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VMware Horizon with View Reference Implementation

syngo.plaza PACS Diagnostic Radiology Reading using Zero-Clients

Technical White Paper | 2015

Introduction

This document is a reference implementation case study for VMware[1] Horizon® with View at the Dell Proof of Concept Center in Round Rock, Texas and performed as a collaborative effort between Barco, Dell, Siemens Healthcare, and VMware. The solution provides scalable Virtual Desktop Infrastructure (VDI) sessions in blocks of eight users for the purpose of remote diagnostic radiology reading.

The intended audience is technical decision-makers considering deploying Horizon with View at scale. The Executive Summary and Conclusion sections are also suitable for nontechnical decision-makers.

The purpose of this document is to detail a working and tested model solution for providing a virtualized "remote desktop" to radiologists or clinicians performing remote diagnosis with a picture archiving and communication system (PACS) client. The details of the tested model solution includes server-side and client-side components used, WAN connectivity details and limitations, and scalability considerations.

VMware Reference Implementation Case Studies

A reference implementation case study shows how specific customers in differing geographies and industry verticals have deployed and benefited from a VMware solution. It details the project approach, business benefits for a specific customer site, lessons learned, and architecture used. These implementations are typically based on reference architectures validated by VMware.

A reference implementation is built on a foundation of best practices, but trade-offs are made to meet specific project requirements or constraints. When referencing these implementations, it is critical to know where the architecture has deviated from best practice and where improvements could be made. To understand the modifications, you can compare a reference implementation to VMware reference architecture documentation. For information about other technical reference architectures, visit VMware Horizon with View Design resources (http://www.vmware.com/products/horizon-view/resources#Design).

[1]VMware, Inc. provides virtualization of workspaces.

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This case study is intended to help customers—IT architects, consultants, and administrators—involved in the early phases of planning, design, and deployment of Horizon–based solutions. It provides an example of a successful implementation that meets specific industry vertical challenges and the benefits gained.

Executive Summary

In October 2014, an initiative was started at Siemens Healthcare to define a solution to overcome the limitations that increasing medical image sizes have placed on remote diagnostic radiology reading. With collaboration efforts by Barco, Dell, Siemens and VMware (the team) a platform has been defined and tested to provide a satisfactory diagnostic radiology remote working experience for radiologists and clinicians reading from offsite facilities or from home.

The team looked to define a solution with the following requirements:

- **User experience** – provide lossless image quality with acceptable speed and response of user interaction
- **Working area** – allow a PACS Client user the standard workspace of Dual 3MP Color diagnostic-quality displays
- **Security** – ensure a protected environment for medical data interaction, without worry of equipment theft and HIPAA disclosure
- **End-to-end support** – work within fully-supported boundaries, and detail responsible support parties for each component
- **Scalability** – show how many users effectively fit within a clearly defined environment, and how to grow the environment
- **Ease of deployment** – work to provide an easy to deploy solution that scales in a simple building-block model

Project Overview

Siemens Healthcare, a leader in healthcare information technology, recognized that the increasing quality, and growing size and number of images per radiology study are vastly increasing due to the diagnostic needs of finding and treating diseases in the earliest stages of illness. The growth in the data produced by these studies has consistently surpassed the availability of WAN bandwidth in client/server scenarios for high throughput use of remote diagnostic radiology reading. An initiative was started to find a cost-effective solution using modern, commonly available and supported IT infrastructure to overcome the limitation of direct client/server bandwidth needs.

The underlying issue of increasing image data size per study, additional historical images needed for medical comparison, and waiting for all that data to be transmitted between the server and client has had significant impacts. Within the medical facility, the impact shows in the need for larger servers and storages, high-speed networking equipment, high-performance diagnostic workstations, and high-bandwidth WAN connections. At satellite facilities, the impact shows as the tradeoff of paying to increase available WAN bandwidth, or suffering increased wait times and decreased productivity. At doctor's home offices the impact shows in the inability to work remotely at all, because the cost of needed WAN bandwidth is cost prohibitive or unavailable.

Potential solutions discussed were using proprietary compression algorithms and transmission protocols, using software server-side rendering, using cloud servers/storage, and using virtual desktop infrastructure (VDI). Maintenance and development of proprietary methods are costly, software server-side rendering is limited by the need for image refresh speed, and cloud servers/storage can have security risks with severely detrimental impacts to healthcare transactions. Because VDI has evolved to the point that user experience is satisfactory, larger and multiple desktops are supported, and no permanent data resides on the client after the user session ends, the decision was made to investigate the diagnostic usability VDI solution. Both Citrix and VMware have a VDI solution, but only VMware's Horizon with View, and specifically using the Teradici PCoIP protocol, has support for build-to-lossless image quality at dual 3MP color resolution.

Testing Overview

Siemens Healthcare contacted Barco, Dell and VMware to coordinate use of equipment and expert resources. Barco provided the medical displays, cables and display calibration software. Dell provided the servers, workstation and zero-client, LAN networking and WAN simulation environment. Siemens Healthcare provided the PACS client/server software, operating system licenses, and several de-identified diagnostic medical images. VMware provided the server and desktop virtualization platform software. Testing took place across four individual days at Dell's Proof of Concept center in Round Rock, TX.

Dell created the VMware vSphere and the Horizon with View testing infrastructure based on minimum specifications for Siemens Healthcare *syngo*®.plaza[2] PACS client/server software, and also with best-practice implementations for both Dell hardware and VMware software. The result was a minimum of one VMware ESXi 6 host server for the server guests and one other VMware ESXi 6 host server for the desktop client guests. Dell also provided gigabit Ethernet networking equipment, a hardware WAN simulator, and several WYSE zero-client devices. Barco provided several sets of 3MP and 6MP color diagnostic displays, which are the standard for reading digital radiography images. Siemens Healthcare provided a high-performance Dell workstation with PACS client application installed for the comparison testing "standard" of a LAN-connected client/server user. Siemens Healthcare also provided clinical and technical professionals to view and compare WAN-connected PCoIP client test scenarios against the LAN-connected "standard" workstation client.

The testing process started with several baseline runs of the WYSE zero-client operating at unrestricted LAN speed to determine how much bandwidth could be consumed at maximum, and simultaneous comparison against the LAN-connected workstation to check image quality and user interaction responsiveness. These baseline runs were followed by repeated testing scenarios of using different virtual video-sharing methods, reducing network bandwidth and increasing network latency for the WYSE zero-client to determine minimum WAN network requirements for recommended acceptable diagnostic use. After a networking threshold was crossed where the user session became unacceptable, either by visual screen artifacts or by a response delay allowing a missed slice in scrolling, then other testing scenarios were performed. The user session being "acceptable" was determined when three out of three viewing experts saw no problems in viewing quality or user interaction, and "unacceptable" was when any of the three viewing experts expressed any doubt of acceptability.

[2] *syngo*®.plaza is not commercially available in all countries. Due to regulatory reasons its future availability cannot be guaranteed. Please contact your local Siemens organization for further details.

About VMware Horizon with View

Horizon with View[3] is a desktop virtualization solution that simplifies IT manageability and control while delivering the highest fidelity end-user experience across devices and networks.

The Horizon with View solution helps IT organizations automate desktop and application management, reduce costs, and increase data security by centralizing the desktop environment. This centralization results in greater end-user freedom and increased control for IT organizations. By encapsulating the operating systems, applications, and user data into isolated layers, IT organizations can deliver a modern desktop. IT organizations can then deliver dynamic, elastic desktop cloud services such as applications, unified communications, and 3D graphics for real-world productivity and greater business agility.

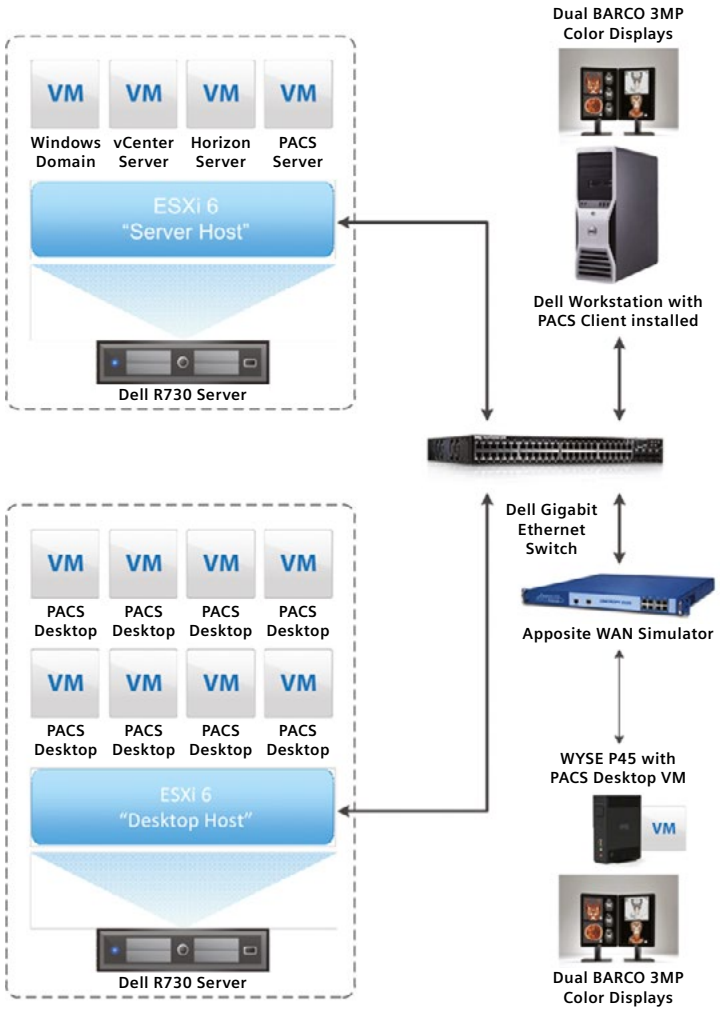
Unlike other desktop virtualization products, Horizon with View is built on and tightly integrated with VMware vSphere, the industry-leading virtualization platform, allowing customers to extend the value of VMware infrastructure and its enterprise-class features such as high availability, disaster recovery, and business continuity.

Horizon with View delivers important features and enhancements that improve the performance, security, management, and flexibility of virtual desktops.

Support for VMware vSphere leverages the latest functionality of the leading cloud infrastructure platform for highly available, scalable, and reliable desktop services.

Reference Architecture

This diagram depicts the reference architecture used for testing, and details both the virtual servers and virtual desktops aspects of the deployment.



[3]Visit the VMware website for more information on Horizon with View (https://www.vmware.com/support/pubs/view_pubs.html)

Reference Architecture Details – ESXi 6 "Server Host"

- Dell PowerEdge R730 Rack Server
- 2x Intel Xeon E5-2660 v3, 2.6GHz, 10 Core CPUs
- 128GB RAM, 2133MHz
- FC Host Bus Adapter for SAN-Connected Disk Array-based Shared Storage
- Dell OEM VMware ESXi 6 Host Hypervisor
- Dell OEM Windows 2008R2 Server-based Dell OEM VMware vCenter 6 Server (Guest VM)
- Dell OEM Windows 2008R2 Server-based Non-OEM VMware Horizon View 6 Connection Server (Guest VM)
- Windows 2008R2 Server-based Domain Controller with Active Directory (Guest VM, provided by Customer)
- Windows 2008R2 Server-based Siemens *syngo*.plaza VB10 PACS Server Application (Guest VM, provided by Customer)

Reference Architecture Details – ESXi 6 "Desktop Host"

- Dell PowerEdge R730 Rack Server
- 2x Intel Xeon E5-2660 v3, 2.6GHz, 10 Core CPUs
- 128GB RAM, 2133MHz
- PERC 730P RAID Controller
- 8x 200GB SAS SSD Drives in RAID5-based Local Storage
- Dell OEM VMware ESXi 6 Host Hypervisor
- Dell OEM Teradici APEX 2800 HW PCoIP Accelerator Card (using APEX Client VM Driver 2.5.0.43294)
- 2x Dell OEM NVIDIA GRID K2 cards (using the NVIDIA GRID host driver for VMware ESXi 6.0)
- VMware ESXi 6 Host Hypervisor
- Up-to 8x PACS Desktop Guest VMs, each with 4x CPU Cores, 12GB RAM, 80GB HDD Datastore, NVIDIA GRID K260Q Virtual GPU with 2GB video memory & NVIDIA GRID guest OS driver, Windows 7 Ultimate Edition 64-bit Operating System, and Siemens *syngo*.plaza VB10 PACS Client Application
- GPO Policy Changes: Configure PCoIP image quality = Enabled, Set maximum frame rate value = 30, Set maximum initial quality value = 100, Set minimum initial image quality = 100, Use image settings from zero client if available = Disabled, Turn off Build-to-Lossless feature = Disabled

Reference Architecture Details – Dell Workstation Client

- Dell Precision Workstation T3600
- 1x Intel Xeon E5-1620, 3.6GHz, 4 Core CPU
- 8GB RAM, 1600MHz
- 256GB SATA SSD Drive
- 2x NVIDIA Quadro K600 1GB Video Cards
- Windows 7 Ultimate Edition 64-bit OS
- Siemens *syngo*.plaza VB10 PACS Client Application

Reference Architecture Details – WYSE P45 zero-client

- Dell WYSE P45 zero-client device with 4x DisplayPort connections
- Dell USB Keyboard and USB Optical Scroll Mouse
- 2x Barco Nio Color 3MP LED model MDNC-3321 (each at 1536x2048 pixel resolution) with DisplayPort (DP) Cables
- Alternately, 1x Barco Coronis Fusion 6MP LED model MDCC-6230 (at 2x 1640x2048 pixel resolution) with DP Cables

Reference Architecture Details – Ethernet LAN/WAN

- Dell PowerConnect 24-port 10/100/1000 Ethernet Switch with Category 5e Ethernet Patch Cables
- Apposite WAN Simulator, 8-port model (only required to simulate and test WAN connections, not for production scenarios)

Testing Scenario

For our first testing scenario, we explored different methods of GPU virtualization and sharing. Tests were done at unrestricted bandwidth.

Video Method	Outcome*
No GPU, only CPU rendering	Unacceptable
vSGA (Virtual Shared Graphics Acceleration)	Unacceptable
vDGA (Virtual Dedicated Graphics Acceleration)	Acceptable, Limited to 2 Users per card
NVIDIA GRID vGPU (Virtual GPU)	Acceptable, Scales to 4 Users per card

For our second testing scenario, the bandwidth of the WYSE zero-client started at 100Mbps and was reduced in 10Mbps increments until effects were deemed unacceptable. The user of the PACS client loaded and viewed several studies of CR, DR, CT, MR and PET, including standard image manipulation methods of window/leveling, pan/zoom and series scrolling.

Bandwidth	Outcome*
100Mbps	Acceptable
50Mbps	Acceptable
40Mbps	Acceptable
30Mbps	Acceptable
20Mbps	Unacceptable
15Mbps	Unacceptable

For our third testing scenario, the bandwidth of the WYSE zero-client was maintained at 30Mbps and network round-trip time (latency) was introduced in 10-20 millisecond increments until effects were deemed unacceptable. The user of the PACS workstation client performed the same reading as during bandwidth reduction.

Bandwidth	Latency Total	Outcome*
30Mbps	20milliseconds	Acceptable
30Mbps	40milliseconds	Acceptable
30Mbps	60milliseconds	Acceptable
30Mbps	70milliseconds	Acceptable
30Mbps	80milliseconds	Unacceptable
30Mbps	100milliseconds	Unacceptable

*Note: The user session being "acceptable" was determined when three out of three viewing experts saw no problems in viewing quality or user interaction, and "unacceptable" was when any of the three viewing experts expressed any doubt of acceptability.

Best Practices

Have sufficient quality WAN bandwidth.

- User satisfaction was directly related to WAN bandwidth and quality (low latency, or round-trip time). Use below minimum acceptable bandwidth produces screen artifacts and should not be used for making a definitive diagnosis. Use above maximum latency produces choppy interaction for the user and should not be used for making a definitive diagnosis.

Use non-persistent linked clones for client VMs.

- This provides additional speed as most of a linked clone's HDD activity is handled "in memory" as block deltas to minimize physical HDD requests to the clone master.
- This provides additional security, as the medical images and metadata usually cached by the application on the HDD are not retained at logoff. Additionally, any user installed software or inadvertent virus/malware infection is not retained at logoff.

Use PCoIP zero-client or thin-client devices on the user end.

- Use of client "devices" instead of workstations provides additional security as no data is kept on the client device. All data is accessed through a secure session and information is only kept in memory for the duration of the session. Theft or loss of the client device has no data loss risk.
- Zero/thin-clients can provide additional performance and reduction in networking needs because zero/thin-clients with a PCoIP encoder/decoder chip operate much faster than a high-performance workstation running the Horizon View client (which has to use the CPU for PCoIP encoding/decoding).

Use the Teradici APEX 2800 HW PCoIP Accelerator Card on the desktop server end.

- This provides additional performance and reduction in client-side networking needs by using a hardware-based PCoIP encoder/decoder chip on the server end as well. The benefit was seen in the ability to handle latency much better.

Use NVIDIA GRID vGPU for the best balance of performance and users per host.

- Unlike other dedicated graphics solutions (like vDGA) that are constrained to one user per GPU, GRID vGPU technology lets you cost-effectively scale superior graphics performance. The benefit was seen in the ability to deliver acceptable performance while sharing and scaling to four users per GRID K2 card.

Use 10 gigabit Ethernet interconnects between servers.

- This provides sufficient bandwidth for fast VMotion failover in the event that VMware detects an impending hardware problem, and also provides unrestricted 1 gigabit bandwidth for multiple guest VMs to communicate at the same time without contention. In the event that all users of a server are not communicating at exactly the same time, all available bandwidth will be available for client/server requests, and significantly decrease image transfer times.

Use solid state disks for the datastores of the desktop server end, and for the PACS server VM.

- There were surprising improvements in image load and display times from server to client when the PACS server VM used solid state disks for the datastores hosting the PACS image cache, the database and the log files. Experienced users felt that image load and display times were consistently happening in half the time that it takes systems with spinning disk-based storage.

Conclusion

Summary

The technology of virtual desktop infrastructure (VDI) using VMware Horizon with View has matured significantly in recent years. With regard to our initial solution requirements, the proposed reference architecture can provide a secure reading experience for remote diagnostic radiology PACS users with dual 3MP+ displays at lossless image quality. The proposed solution is also easily deployed to remote locations, scales in reasonable user increments for the intended market, and is fully supportable from end-to-end. Major considerations in the decision-making process are:

- **Business-class WAN connections** – WAN connectivity is the responsibility of the end-user customer, and reliable WAN connections with a minimum of 30Mbps bandwidth with a maximum of 70 millisecond round-trip-time are critical to acceptable image quality and user satisfaction of VDI using the reference architecture presented. Business-class Internet connections typically meet these needs, but it is important to check and confirm bandwidth and latency service levels with your Internet service provider (ISP). In situations where the remote desktop user must always have a persistent connection to the server, a WAN connection with a guaranteed Service Level Agreement (SLA) is required. In situations where Internet connections with VPN are required for the remote user, a small VPN endpoint device would be required to establish and maintain a secure connection tunnel.
- **Cost versus user needs** – Implementing net-new virtualization solutions can have significant capital costs for purchasing the servers, clients, and networking infrastructure, but most customers already have significant virtual server infrastructure in place to build upon. Costs of using VDI can pay out over time in reduced WAN fees, maintenance, and software roll-out efforts. It is important to weigh the benefits of VDI against the needs of the users. In situations where the remote user must work without waiting for large image datasets to load, but sufficient bandwidth is not available for a full PACS workstation, or situations where the remote user is reading limited image types or only emergency cases, then a VDI solution shows significant benefit.

Lessons Learned

A zero-client or thin-client device gives much higher levels of user performance than full workstations running the Horizon View Client software because the dedicated hardware PCoIP chip in the zero/thin-clients can encode/decode the communication stream much faster than a software client encoding/decoding with a modern workstation CPU can. Using PCoIP even at minimum required networking thresholds provided build-to-lossless quality in about a quarter of a second.

Because of the intensive graphics needs of a PACS desktop, 2GB of video RAM per desktop in our case, one NVIDIA GRID K2 8GB card can be virtually allocated (using NVIDIA GRID vGPU) to a maximum of four remote desktops (each with 2x 3MP color displays). Since our Dell R730 chassis only supports two of the NVIDIA GRID K2 cards, then the maximum number of remote desktops is eight in total (each with 2x 3MP color displays).

The boundaries of support can sometimes be unclear for virtual solutions, but in our solution there are clearly defined boundaries. All Dell/NVIDIA/Teradici/WYSE hardware and Dell OEM (VMware or Microsoft) software are supported by Dell. VMware and Microsoft support the non-OEM versions of their software and operating system. VMware and Teradici support the PCoIP remote communication protocol, and also the number and pixel resolution of displays connected. Barco supports the displays and cables for connecting to the client devices, along with support for calibration of the displays. Siemens supports the PACS server and client applications inside the VM guest environments. The customer is responsible for supporting the LAN/WAN network connectivity and security, including the connections between servers and client devices, and VPN endpoint devices if used. The customer is also ultimately responsible for the overall solution, including (but not limited to) maintenance and upkeep of all hardware/software and VM guests, monitoring for errors, initiating and handling of support calls (including hands-on diagnostics and troubleshooting if needed by a third-party), backups and restorations, and recreation of VM containers and guests.

Limitations and Next Steps

In order for a VDI solution to exactly match the usability profile of a fully integrated radiology "reporting" workstation, additional applications will need to be added to the client desktop solution, such as a radiology information system (RIS) client and a speech recognition system client. We expect no difficulties with integrating a RIS client into the existing reference architecture because these clients typically use minimal resources and frequently do not require additional CPU and RAM beyond the needs of the PACS client. There are challenges expected with implementing speech recognition over VDI because of needed support for USB-connected Headsets/ Microphones by the speech recognition system manufacturers. Siemens plans to continue building upon the proposed reference architecture to include testing Siemens *syngo* Workflow RIS and a third-party speech recognition application to provide a fully integrated and supported VDI radiology reporting solution.

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