VMware View® 5 Performance and Best Practices

Performance Study

TECHNICAL WHITE PAPER

vmware®

Table of Contents

Introduction 4
View 5 New Features 5
End User Experience Monitoring 5
Support for 3D Graphics 5
Continuity Services 5
Performance Improvements in View 5 5
PCoIP Protocol Improvements 5
Platform Improvements with VMware vSphere 5 5
CPU Scheduler 5
Memory Footprint Reduction 5
Conservative Ballooning 6
PCoIP Protocol Improvements in View 5 6
Bandwidth Improvements 6
Lossless Codec Optimizations 6
Client-side Caching 6
Build-to-Lossless 7
Overall Bandwidth Reductions 8
CPU Improvements 8
Idle CPU Usage 8
Code Optimization 8
SIMD Acceleration 9
Performance Results – View PCoIP Improvements 9
Experimental Setup 9
Network Conditions 9
Performance Metrics 10
Workload 10
Performance Improvements Compared to View 4.5 10
Application Response Time 10
Bandwidth Usage 11
CPU Usage 11
Comparison with Other Remote Display Protocols 12
Response Time 13
Bandwidth Usage 13
CPU Usage 14
Performance Results – vSphere 5 Platform Improvements 15
Comparison with View 4.5 15

CPU Usage 15
Memory Overhead Reduction 16
Storage 17
View Composer 18
View 5 Best Practices 19
Platform best practices 19
CPU Consolidation 19
Memory Consolidation 19
Storage 20
Guest Best Practices 20
View PCoIP Best Practices 21
Network optimizations 23
Conclusion 24
References 25
About the Authors 25
Acknowledgements 25

Introduction

VMware View liberates the end user identity from being locked to a particular system and enables anywhere computing. It transforms IT by simplifying and automating desktop management. IT administrators can compose virtual desktops on demand, based on locations and profiles, and can deliver at any time to desktops and devices anywhere. As shown in Figure 1, by centrally maintaining desktops, applications, and data, VMware View reduces costs, improves security, and, at the same time, increases availability and flexibility for end users.

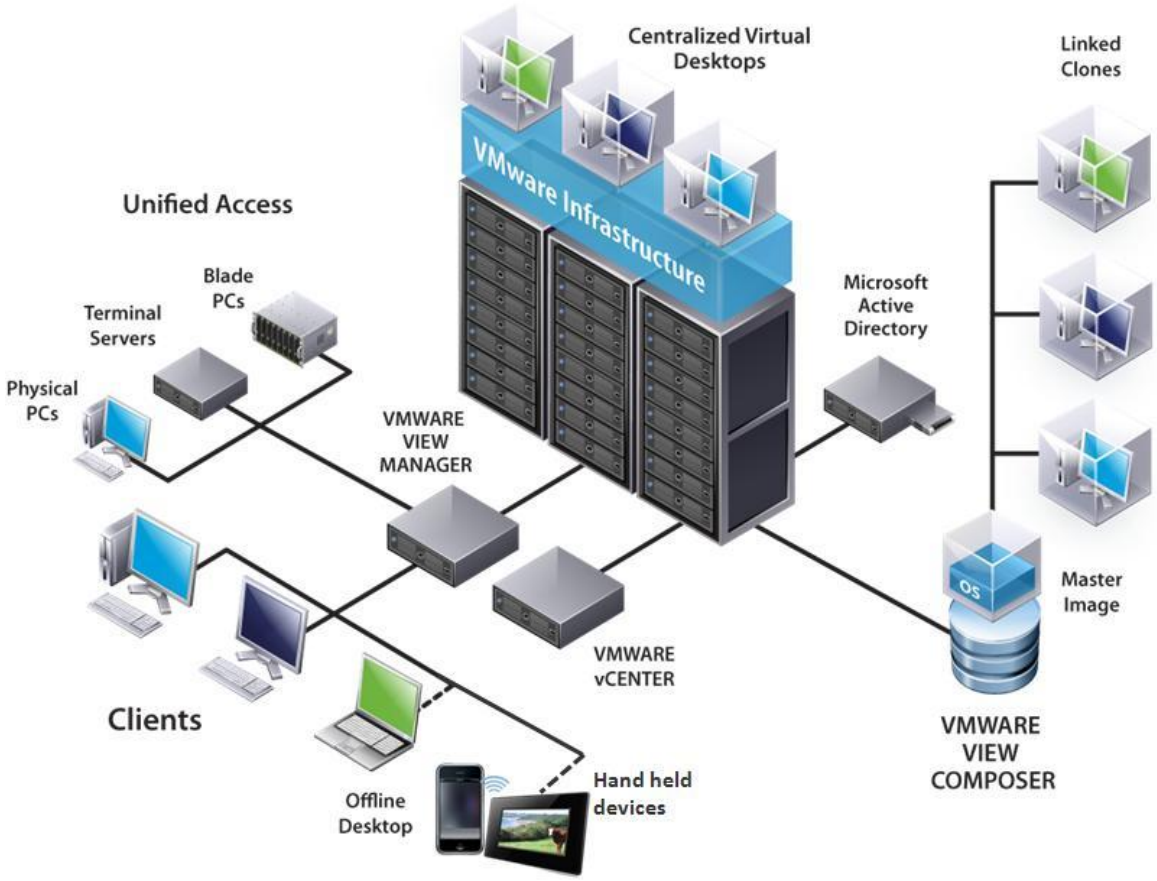


Figure 1. View Architecture Diagram

VMware View 5 offers the best end-user experience and performance over LAN, WAN, and extreme WAN. The VMware View PCoIP display protocol's adaptive technology provides an optimized virtual desktop delivery on both the LAN and the WAN. View 5 addresses the broadest list of use cases and deployment options with a single protocol and enables access to personalized virtual desktops complete with applications and end-user data and settings anywhere and at any time. View 5 also reduces the overall costs of desktop computing by centralizing management, administration, and resources and by removing IT infrastructure from remote offices.

View 5 New Features

In addition to the significant performance optimizations that are discussed in later sections, VMware View 5 also introduces a number of new key features.

End User Experience Monitoring

View 5 provides users easy access to key PCoIP protocol performance metrics. There are over 30 individual statistics collected, ranging from imaging statistics to network bandwidth information. Not only do these metrics allow users and administrators to use WMI based tools, such as perfmon, to quickly troubleshoot individual desktop issues, but these metrics are available to VMware vCenter Operations and other third party management solutions to provide improved monitoring fidelity.

Support for 3D Graphics

VMware vSphere 5 introduced support for non-hardware accelerated 3D graphics in VMs (support is provided for DirectX 9 and OpenGL 2.1). View 5 takes full advantage of this support, enabling basic 3D applications in View desktops like Aero, Office 2010, or those requiring OpenGL or DirectX without the need for specialized graphics cards or client devices.

Continuity Services

View 5 delivers a seamless end-user experience regardless of network reliability. The PCoIP protocol automatically detects network interruptions and automatically attempts to reconnect the session. The PCoIP protocol will try for up to 30 seconds to reconnect the session, eliminating the requirement to re-launch and re-authenticate sessions as a result of temporary network interruptions. Additionally, continuity services provide better session resilience in networks with high packet loss.

Performance Improvements in View 5

PCoIP Protocol Improvements

In View 5, there are significant performance improvements in PCoIP protocol including, WAN optimizations with substantial bandwidth reduction and reduced CPU usage. These improvements are discussed in detail in subsequent sections.

Platform Improvements with VMware vSphere 5

VMware vSphere 5 brings with it some great performance improvements which allow more desktops to be consolidated on a single ESXi server.

CPU Scheduler

VMware has improved CPU scheduling for desktop workloads especially on hyper-threaded processors. The result is that desktop workloads have good out-of-the-box performance on ESXi servers. In vSphere 4.1, an advanced scheduler option was required to get the best performance for desktop workloads (KB 1020233), but this is no longer necessary with vSphere 5.

Memory Footprint Reduction

In addition to the VRAM assigned to a virtual machine, ESXi maintains book-keeping memory on behalf of a virtual machine. In vSphere 5, the book-keeping memory scheme has changed by allocating memory on demand

and by implementing a swap mechanism which lets more of the guest VRAM to stay in the main memory. The footprint reduction is as much as 60%, which leads to a better consolidation ratio.

Conservative Ballooning

In vSphere 5, the ballooning mechanism was changed to a more conservative one compared to vSphere 4.1. In vSphere 4.1 and earlier, the balloon driver in the virtual machines used to get activated when the system free memory dropped below 6% of the total memory. On servers with a large amount of main memory, 6% free memory is sufficiently large that ballooning is not really required. Hence vSphere 5 implements a slab-based ballooning mechanism that keeps the threshold at 6% for machines with less memory and as low as 1% for machines with a large amount of memory. This greatly improves VM consolidation on large servers.

PCoIP Protocol Improvements in View 5

VMware View 5 introduces a variety of important optimizations to the PCoIP protocol that deliver a significant reduction in the PCoIP protocol's resource utilization, benefiting users in almost all usage scenarios. Broadly speaking, these optimizations fall into two broad categories: bandwidth optimizations and compute optimizations.

Bandwidth Improvements

Controlling network bandwidth utilization is obviously a key consideration for VDI display protocols. This is especially true in the WAN environment, where network bandwidth can be a relatively scarce and highly shared resource. View 5 makes significant improvements in the efficiency with which the PCoIP protocol consumes this resource, while maintaining user experience. In many typical office user environments, bandwidth consumption is reduced by up to 75% (around 4X improvement). In the following section, the optimizations that deliver these gains are discussed.

Lossless Codec Optimizations

In the VDI environment, a user's screen is frequently composed of many forms of content, including icons, graphics, motion video, photos, and text. It is the responsibility of the VDI display protocol to actively monitor the type of content the user is viewing and dynamically manage the compression algorithms utilized for each screen region to ensure the best user experience. For instance, naively applying lossy compression techniques to text-orientated content can result in blurred text edging, which can be very noticeable to users. Accordingly, the PCoIP protocol uses an efficient lossless compression algorithm that has been developed with text compression as a key consideration in order to minimize both bandwidth and CPU utilization.

With View 5, PCoIP protocol debuts a major enhancement to its lossless compression codec. The improved lossless compression algorithm delivers both greater compression ratios and improved robustness. As an example, the improved algorithm delivers twice the compression of its predecessor when applied to content containing anti-aliased fonts (for example, ClearType).

If you consider the desktop belonging to the typical office user, there's frequently significant text content—text on web pages, emails, presentations, and PDF documents. Accordingly, a significant proportion of the imaging data being transmitted to the client device is frequently compressed using lossless compression algorithms. As a result, View 5's improved lossless compression algorithm delivers a 30% to 40% reduction in bandwidth consumption for typical office user workflows.

Client-side Caching

PCoIP protocol is tasked, among its many responsibilities, with efficiently communicating desktop screen updates to the client device for local display. In many instances, only a small region of the screen may change. VDI protocols such as PCoIP protocol perform spatial filtering and only send information related to the portion of the

screen that changed (rather than naively sending the entire screen). However, in additional to spatial filtering, temporal analysis can also be performed. For instance, consider minimizing an application, dragging a window, flicking through a slide-set, or even scrolling through a document. In all these examples, each successive screen update will be largely composed of previously seen (potentially shifted) pixels. As a result, if the client device maintains a cache of previously seen image blocks, PCoIP protocol can deliver significant bandwidth savings by merely encoding these portions of the screen update as a series of cache indices rather than retransmitting the blocks.

View 5 introduces a client-side image cache, providing bandwidth savings of 30% in many instances (of a typical office user's workflow). This cache is not merely a simple fixed position cache, but captures both spatial and temporal redundancy in the screen updates. In addition to providing bandwidth optimizations for obvious operations (for example, window minimize/maximize, start menu), the image cache also significantly reduces the bandwidth consumption for many interactive operations, such as scrolling and window dragging, ensuring smooth, highly responsive operations even in WAN environments with very constrained bandwidth.

For instance, consider scrolling through a PDF document. As we scroll down, new content appears along the bottom edge of the window, and the oldest content disappears from the top edge. All the other content in the application window remains essentially constant merely shifted upward. The PCoIP protocol image cache is capable of detecting this spatial and temporal redundancy. As a result, for scrolling operations, the display information sent to the client device is primarily just a sequence of cache indices—delivering significant bandwidth savings.

This efficient scrolling has a couple of key benefits;

- On LAN networks, where bandwidth is relatively unconstrained, there's sufficient bandwidth available for high quality scrolling even when client-side caching is disabled. In these situations, enabling client-side image caching delivers significant bandwidth savings—experimenting with a variety of different applications and content types (text heavy, image heavy, and so on), we see bandwidth reductions of over 4X (compared with caching disabled. mileage may vary, but we see this fairly consistently).
- On WAN networks, where bandwidth is fairly scarce, when client-side caching is disabled, scrolling performance is often degraded to stay within the available bandwidth. In these situations, in addition to bandwidth reductions (which vary based on the degree to which scrolling performance is degraded when client-side caching is disabled), client-side caching also ensures smooth, highly responsive scrolling operations even in WAN environments with very constrained bandwidth.

Build-to-Lossless

In combination, the compression improvements and image caching deliver bandwidth savings of around 60% (a 2.5X improvement) out-of-the-box in both LAN and WAN use cases for typical office users.

Additional bandwidth improvements can be obtained in View 5 by leveraging the new image quality controls that have been introduced. By default, PCoIP protocol will build to a lossless image—when a screen update occurs, PCoIP will almost immediately transmit an initial image for display on the client. In rapid succession PCoIP will continue to refine the client's image until a high quality lossy image is achieved. In PCoIP vernacular, this is termed building to a "perceptually lossless" image. If the screen remains constant, PCoIP will, in the background, continue to refine the image on the client until a lossless image is obtained (that is, PCoIP builds to lossless (BTL)). In certain application-spaces, building to a lossless image is a key feature. However, for many office users, the BTL support can be disabled without impact on image quality (indeed, in many cases it is almost impossible to discern any quality difference). And disabling BTL can deliver significant bandwidth savings—in many situations disabling BTL will provide up to around 30% reduction in bandwidth.

In many situations, the difference between fully lossless and perceptually lossless images can be virtually impossible to discern. This can be visually apparent, as illustrated in Figure 2, which shows a zoom-in of two small images. For both images, View fully lossless and View BTL images are shown side-by-side for comparison, clearly illustrating how difficult it is, even when zoomed, to see differences.

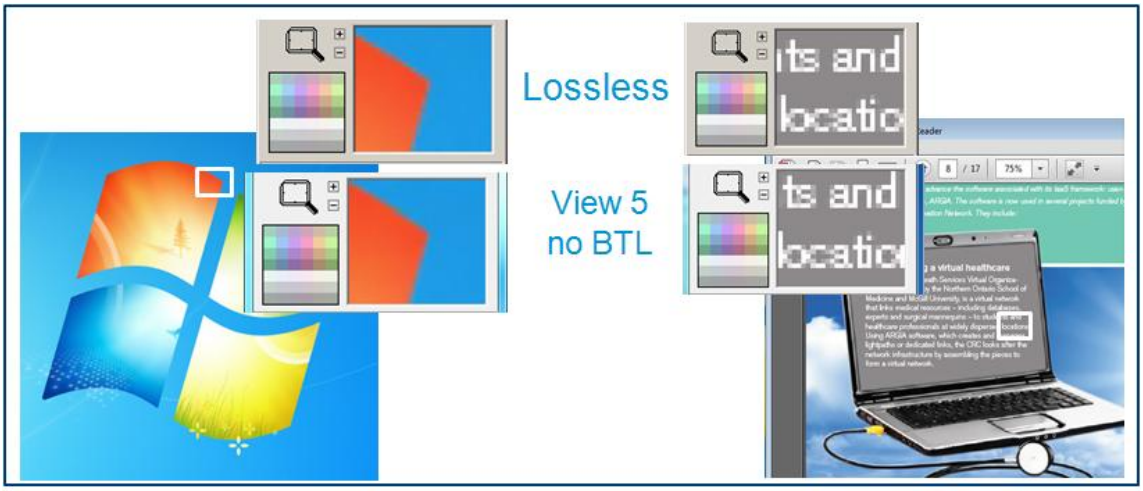


Figure 2. Comparing Fully Lossless and Perceptually Lossless Image Quality

In addition to qualitative analysis, a more quantitative analysis with PSNR (peak signal to noise ratio) and RMS (root-mean-square) error data is also interesting. For a fairly complex image—a fall-colors landscape with significant fine detail in the background tree colors—comparing the perceptually lossless build to a fully lossless build (RGB space), yields a PSNR value of 45.8dB, and RMS error value of 1.3. This clearly illustrates how little loss in quality is associated with perceptually lossless images. For instance, consider the RMS error of 1.3; for 32-bit colors, each RGBA component has 8-bits of precision, with values ranging from 0 to 255. For this image, perceptually lossless is introducing an average error of +/-1.3 to these values—fairly negligible for most use cases.

Overall Bandwidth Reductions

Combining the compression improvements, client caching and disabling BTL commonly delivers a bandwidth improvement of up to 75% (a 4X improvement), for typical office workloads.

CPU Improvements

In VDI environments, desktop consolidation is a key consideration. The more user desktops that can be handled per system (that is, the higher the consolidation ratio), the better the cost savings that can be realized for the VDI deployment. Accordingly, the CPU overheads introduced by the VDI protocol must be carefully constrained. With View 5, PCoIP protocol has been further enhanced to minimize its CPU overhead in a number of significant ways.

Idle CPU Usage

From the VDI protocol's perspective, unless the user is viewing a video, the user is idle for a large proportion of the time. For instance, if a user loads a new web page, there is a flurry of activity as the web page loads and the screen update is displayed, but many seconds or even minutes may elapse with the screen remaining static, as the user reads the content of the page. For a VDI protocol, it is not only important to encode any screen changes efficiently, but to minimize the overheads associated with all background activities that occur during these idle periods. With View 5, VMware has significantly optimized these code paths, and PCoIP protocol's idle CPU consumption is now negligible. Further, the session keep-alive (heartbeat) bandwidth has been reduced by a factor of 2 for many workloads.

Code Optimization

In View 5, many of the hottest image processing and compression functions have been reexamined, their algorithms tweaked for efficiency and their implementations further optimized.

SIMD Acceleration

Image manipulation operations are typically suitable to acceleration via the use of SIMD (Single Instruction Multiple Data) instructions, such as the SSE instructions supported on recent x86 processors. With View 5, PCoIP protocol has been optimized to take even greater advantage of the SSE SIMD support available on x86 processors, not only providing an expanded coverage of the code base, but also, when available, leveraging the SSE instructions available on the very latest processors (for example, SSE 4.2 and AES-NI).

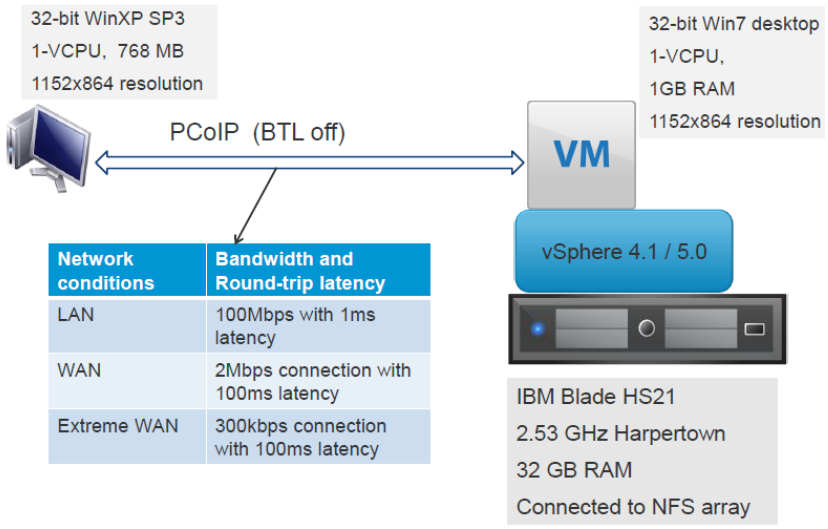
Performance Results – View PCoIP Improvements

In this section, we present the performance results on View 5 PCoIP improvements. In the next section, we present the performance improvements in View due to integration with vSphere 5 platform.

The following sections first present the details of the experimental setup used to analyze the performance improvements, followed by the results comparing View 5 to View 4.5. Also presented is a comparative study of different remote display protocols including Citrix PortICA (XenDesktop 5) and Microsoft RDP (RDP 7.0).

Experimental Setup

All the protocol experiments used the same setup, which is shown in Figure 3. An IBM blade with a 2.53GHz Intel Xeon 5400 processor and 32GB physical memory hosted the desktop VM. This blade was connected to an NFS storage array. The desktop VM ran Windows 7 32-bit with 1 vCPU and 1GB of virtual memory. For the comparison study, a screen resolution of 1152 x 864 was used. A Windows XP 32-bit client connected to a remote desktop with the PCoIP protocol. The build-to-lossless (BTL) setting in PCoIP protocol was disabled to build to perceptually lossless quality (which is hard to differentiate from a fully lossless quality for an office user workload).



Network conditions	Bandwidth and Round-trip latency
LAN	100Mbps with 1ms latency
WAN	2Mbps connection with 100ms latency
Extreme WAN	300kbps connection with 100ms latency

Figure 3. Experimental Setup for Comparing Remote Display Protocols Performance

Network Conditions

Since the remote desktop can be accessed from a main office, branch office, or home office, the network conditions will be significantly different in all these cases. Therefore, three typical network conditions were used as shown in the experimental setup diagram.

- LAN – Plentiful bandwidth available with almost no latency.
- WAN – Bandwidth is limited (2 Mbps) and there is 100ms round-trip latency.
- Extreme WAN – Bandwidth is severely limited (300 kbps) and there is 100ms round-trip latency.

Performance Metrics

In a typical VDI deployment, it is important to consider:

1) How many users can be supported on a given hardware platform and a network link
2) How to minimize the cost of the deployment
3) How to maximize the VDI user experience

For (1) user consolidation and (2) costs, the numbers of users per CPU core are relevant to look at. This number represents the guest CPU usage for a typical office user workload. For (2) costs and (3) better user experience, the application response time and the bandwidth usage for WAN environments need to be examined. So, from a performance perspective, three important metrics that stand out are:

- Application response time – To measure the user experience
- Bandwidth usage – How many users can be supported on a shared network link
- CPU usage – How many users can be supported per core on a given platform

Workload

For all the experiments, we have used VMware View Planner, a workload generator that simulates typical office user operations, such as typing a word in MS Word, playing a PowerPoint slideshow, reading Outlook emails, browsing PDF pages, browsing Web pages, watching video, and so on. More details about the View Planner are described in the VMware View Planner user guide [5].

Performance Improvements Compared to View 4.5

The VMware View Planner workload was run for three network conditions (LAN, WAN, and extreme WAN) for both View 4.5 and View 5. Performance results were collected including application response time, downlink bandwidth usage, and the guest CPU usage. Chart data shows results that were normalized to the "maximum" values seen in View 4.5 and View 5 in all network conditions. For example, if View 4.5 with a LAN configuration had the highest bandwidth usage, then it is normalized to 1.0 and other values are scaled with respect to that. In this example, View 4.5 with LAN is used as the baseline for comparison.

Application Response Time

To maximize the user experience, a lower application response time is needed in any network conditions. Due to recent bandwidth improvements, better response times are seen with the PCoIP protocol in extreme WAN conditions. The normalized response time comparing View 5 and View 4.5 is shown in Figure 4.

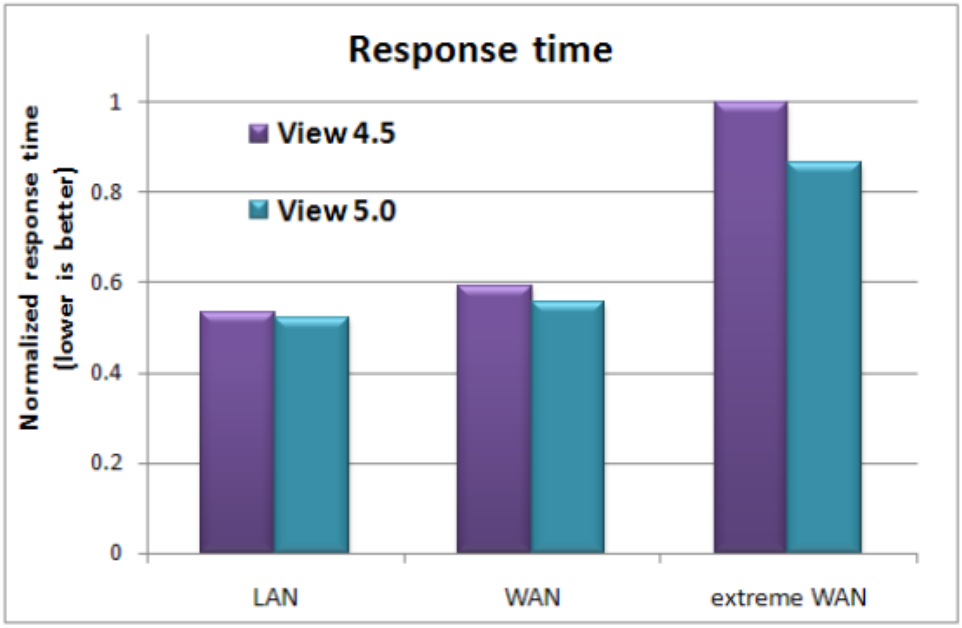


Figure 4. Application Response Time for View 4.5 and 5 for Different Network Conditions

The figure shows that the response time in general increases going from LAN to extreme WAN conditions. Here, the View 4.5 extreme WAN case has the highest latency and hence it is normalized to 1.0 and is used as the baseline. Looking at LAN and WAN conditions, no significant differences in response times are seen in View 4.5 and 5. However, in extreme WAN, there is about 15% better user experience with View 5. This is due to the WAN improvements in View 5 PCoIP which minimizes the bandwidth usage and requires less data and time to send the updated display frames.

Bandwidth Usage

Bandwidth usage has been significantly optimized in View 5 to provide a better WAN experience. Figure 5 presents the bandwidth usage of View 4.5 and View 5 for different network conditions. The y-axis shows the normalized bandwidth usage (lower the better). Results show a significant bandwidth reduction in View 5 for a typical office user workload. In the LAN case, there is about 75% bandwidth improvement, whereas in WAN and extreme WAN, there is about 70-75% bandwidth improvement. This is a very significant reduction and means that you can now support up to 4x more users on the same network link. Additionally, bandwidth usage of about 50kbps or less is seen for almost all network conditions for the View Planner workload.

CPU Usage

Optimizations in View 5 include an idle CPU optimization, code optimizations, and use of optimized libraries. Even with new features such as caching and lossless codec, the overall guest CPU usage is reduced. This is seen in Figure 6.

The View 4.5 LAN case shows the highest CPU usage, so it is normalized as 1.0 and is used as the baseline. In the LAN case, more than a 10% guest CPU improvement is seen, whereas in WAN and extreme WAN, between 5% to 10% CPU improvements are seen. This means that with View 5, we can realize better host consolidation.

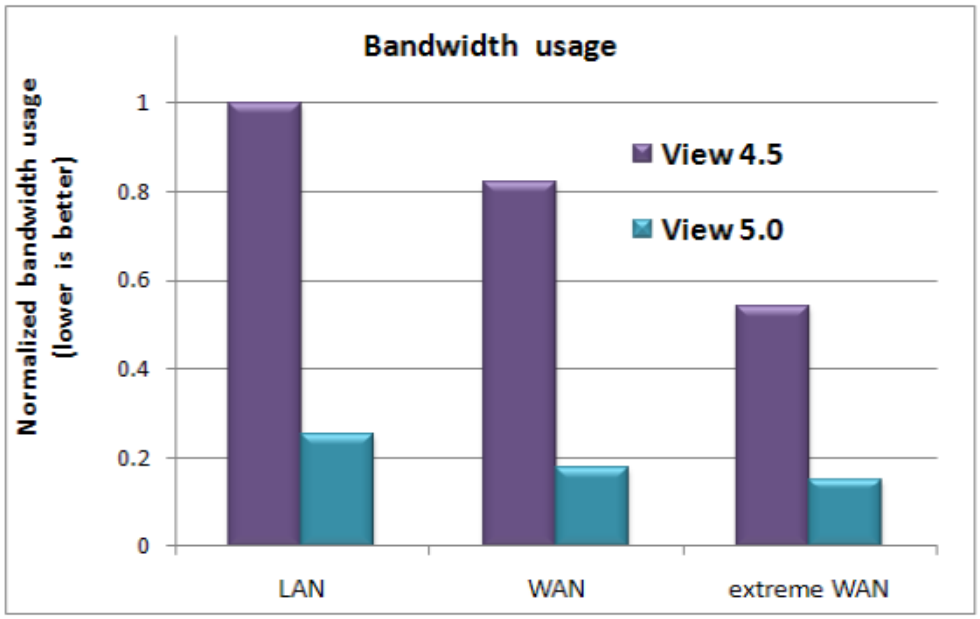


Figure 5. Bandwidth Usage for View 4.5 and 5.0 for Different Network Conditions

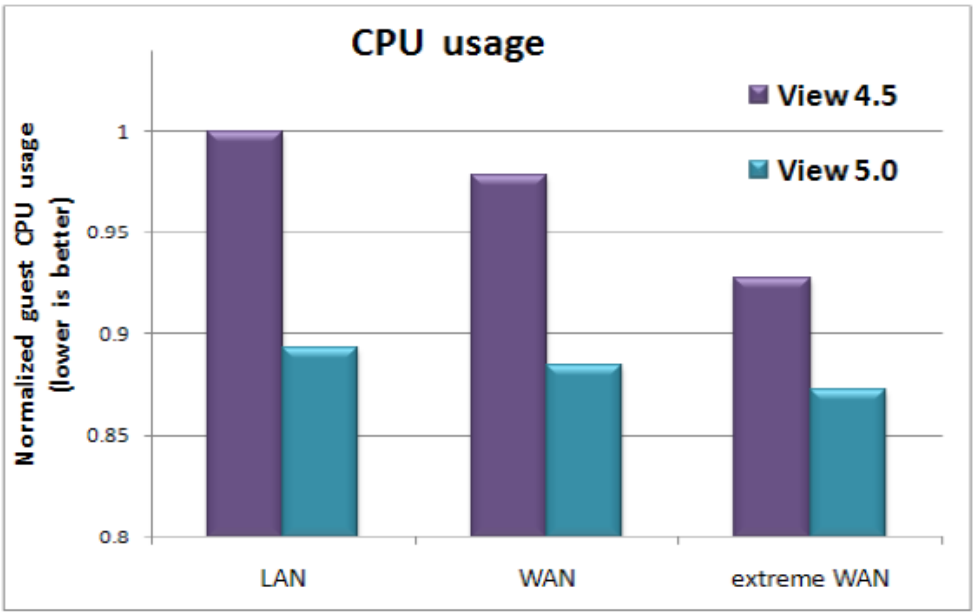


Figure 6. Guest CPU Usage for View 4.5 and 5.0 for Different Network Conditions

Comparison with Other Remote Display Protocols

This experiment used the same setup described in the previous test and the same workload (VMware View Planner) to compare the performance of different remote display protocols. Some specifics include:

- VMware View PCoIP – View version 5 and disabled BTL in PCoIP protocol settings
- Citrix PortICA or HDX – XenDesktop version 5, enabled progressive build with medium compression settings

- Microsoft RDP – RDP version 7.0 is used with MMR enabled and network condition is set accordingly

Results are normalized to the "maximum" value that was seen across all protocols and all network conditions

Response Time

The View Planner workload was run for all remote display protocols for all the network conditions and performance results were collected. The application response time comparing all three protocols is shown in Figure 7. The y-axis shows the normalized response time. RDP had the highest response time in extreme WAN conditions, so it is used as the baseline for comparison purposes.

Looking at the LAN condition in Figure 7, no noticeable difference is seen in the response time across all protocols. In the WAN scenario, PCoIP protocol provides the best response time and therefore provides the best user experience, whereas RDP suffers the most. In extreme WAN, RDP is about 40% slower, whereas PCoIP protocol provides a better user experience even under extreme WAN conditions.

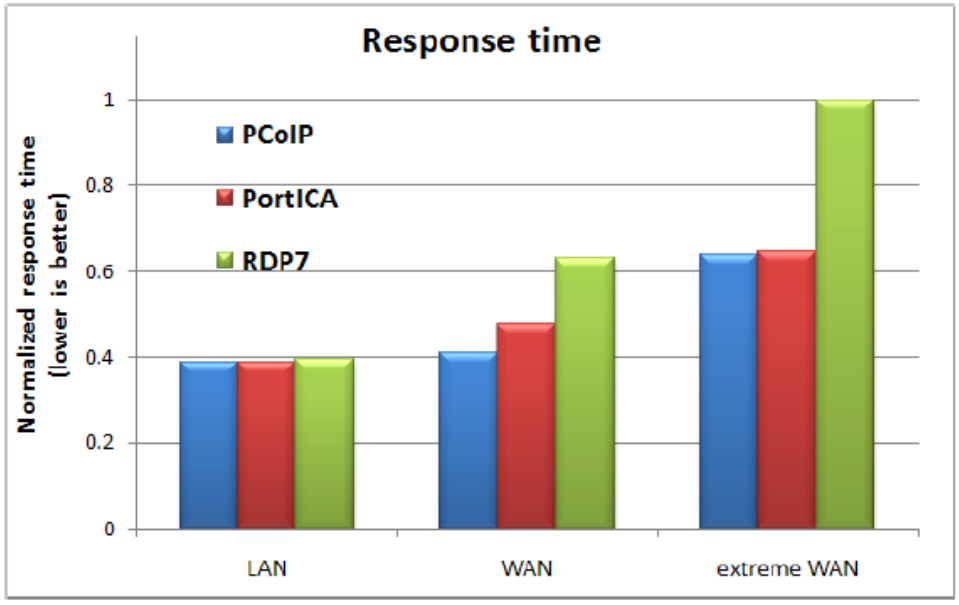


Figure 7. Application Response Time for Different Display Protocols with Different Network Conditions

Bandwidth Usage

Figure 8 compares bandwidth usage across different network conditions. The bandwidth usage is highest in RDP in LAN conditions and this is used as a baseline to compare against the different cases. The figure shows that PCoIP protocol consumes significantly less bandwidth in almost all network conditions and is comparable to PortICA in terms of bandwidth usage. Additionally, RDP consumes higher bandwidth in almost all network situations. Another interesting observation is that the bandwidth usage drops 50% in the case of PCoIP protocol moving from LAN to extreme WAN conditions while maintaining similar quality. In RDP, video playback was degraded and graphics-sensitive operations responded more slowly, which resulted in the drop in bandwidth usage.

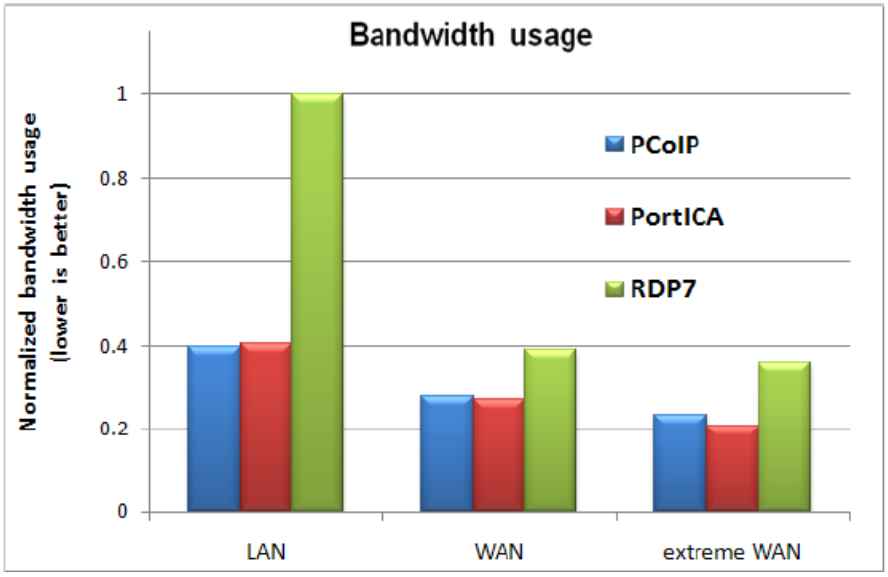


Figure 8. Bandwidth Usage for Different Display Protocols with Different Network Conditions

CPU Usage

Minimizing guest CPU usage is very important in providing the needed user consolidation on a given hardware platform. Figure 9 compares the guest CPU usage of the View Planner workload for the View PCoIP, PortICA, and RDP7 protocols for LAN, WAN, and extreme WAN conditions. Figure 9 shows that PortICA in the LAN condition has the highest CPU usage. PCoIP protocol provides about 10% better CPU usage compared to PortICA in the LAN condition and similar improvements are also seen in both the WAN and extreme WAN conditions. In extreme WAN, lower CPU usage is seen with RDP because of excessive slowness of video and high graphics-intensive operations.

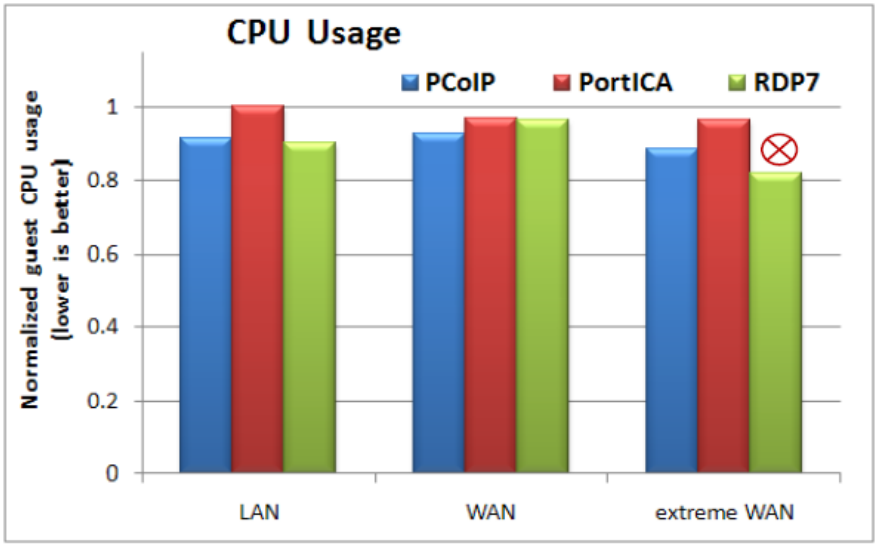


Figure 9. Guest CPU Usage for Different Display Protocols with Different Network Conditions

Performance Results – vSphere 5 Platform Improvements

Comparison with View 4.5

The CPU and memory optimizations in vSphere 5 help achieve a higher consolidation ratio of desktops. The memory optimizations especially help Windows 7 deployments, because Windows 7 consumes more memory resources than Windows XP. The following graph gives an overview of the consolidation improvement that vSphere 5 achieves in comparison to vSphere 4.1, for Windows 7 deployments.

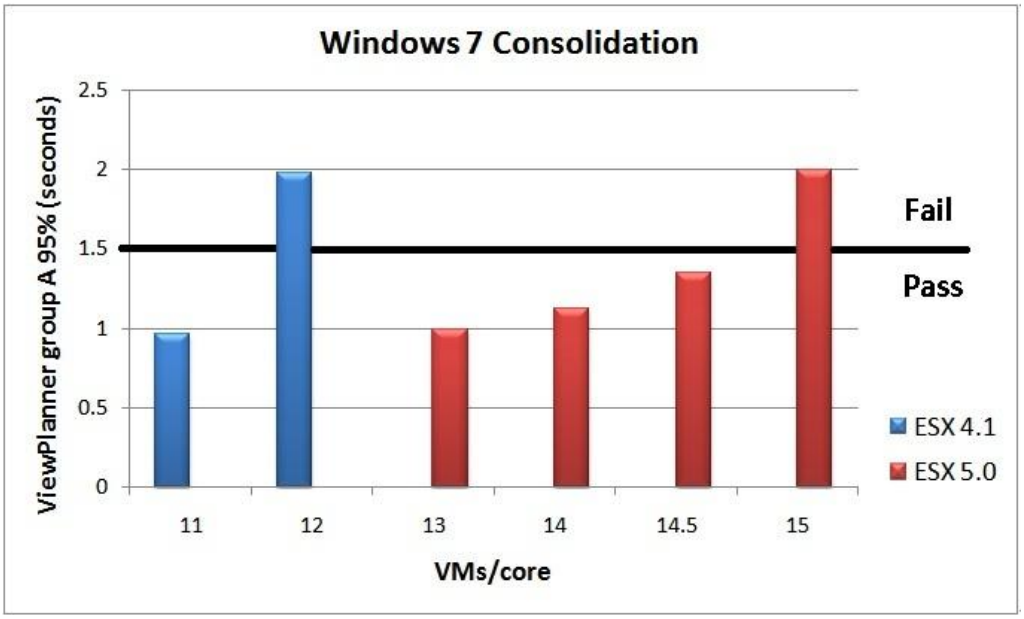


Figure 10. Windows 7 Consolidation Comparison with VMware vSphere 4.1 and 5.0

Figure 10 depicts the number of desktops that successfully passed Quality of Service requirements using the VMware View Planner workload. A run is considered passed if application response times are below 1.5 seconds, and failed otherwise. vSphere 4.1 could achieve 11 Windows 7 VMs per core, while vSphere 5 is able to achieve 14.5 VMs per core. The following sections present some of the performance metrics that were measured during the View Planner run.

CPU Usage

VMware vSphere 5 has CPU scheduler optimizations, especially those related to hyper-threading. These optimizations make efficient use of the CPU by optimally scheduling the different desktops on hyper-threaded cores. Figure 11 shows the histogram of CPU utilization for Windows 7 VMs on vSphere 5.

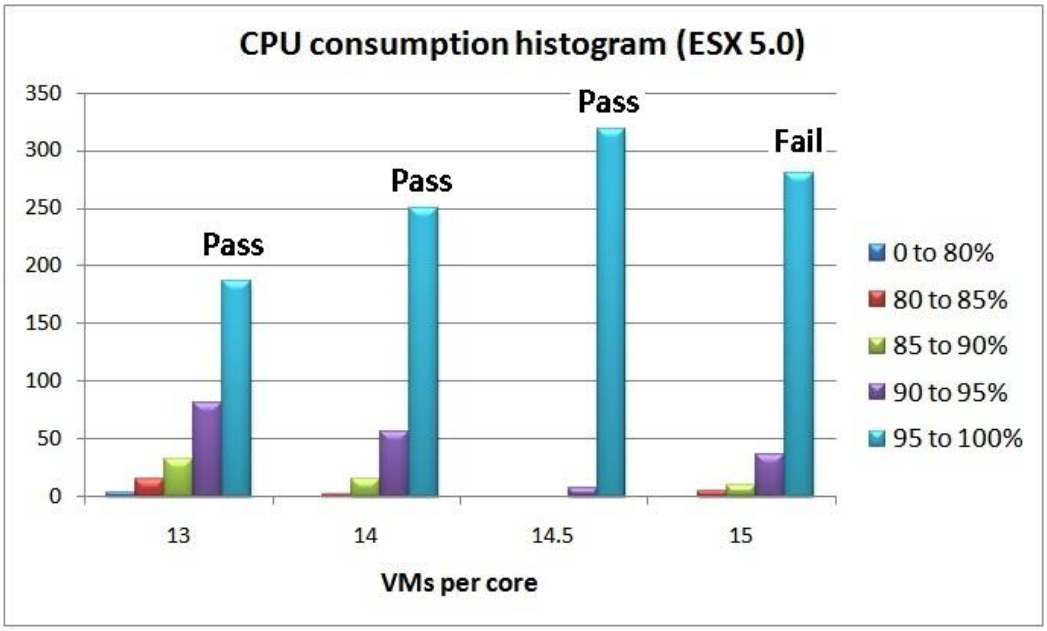


Figure 11. Host CPU Usage Histogram for Different VMs/core

In the above figure, the histogram of CPU utilization on the ESX server is shown. While the View Planner workload ran, CPU utilization was measured using esxtop in batch mode. Esxtop collected performance samples every few seconds. CPU utilization was extracted from the samples and plotted as a histogram. For the 14.5 VMs per core case, almost all samples fall in the 95% to 100% range, which means that the CPU is being efficiently used. Beyond 14.5 VMs per core, the CPU utilization decreases because of other factors like increased ballooning, when guest memory is written to the page file.

Memory Overhead Reduction

vSphere 5 reduces the amount of virtual machine book-keeping data that needs to be kept in main memory, making more memory available for desktop VRAM. Figure 12 shows the memory footprint reduction for a 1GB Windows 7 desktop.

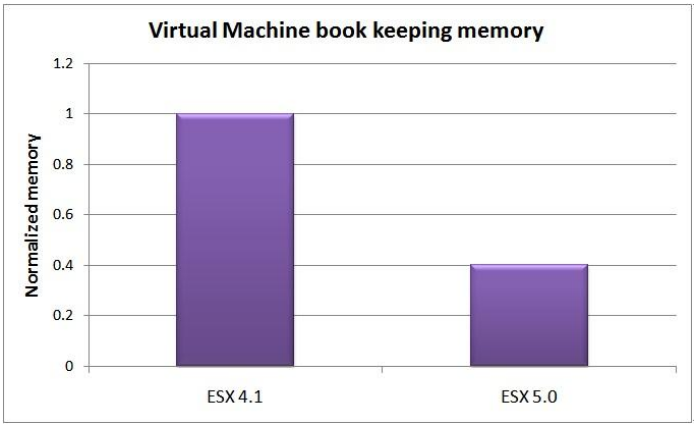


Figure 12. Virtual Memory Book-Keeping Memory Reduction in ESX 5

Figure 12 shows that the amount of book-keeping memory per virtual machine was reduced 60% in ESX 5. This enables more desktops to be run on an ESX server.

Another improvement in ESX 5 is the use of a conservative ballooning technique. ESX 5 uses a slab-based approach to determine the system free memory threshold to determine when to start ballooning. The bigger the main memory size, the smaller is the free percentage threshold. Figure 13 shows that even with a 21% memory overcommitment on the ESX server, the average ballooned memory is very low.

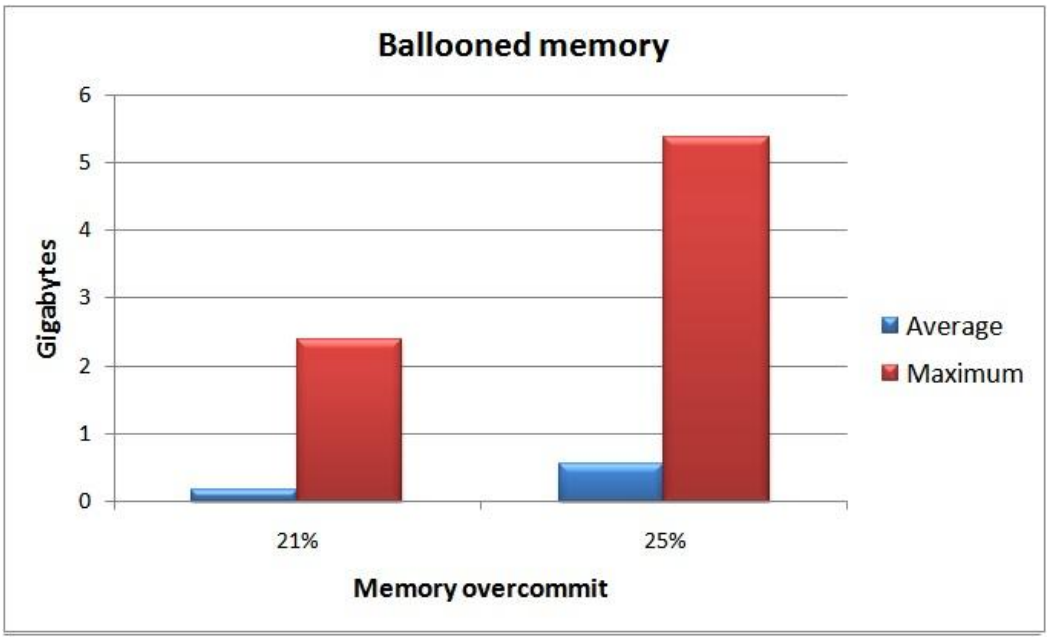


Figure 13. Ballooned Memory in ESX 5.0 with Different Memory Overcommitment Percentages

Storage

VDI workloads are bi-modal in their I/O load characteristics. There is heavy I/O load when the desktops are booting up, but relatively light I/O when the desktops are running an Office workload. Storage tiering is very well suited for this kind of an environment, especially for VDI.

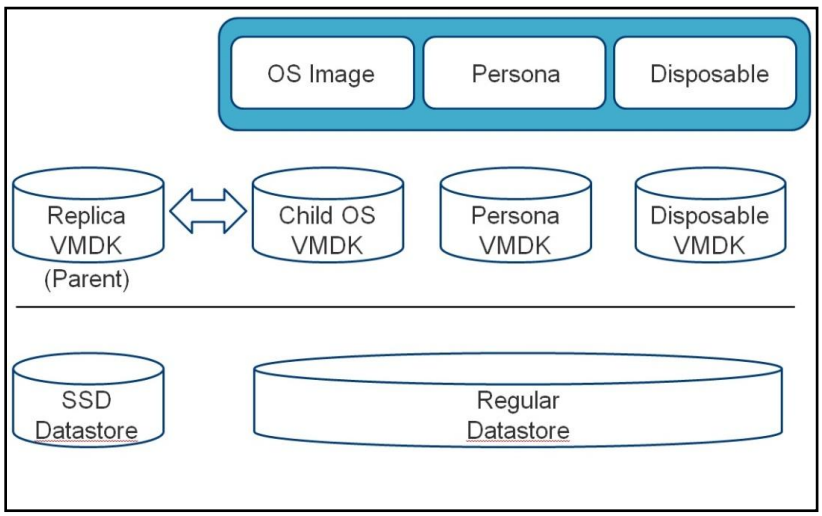


Figure 14. VDI Storage Tiering Configuration

Figure 14 shows the storage tiering configuration that can be used for VDI. The desktop VM has different virtual

disks including OS image, persona management data and a disposable disk for page file. I/O generated during boot is primarily targeted at the OS image disk. The OS image disk is typically a linked clone that has the replica disk as its parent. Therefore to get best performance during a boot storm, store the replica disk on an SSD datastore that can support the required amount of I/O load. The other disks can be stored on a regular datastore composed of slower spinning media to support the lighter Office workloads during steady state.

View Composer

Desktop provisioning in View depends on a variety of factors, as it makes use of services provided by the vSphere platform and the underlying hardware resources. The concurrency of operations determines how many simultaneous requests can be sent out to the vSphere platform. The default value has been adjusted such that it works for most typical hardware installations. But if the hardware can handle the load, then a couple of concurrency parameters can be increased in order to speed up the provisioning process.

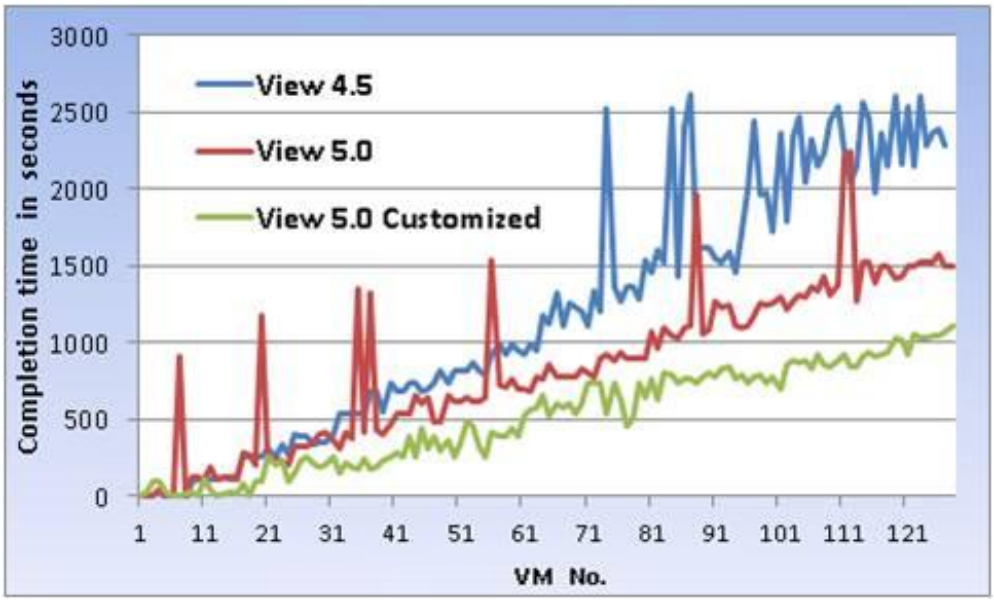


Figure 15. Provisioning Time Taken in View 4.5 and View 5.0

Figure 15 shows the relative provisioning performance of View 4.5 and View 5. It can be seen that View 5 has better performance compared to View 4.5 even with default settings. When the concurrency parameters are set, the provisioning time in View 5 further decreases by about 30%. Table 1 enumerates the concurrency settings that can be applied in the ADAM server.

ADAM PARAMETER	VALUE
pae-VCAllRefitRampFactory	12
pae-SVICreateRampFactor	20

Table 1. ADAM parameters for View provisioning

View 5 Best Practices

This section describes all the best practices that can be applied to the guest, platform, protocol, or even at the network layer.

Platform best practices

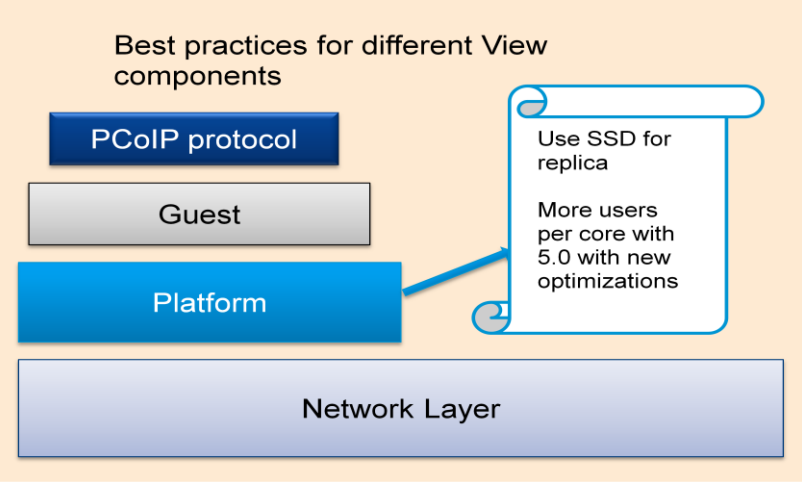


Figure 16. Platform Best Practices

CPU Consolidation

vSphere 5 successfully runs up to 14.5 Windows 7 desktops per core with good performance. This number is for light to medium Office workloads. Heavier workloads will cause more CPU consumption and will result in reduced consolidation ratios.

Memory Consolidation

For Windows 7 desktop VMs with 1GB of memory, vSphere 5 can support more desktops per memory real estate. The following numbers can be used as rough examples:

PHYSICAL MEMORY (GB)	NUMBER OF VMS IN ESX 4.1	NUMBER OF VMS IN ESX 5
96	84	91
256	223	242
512	446	483

Table 2. Increased Consolidation of VMs in ESX 5.0

From Table 2 it is apparent that for Windows 7 VMs with 1GB, administrators can consolidate around 8% more on vSphere 5 compared to vSphere 4.1.

Storage

Use storage tiering for VDI environments. While provisioning the desktop pool, create the replicas on an SSD datastore to support boot storm and login storm. For the other virtual disks, use regular datastores made up of spinning media of appropriate speed and capacity as the situation requires.

Guest Best Practices

Optimizing the master VM is very important before the linked clones or full clones are created. Many optimizations can be applied to the guest VM which will save some precious resources such as bandwidth consumption, storage requirements, etc. Some of the guest best practices are shown in Figure 17.

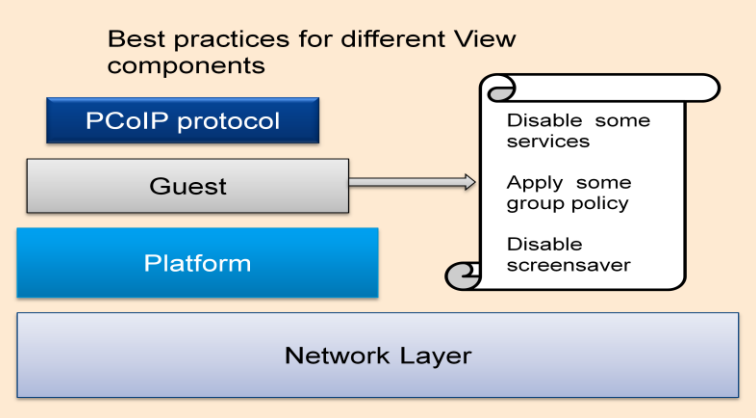


Figure 17. Guest Best Practices

Table 3 provides the settings that were applied to collect some of the single-VM results. For a typical hardware configuration, 1 vCPU is recommended for a typical office user. However, for users running heavy multimedia apps or CPU-intensive applications, 2 vCPUs are recommended.

For WinXP, the virtual memory can be set to 512MB to 768MB, whereas for 32-bit Windows 7, it can be set to 1GB and for 64-bit Win7, it can be set to 2GB. For the network adapter, install the vmxnet3 driver to achieve better performance. PVSCSI or LSI logic SAS can be used as one of the storage adapters. We also recommend that you have latest VMware Tools installed and make sure that the balloon driver is running correctly.

To save on storage space and bandwidth usage, further optimizations can be applied inside the guest. To curtail the redo logo growth with the linked clones, consider disabling some services such as Windows update, super-fetch, and the Windows search and indexing service. Moreover, some of the group policies can be applied to disable hibernation and system restore. Also disable the screensaver and set wallpaper to none. To save some bandwidth usage, adjust Windows visual settings to best performance. This can provide an additional 10-20% bandwidth savings in WAN environments. To further reduce the bandwidth, disable fading effects and clear-type. Additionally, external drive caching for quick release and autoplay can be turned off so that it doesn't try to pull USB drive info over the WAN. There are more guest optimizations that are discussed in the Windows 7 Optimization Guide for VMware View [1].

PARAMETER	CONFIGURATION
vCPU	1 for WinXP and Win7, 2 for multimedia intensive apps
Memory	512-768 MB for WinXP, 1GB for 32-bit Win7, 2GB for 64-bit Win7 1.5-2GB for WinXP and Win732-bit and 3GB for Win7 64-bit for memory intensive apps
Network adapter	Vmxnet3, flexible
Storage adapter	PVSCSI or LSI logic SAS
VMware Tools	Latest installed
Visual settings	"Adjust to best performance"
Disable services	Windows Update, Super-fetch, Windows Index
Group policy settings	Disable Hibernation System restore disable Screensaver to None
Other settings	Turn off clear-type Disable fading effects Disable auto-play and external drive caching for quick release Disable last access timestamps

Table 3. Guest Best Practices to Save Bandwidth and Storage Resources

View PCoIP Best Practices

After optimizing the master VM, you can apply some PCoIP protocol best practices to realize the best user experience as shown in Figure 18.

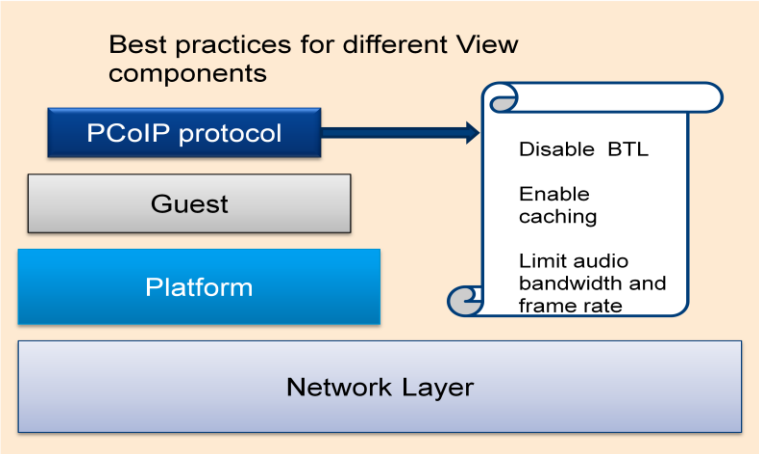


Figure 18. PCoIP Protocol Best Practices

Table 4 lists some of the GPO settings that you can apply to improve the user experience for WAN environments. The first two settings in the table can be made regardless of network conditions—these changes will save lot of bandwidth with almost no discernible difference in quality.

SETTING	DEFAULT	RECOMMENDATION	DESCRIPTION
Build to lossless	On	Turn Off	Enables the ability to enable or disable build to lossless
Session Audio BW limit	500Kbps	50 - 100Kbps	Reduces BW usage of audio with usable quality
Maximum frame rate	30	Change to 10-15 based on network settings	In WAN conditions, this will be helpful for video playback and fast graphics operations
Maximum session bandwidth	-	Set it as per network conditions	Good for better bandwidth estimation

Table 4: PCoIP Protocol GPO Settings and Best Practices

The first setting of disabling build-to-lossless is quite important as for perceptually lossless quality (which is hard to differentiate from fully lossless quality for an Office user workload), you will save 20-30% bandwidth savings. We also suggest limiting the session audio bandwidth to be in the range of 50-100kbps and it will still provide the usable audio quality with significant lower bandwidth usage. The last two settings of maximum frame rate and maximum session bandwidth can be set as per the network conditions. The default value of maximum frame rate is 30 and it can be lowered to anywhere between 10 to 15 for typical WAN conditions and it will provide decent video playback performance. The last setting of maximum session bandwidth can be set as per your link bandwidth and this will help in maximizing the users experience sharing the same link and will also help the PCoIP protocol in better bandwidth estimation. There are more PCoIP protocol settings which are discussed in View Network optimization guide that can be found on VMware site.

Network optimizations

This section describes the network optimizations and best practices that realize the best experience from end-to-end. Some of these practices include assigning right traffic priority, minimizing packet loss, and using UDP for VPN connections, as shown in Figure 19.

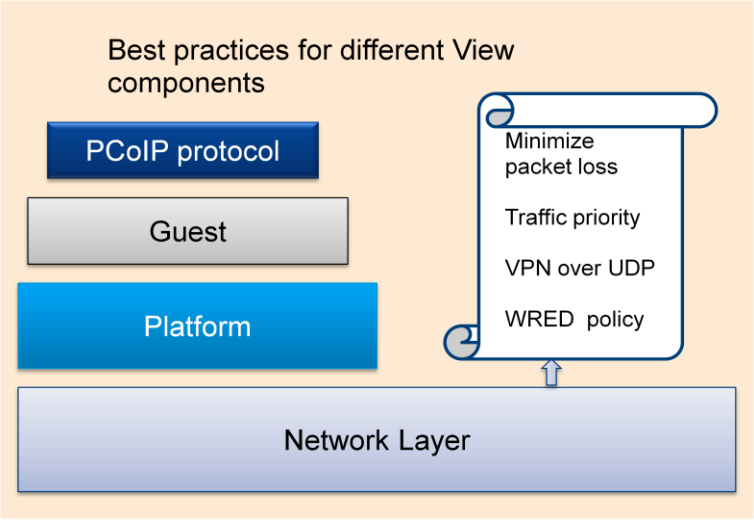


Figure 19. Network Best Practices for PCoIP Protocol Traffic

In the end-point device, View 5 adds new ways to monitor PCoIP protocol performance (about 30 new performance counters that can be analyzed in a WMI based tool) and can be used for performance monitoring and troubleshooting.

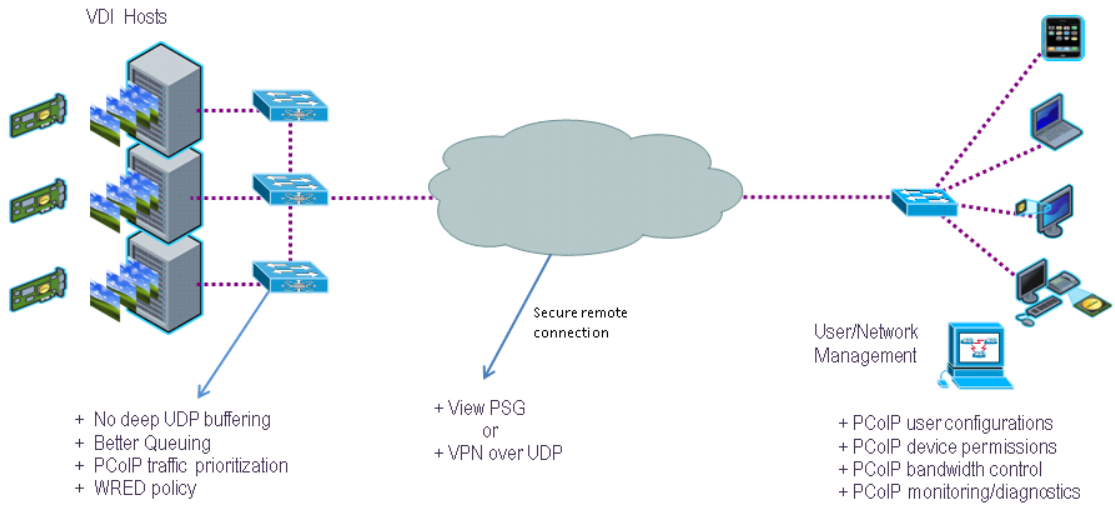


Figure 20. Network Best Practices at Edge Routers and End-Point Devices

Figure 20 shows the network architecture diagram and the best practices that can be applied at the edge routers, and the end-point devices. If you find deep UDP buffers in your edge routers, this will increase latency and since PCoIP protocol is an adaptive protocol, this may affect the performance a bit. So, we suggest taking a look at the UDP buffers at the routers and configuring it to absorb about 50 to 100ms of traffic. We also recommend taking a look at the packet re-ordering and packet loss in the network and minimizing it if seen. Assigning a good traffic priority is also very essential for the PCoIP protocol traffic to realize better performance. You may consider assigning higher priority than TCP traffic, but it may be lower than the VoIP traffic. To do better congestion avoidance, we recommend using weighted random early drop (WRED) policy instead of tail drop technique. Another thing that comes up at the backbone or edge routers is data fragmentation if the packets are bigger than a particular size, for example, 1500 bytes. The fragmentation and reassembly adds unnecessary delay to the traffic and may not be optimal, hence the GPO settings can be applied accordingly to limit the PCoIP MTU to 1300 bytes.

To provide secure remote PCoIP connections, you can use PCoIP security gateway (PSG) shipped with View 4.6 version and onwards. However, if you are using VPN to connect to the desktop, we have seen VPN over UDP or VPN in DTLS mode provides better performance and hence, UDP/DTLS must be used for VPN connections.

Conclusion

The combination of View 5 and vSphere 5 deliver significant improvements in user experience and consolidation ratios, while at the same time delivering significant reductions in bandwidth consumption. This paper highlighted how enhancements to View's PCoIP lossless compression algorithm and support for client-side image caching in combination deliver up to 75% bandwidth reduction in both WAN and LAN conditions when compared with the previous release of View.

Further, this paper illustrated how, across all network configurations, View 5 delivers improved user experience compared with other VDI solutions, while consuming significantly less bandwidth and CPU resources than Microsoft RDP7 and comparable bandwidth to Citrix HDX.

Finally, while View 5 PCoIP protocol dynamically adapts to changing network and CPU constraints, ensuring great user experience out-of-the-box, this paper listed a number of environment variables and VDI best practices that ensure users can get the most out of their VDI environment.

References

1. Windows 7 Optimization Guide for VMware View

2. Using PCoIP Host Cards Brokered by VMware View 4

3. Using PCoIP Zero Clients with PCoIP Host Cards

4. VMware View documentation:

    VMware View Architecture Planning

    VMware View Administration guide

    VMware View Installation guide

    VMware View Upgrades guide

    VMware View Clients documentation

    VMware View Integration guide

5. VMware View Planner: Scaling and Characterization tool for Large scale VDI deployments

6. Performance Best Practices for VMware vSphere 5

About the Authors

Dr. Banit Agrawal is a Sr. Performance Engineer at R&D performance team at VMware. He has expertise in VMware View and remote display protocols including PCoIP protocol, performance characterization using suite of display benchmarks, View Planner and performance troubleshooting.

Dr. Lawrence Spracklen is a Senior Performance Engineer at VMware. His current research focus is VDI deployments, specifically protocol optimization and multimedia quality analysis.

Sunil Satnur has worked for VMware performance engineering for the past five years. During this time, he has focused on improving storage scalability for desktop and cloud environments. He has implemented and analyzed desktop workload generators and holds a patent in the area of display benchmarking.

Rishi Bidarkar is Sr. Manager in the performance team at VMware. He leads the VDI Performance and View Planner team. He has filed several patents in the area of VDI performance and display benchmarking.

Acknowledgements

We would like to thank Uday Kurkure, Mason Uyeda, View development team, Teradici team, and Julie Brodeur for their invaluable feedback and suggestions.

VMware, Inc. 3401 Hillview Avenue Palo Alto CA 94304 USA Tel 877-486-9273 Fax 650-427-5001 www.vmware.com

Copyright © 2011 VMware, Inc. All rights reserved. This product is protected by U.S. and international copyright and intellectual property laws. VMware products are covered by one or more patents listed at http://www.vmware.com/go/patents. VMware is a registered trademark or trademark of VMware, Inc. in the United States and/or other jurisdictions. All other marks and names mentioned herein may be trademarks of their respective companies. Item: PS-View-102011-01