also leaves enough processor headroom for occasional spikes in workload.

Memory utilization values refer to the overall utilization of RAM. As Figure 5 shows, the memory utilization increased from 45 percent to 78 percent as the desktop sessions were started. Subsequently, transparent memory sharing among virtual machines decreased the memory utilization to 50 percent in the steady state until the workload spike happened at the 260-minute mark. As



Figure 5. Memory utilization with PCoIP

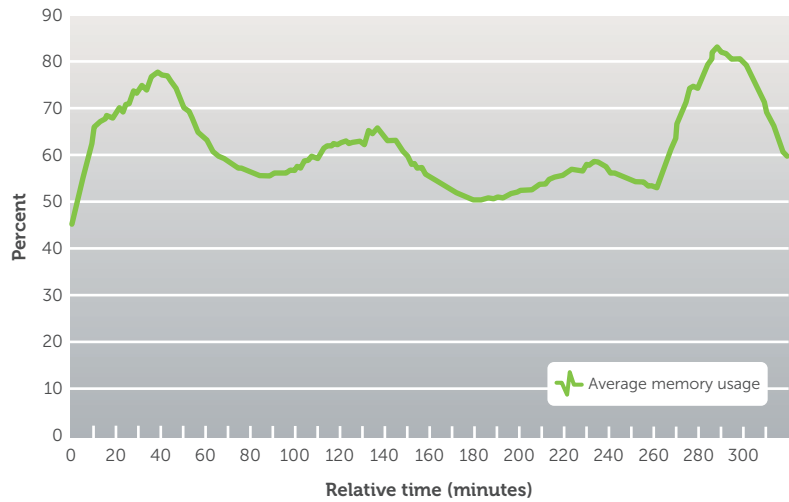
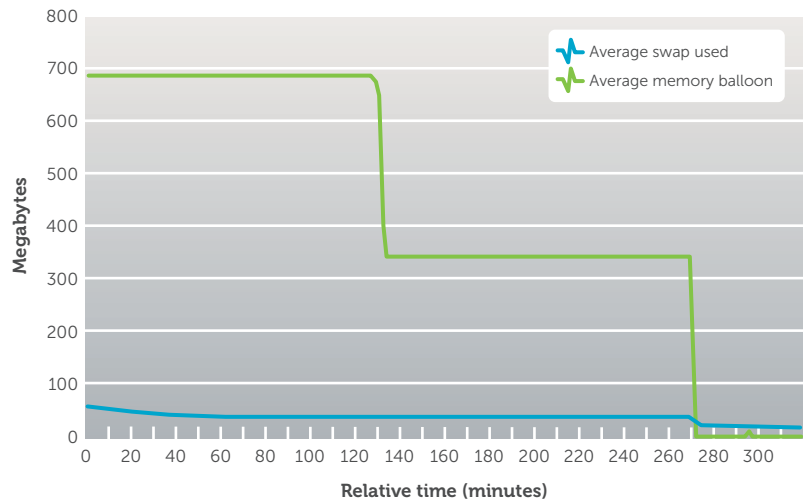


Figure 6. Ballooning and swapping with PCoIP



utilization crossed 80 percent, vSphere took measures, including ballooning and swapping, to conserve physical RAM.

Ballooning and swapping is a memory conservation technique that asks the virtual machine to swap some of its used memory to its local swap file (in the case of Windows, for example, pagefile.sys) and gives the free memory back to the general pool of available memory. This method is highly efficient and has minimal impact on performance, since the guest OS determines what to swap out. If RAM is still scarce, the system can resort to swapping, where vSphere swaps out some memory to an individual virtual machine

swap file. Swapping generally degrades virtual machine performance and should be avoided when possible (see Figure 6).

Network bandwidth performance includes all network traffic—iSCSI, virtual machine traffic to the Internet, and domain controllers, as well as general vSphere management traffic. In this proof-of-concept test case, the total traffic (39 MB/sec receive rate and 45 MB/sec transmit rate at the peak) was well below the capacity (approximately 440 MB/sec) of the network to handle the load and did not create a bottleneck (see Figure 7).

Disk response time (see Figure 8), also known as disk latency, measures the time needed to complete

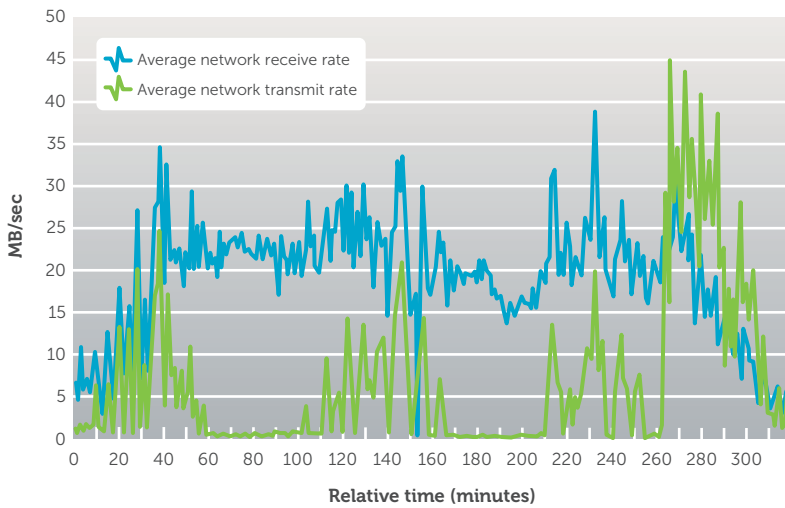


Figure 7. Network bandwidth with PCoIP

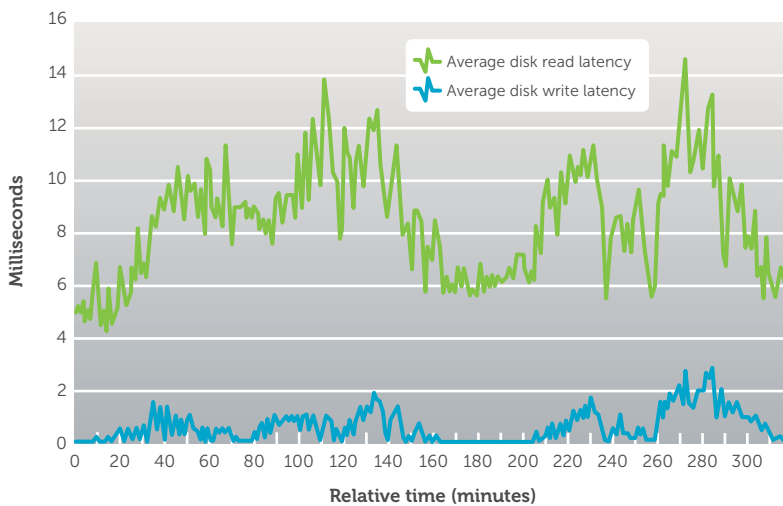


Figure 8. Disk response time with PCoIP

a disk read or write request by the ESX server host. Application response time, as observed by the desktop user, is directly linked to the disk latency seen by the host, and therefore disk latency is a key indicator of the quality of the user experience. Typically, a disk latency of 15 ms or less corresponds to a very good user experience. As Figure 8 shows, the disk latencies were below that threshold throughout the test run, including the sudden workload spike toward the end of the test.

Network I/O statistics

The SAN HQ performance-monitoring tool included with EqualLogic storage arrays presents data

volume and network I/O statistics from the array perspective. Most of these I/O statistics apply to the data volumes used in testing. Latency, total I/Os per second (IOPS), and average I/O size characterize the key performance indicators—response time and throughput—of the array under a given workload. These three important I/O statistics are shown in Figure 9. The test data confirms that the storage array managed the workload, including the spikes, without any issues.

Figure 10 shows the amount of network traffic relative to iSCSI. This traffic, when subtracted from the total network I/O reported from vSphere, can be used to determine the total non-iSCSI traffic. As



Centralized desktop delivery: Dell and VMware reference architecture

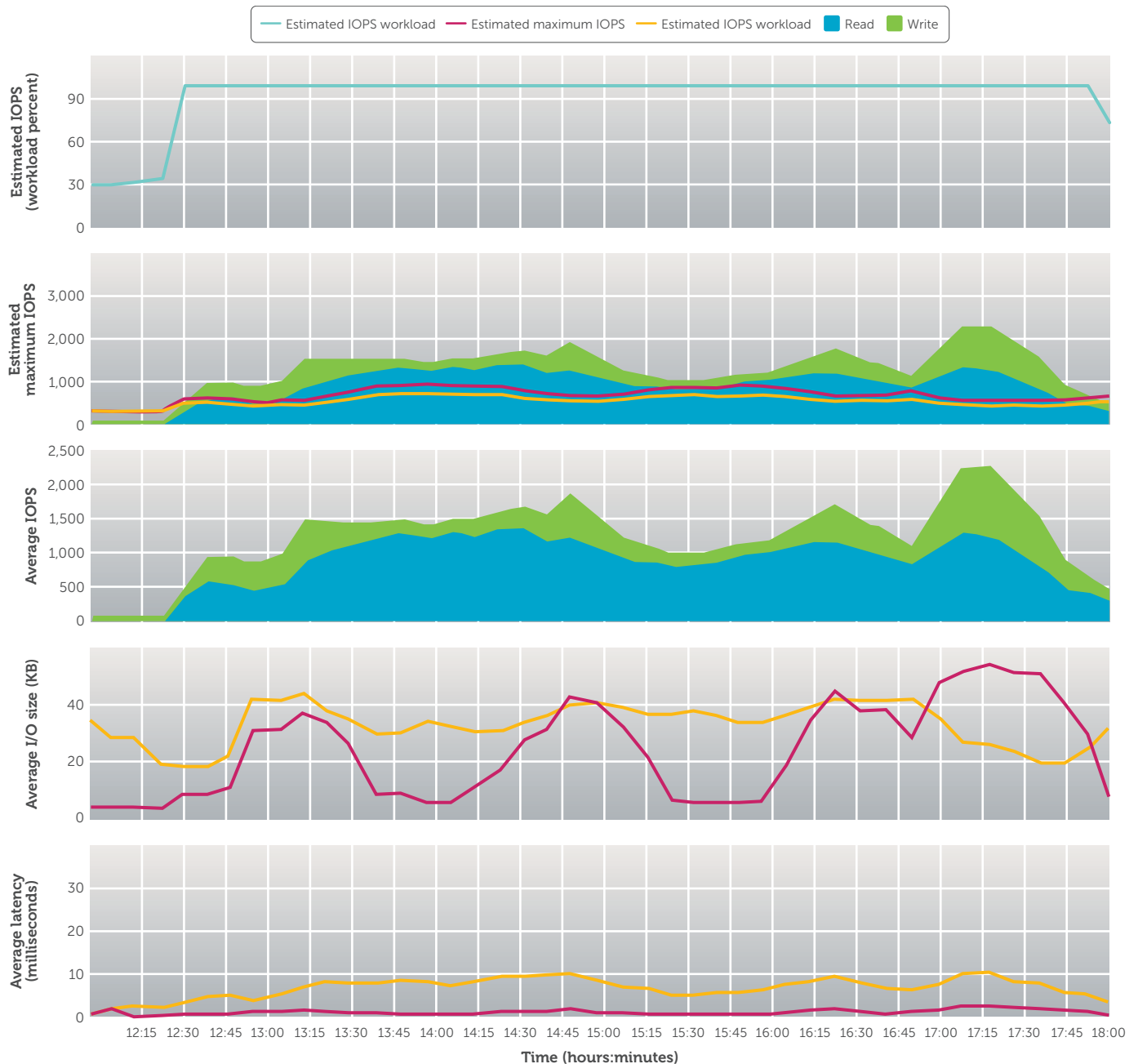


Figure 9. LUNs with PCoIP

shown in Figures 7 and 10, network I/O did not create a bottleneck in this test case.

Application response times

Response times, including average operation times, were recorded in various application response tests (see Figure 11). The response times are the actual measure of how responsive an application is to the

virtual desktop user. As shown in Figure 11, all but one application operation time was less than half a second. For the "Excel Save Doc 1" operation that took 1.8 seconds on average, most likely it was a huge spreadsheet that the simulator was changing heavily before saving (note that the other "Excel Save" operation took less than 0.2 seconds). Overall, the virtual desktop sessions

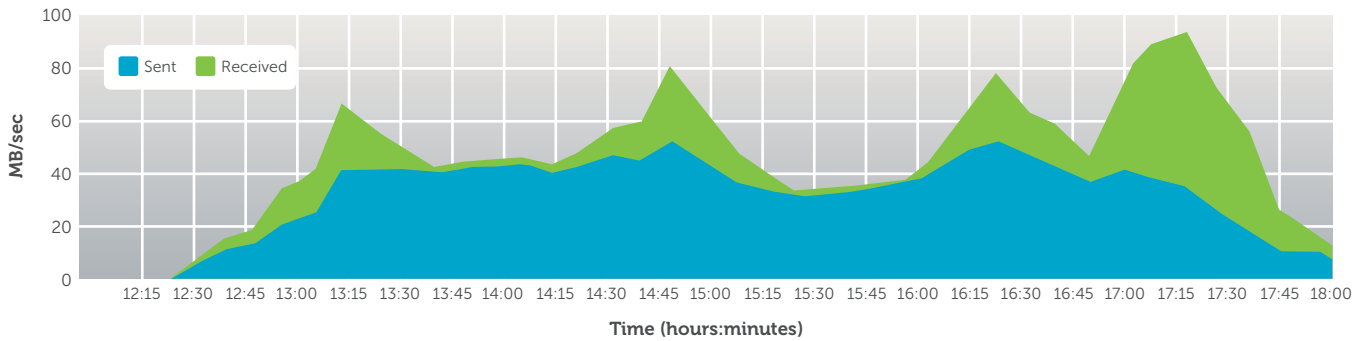


Figure 10. Network I/O with PCoIP

were very responsive to the users and helped provide an excellent user experience.

Delivering a high-quality user experience with PCoIP

The results summarized in Tables 1–3 indicate a high-quality user experience as measured in application response times for the particular user workload profile tested in this study. The user experience from a display perspective is enhanced with PCoIP on a high-speed network. PCoIP required only a little more CPU time than RDP and slowed other tasks only slightly. These results verify that the reference architecture explored in this test case can serve as a starting point for large enterprises looking to scale their VMware View 4 deployments in a predictable, standardized manner.

The values in Table 3 are in megabytes per second, not megabits per second. The goal was calculated as 70 percent utilization maximum on each of the seven active NICs, assuming 1 Gbps full duplex, converted into megabytes per second (where 1 MB/s = 10 Mbps).

Sizing and scaling considerations

As multiple building blocks are deployed into the VMware View 4 environment, the following design considerations should be kept in mind:

- A balanced building-block configuration as described in this document can be selected—and all components in the entire building block can be scaled up or down—based on an organization’s specific workload requirements.

Average application operation times (PCoIP test) (Smaller is better)

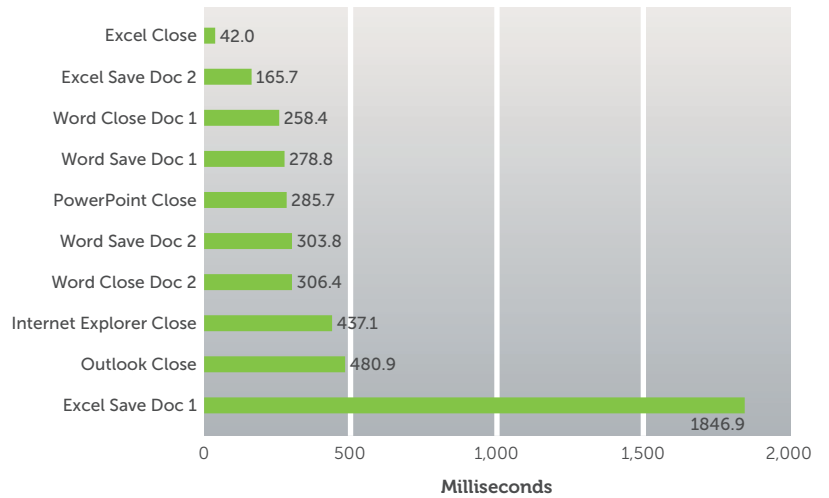


Figure 11. Average application operation times with PCoIP

In the proof-of-concept building-block configuration that was tested and verified in this study, Dell EqualLogic storage performance scaled linearly with capacity. These results indicate that storage performance will increase automatically and proportionately as storage capacity is added.

- The latest VMware configuration maximums should be checked, particularly in large VMware View deployments.
- VMware ESX hosts running the virtual desktop environment can form their own cluster, or they can be part of an existing cluster containing other server workloads.



Table 1. RDP versus PCoIP test summary: CPU utilization and disk response time

| Test | Servers | Users | CPU utilization | Disk response time |
|-------|---------|-------|---|--|
| RDP | 2 | 130 | Goal: < 75% Average: 39% Maximum: 56% | Goal: < 20 ms Average: 6 ms Maximum: 14 ms |
| PCoIP | 2 | 130 | Goal: < 75% Average: 43% Maximum: 59% | Goal: < 20 ms Average: 4 ms Maximum: 15 ms |

Table 2. RDP versus PCoIP test summary: memory utilization and ballooning and swapping

| Test | Users | Memory | | |
|-------|-------|---|--|---|
| | | Utilization | Ballooning | Swapping |
| RDP | 130 | Goal: < 90% Average: 51% Maximum: 65% | Goal: < 5 GB Average: 0 MB Maximum: 0 MB | Goal: < 1 GB Average: 84 MB Maximum: 208 MB |
| PCoIP | 130 | Goal: < 90% Average: 62% Maximum: 83% | Goal: < 5 GB Average: 432 MB Maximum: 681 MB | Goal: < 1 GB Average: 37 MB Maximum: 54 MB |

Table 3. RDP versus PCoIP test summary: network bandwidth

| Test | Servers | Users | Network bandwidth | |
|-------|---------|-------|--|---|
| | | | Received | Sent |
| RDP | 2 | 130 | Goal: < 480 MB/sec Average: 17 MB/sec Maximum: 29.8 MB/sec | Goal: < 480 MB/sec Average: 3.3 MB/sec Maximum: 18.4 MB/sec |
| PCoIP | 2 | 130 | Goal: < 480 MB/sec Average: 19 MB/sec Maximum: 33 MB/sec | Goal: < 480 MB/sec Average: 8 MB/sec Maximum: 42 MB/sec |

- Virtual desktops can be managed by their own dedicated VMware vCenter instance.
- As deployments increase in size, return on investment can be enhanced by adding Dell PowerEdge servers with increased processor and memory capabilities and increased storage capacity.
- VMware vCenter Site Recovery Manager (SRM) has not been evaluated in this reference architecture. However, VMware SRM works with EqualLogic PS Series SANs to automate the recovery process and is designed to reduce the complexity of managing and testing recovery plans, particularly in large VMware View 4 deployments.

Easing the transition to centralized desktop delivery

Organizations must support a wide variety of users—local, mobile, and remote—who require access to sensitive information assets on a range of enterprise and personal equipment including desktops, laptops, and unmanaged mobile devices. Increasingly mobile usage models make it difficult to support end users in a consistent and secure manner.

VMware View 4 addresses desktop management challenges by centralizing control and delivery of computing assets and simplifying desktop management. The Dell VRD solution—which encompasses Dell PowerEdge servers, Dell

EqualLogic PS Series iSCSI SAN arrays, Dell PowerConnect network switches, and VMware View 4 client virtualization software—provides a highly efficient and scalable platform designed to simplify the transition to centralized desktop management and delivery. Dell VRD combines the benefits of VMware virtualization, EqualLogic PS Series storage virtualization, and virtualization-optimized PowerEdge servers to boost enterprise efficiency and help reduce total cost of ownership for the desktop infrastructure through tight integration and automation.

The Dell VRD reference architecture discussed in this test study enables administrators to rapidly provision virtual desktops and provide end users with personalized desktop environments while helping eliminate the need for retraining and application sharing. It also empowers organizations to respond quickly and flexibly to changing business needs. Additionally, the Dell Services team is ready to help assess, design, implement, and maintain desktop virtualization in specific organizational environments while offering a single point of contact for ongoing hardware and software support. **PS**

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VMware vSphere:

www.vmware.com/products/vsphere



Workload Considerations for Virtual Desktop Reference Architectures:

www.vmware.com/files/pdf/VMware-WP-WorkloadConsiderations-WP-EN.pdf

