

White Paper

Sizing of Virtual Desktop Infrastructures



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Introduction

This document is designed to illustrate the requirements of a virtual desktop infrastructure (VDI). The focus is on the CPU and RAM requirements and also in particular on the requirements of the storage subsystem. The network and bandwidth requirements are not part of this White Paper. The results can be used as a basis for sizing a corresponding VDI environment based on Citrix XenDesktop 4 / 5 or VMware View 4.5 / 4.6 / 5.1.

In order to offer the best possible efficient VDI solution, it is important to align the three resources CPU, RAM and Disk IO as best as possible. If one of the components is not the correct size, an optimal use of resources is no longer possible. The Disk IO is usually the limiting factor in today's VDI environments. The RAM is second as a possible bottleneck. The CPU resource is usually not a limiting factor in today's VDI architectures – but is frequently incorrectly identified as such. This is due to the manner in which the resource CPU is displayed on the administration consoles. The CPU utilization is usually displayed here. However, there is no differentiation between the actual implemented computing cycles and the wait cycles (so-called "wait states"). In today's VDI scenarios the percentage of actual CPU computing work is normally clearly under 10%. The remaining 90% of the available CPU performance is used up in "Waiting", e.g. for hard disk read processes.

The CPU utilization display in the administration tools (e.g. VMware vCenter Performance, Citrix XenCenter Performance) shows 100% CPU utilization in such situations as the CPU can no longer accept any further jobs. Wait states occur in virtual infrastructures in a massive manner as several virtual machines with multiple operating systems clearly create more wait states than a single physical system with only one operating system. However, both physical and virtual systems struggle with the large CPU performance discrepancy (fastest resource), RAM (2nd fastest resource) and storage (slowest resource). Thus it is not surprising that unfavorably sized RAM and/or storage subsystem performance that is too low (disk IO), are the most frequent reasons for an increased number of wait states on the CPU side. This prevents optimal utilization of existing virtual infrastructure resources.

- The inquiries, seen here as raindrops, fill the wait queues of the respective resource – seen here as containers.
- If a resource such as disk IO is "full", the other resources that are still "empty and free" fill up automatically; wait states arise.
- The CPU is thus filled up until it is "completely full". As soon as the CPU can no longer take on any more jobs, there is a jam waiting usually for "slower" resources. Once this status is reached, you can usually only indirectly determine who is originally responsible for the situation.

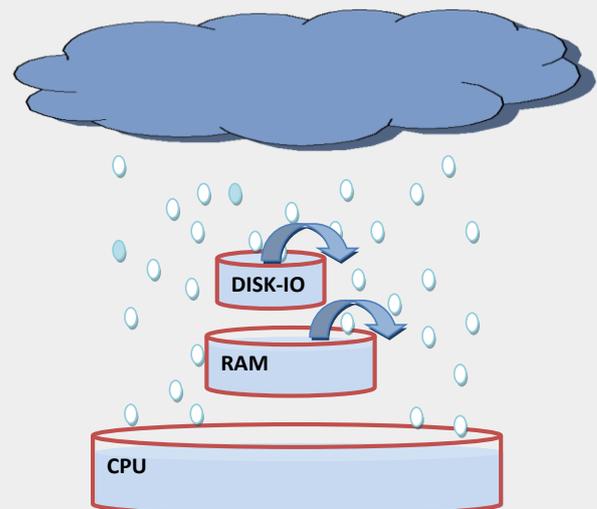


Figure 1: Dependencies of CPU, RAM and storage

¹ As of VMware View 5 it will probably be possible to save the Replica Disk with Linked Clones in the RAM of the vSphere 5.0 Hypervisor Server. This results in clearly fewer read IOPS on the SAN side. If this option is not used, the SAN requirements will probably remain comparable for View 5 as well.

Use of terms and names

Hyperlinks as footnotes have been included in the text for more information about specific products or manufacturers. Recurring abbreviations or terms are explained in the Appendix, together with a hyperlink to the source. The abbreviations and terms when first appearing in the text are linked to the glossary. Product and trade names are usually abbreviated:

➤ Microsoft® Corporation:	Microsoft
➤ Windows® 7:	Windows 7
➤ Citrix® Systems, Inc.:	Citrix
➤ Citrix® XenApp™:	XenApp
➤ Citrix® XenDesktop®:	XenDesktop
➤ Citrix® XenServer®:	XenServer
➤ VMware™:	VMware
➤ VMware™ View™:	View
➤ VMware™ vCenter™:	vCenter
➤ VMware™ vSphere™:	vSphere
➤ VMware™ ThinApp™:	ThinApp
➤ Oracle®:	Oracle
➤ Sun® Microsystems:	Sun
➤ Cisco®:	Cisco

The Microsoft trademarks can be seen at: <http://www.microsoft.com/library/toolbar/3.0/trademarks/de-de.msp>.

The Citrix trademarks as well as the regulations for the correct name and identification can be found here:

<http://www.citrix.com/English/aboutCitrix/legal/secondLevel.asp?level2ID=2210>.

Cisco trademarks are listed here:

<http://www.cisco.com/web/siteassets/legal/trademark.html>.

All other products named in this document are trademarks of the respective manufacturer.

Tasks

- Develop and set up a POC (proof-of-concept) in order to simulate the operations load on virtual clients (vClients) which arises with standard users.
- Compare the technologies VMware "Linked Clone" and Citrix "XenDesktop/Provisioning".
- Create a decision matrix and an in-depth recommendation to continue using suitable technology.
- Create test documentation

The following was taken into account when making the load measurements:

- The load simulation is to be carried out, on the one hand, using normal load simulation programs, and on the other hand the comparison with the manufacturer's determined values should be permitted.
- The basic environment should be kept the same for comparison reasons and any special optimization should be avoided.

Market observation and product selection

The basis for the results document was the following Hypervisor and management solutions:

- Citrix XenServer 5.6 and XenCenter 5.6
- VMware ESX vSphere 4.1 and vCenter 4.1

² Information made available by the market research institute Gartner (May 2010; replaced with updated figures in June 2011) acted as the basis for product and manufacturer selection.

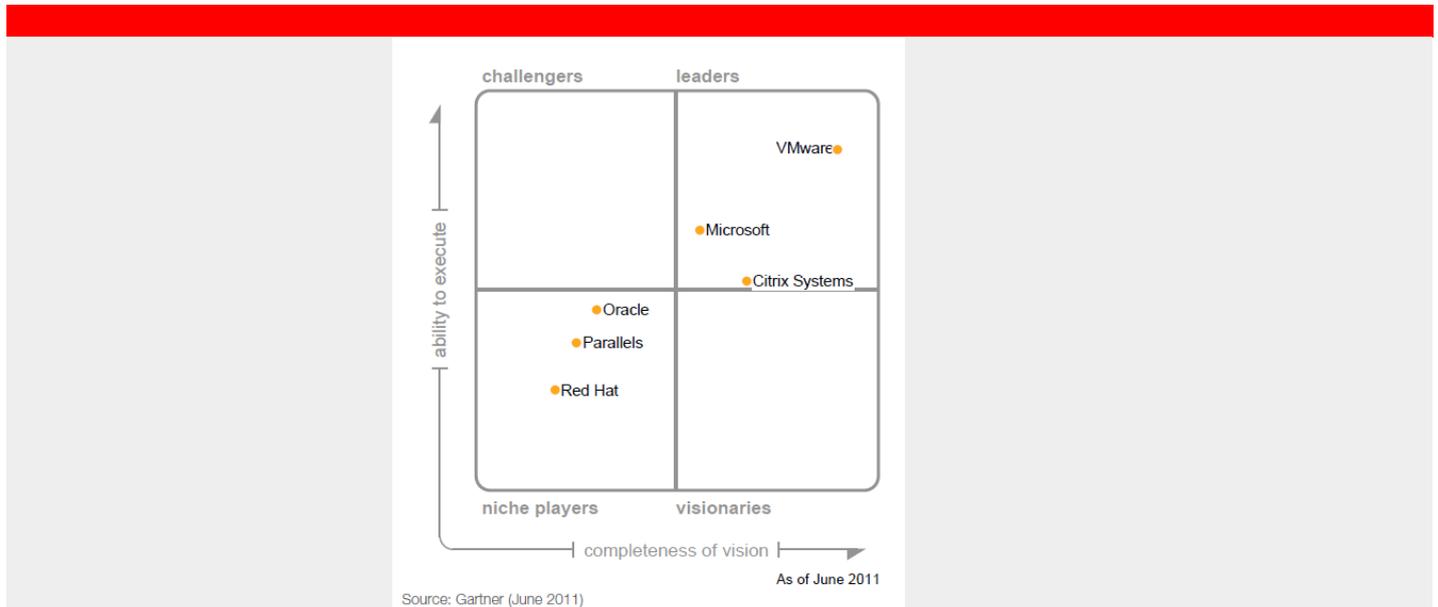


Figure 2: Market positioning Hypervisors (according to Gartner)

The above products from the manufacturers VMware, Microsoft und Citrix are the three most sophisticated and best established Bare Metal Hypervisor products for x86 server virtualization. Furthermore, the operating systems to be virtualized within the measurements are based on Windows, with the focus on Windows 7 (x64) and Windows Server 2008 R2 (x64).

The three Hypervisor product packages specified above from the manufacturers Citrix, Microsoft and VMware have been extended to include desktop virtualization products. As Microsoft in larger environments (> 500 clients) also recommends the Citrix components for brokering and provisioning, it was decided not to run parallel tests with Hyper-V 2.0 for time reasons. Individual measurements on another hardware basis showed comparable results for the XenServer 5.6 with Hyper-V 2.0.

The following combinations were used according to manufacturer recommendations:

- Citrix XenDesktop 4 (VDI component) and Citrix XenServer 5.6 (Hypervisor)
- VMware View v4.5 (VDI component) and VMware ESX vSphere 4.1 (Hypervisor)

Details about the test structure are also in section „Structure of load environment“

² Source: http://www.citrix.com/site/resources/dynamic/additional/citrix_magic_quadrant_2011.pdf

Technology description

Hypervisor components and functions

Citrix XenServer 5.6

According to Citrix the "Citrix® XenServer® is the only cloud-capable server virtualization platform for companies of any size which offers all the main functions for the virtualization of all servers and data centers – scaling for different company sizes, support for Windows® and Linux operating system and complex storage requirements, centralized management of several servers, live migration of virtual machines and much more. Irrespective of the XenServer Edition you choose as starting-point, the various Editions are all compatible with each other. Upgrades can be made easily via a new license key without having to install additional software or take systems out of operation. The pricing for XenServer is per server."

Function		Free	Advanced	Enterprise	Platinum
Free virtual infrastructure	XenServer hypervisor	✓	✓	✓	✓
	XenMotion® live migration	✓	✓	✓	✓
	VM Disk snapshot and revert	✓	✓	✓	✓
	XenCenter multi-server management	✓	✓	✓	✓
	Resilient distributed management architecture	✓	✓	✓	✓
	Conversion tools	✓	✓	✓	✓
Advanced management and automation	High availability		✓	✓	✓
	Memory optimization		✓	✓	✓
	Performance alerting and reporting		✓	✓	✓
	Automated workload balancing			✓	✓
	Heterogeneous pools			✓	✓
	Host power management			✓	✓
	Provisioning services (virtual)			✓	✓
	Role-based administration			✓	✓
	Live memory snapshots and reverts			✓	✓
	Citrix® StorageLink			✓	✓
	Lifecycle management				✓
	Provisioning services (physical)				✓
	Site recovery				✓

Table 1: XenServer Editions

VMware vSphere 4.1

According to manufacturer specifications „VMware vSphere comprises a range of components via which industry standard hardware can be used like a flexible mainframe environment with integrated service level control for all applications. The VMware vSphere components are divided into the following categories:

Infrastructure Services - This group of components virtualizes server, storage and network resources comprehensively, bundles them and assigns applications as required and according to business priority.

Application Services - This group of components offers integrated service level controls for all applications on the platform of the Cloud operating system, irrespective of the type of application or operating system used.

VMware vCenter Server provides a central control point for virtualization management. This is an important component to manage infrastructure and application services which offer a detailed view of all aspects involved in virtual infrastructure, the automation of daily operation procedures and the necessary scaling to manage large data center environments.“



Figure 3: Overview for Hypervisor VMware vSphere 4.1

Functions of the desktop virtualization solution

Citrix XenDesktop 4³

Citrix with XenDesktop is able to retain different types of central virtualized workplaces. The Citrix provisioning concept thus offers a very large range of possible scenarios for providing virtual desktops.

Here is an overview of the XenDesktop scenarios:

Hosted Shared Desktop: This desktop meets the requirements of the so-called "Task Worker". These users do not install any programs on their own and only need a relatively small amount of computer performance. Hosted Shared Desktops are provided on terminal server farms.

Hosted Virtual Desktop: This solution is designed for user groups that use special software or install new programs (e.g. developers). The Desktop is constantly as a vClient on a Hypervisor and is not dynamically created and rejected.

Hosted Central Desktop: If the Hosted Central Desktop high-performance desktop is used, the user is using his own physical hardware (e.g. workstation) in the data center. This version is usually for "Power Users", whose tasks demand particularly large amounts of CPU performance.

Local Streamed Desktop: One or more Citrix Provisioning Servers (PvS) stream individual, multi-useable standard desktop images (vDisks) onto the physical or virtual processors of the users. Booting is via the network. Provisioning Servers are used to provide - having once created a master image - a theoretically unlimited number of desktops with virtualized hard disks. The computer performance itself for this version is supplied by the client device as before. Ideal for companies whose users require absolutely identically configured PC workplaces.

Additional flexibility is provided by separating the operating system and the application level: XenApp - as a separate unit - provides the desktops centralized via XenDesktop with applications. The administrator can always choose whether to have the applications fixed in the operating system or whether to provide them virtualized or streamed via XenApp.

VMware View 4.5

VMware has the following solutions:

Automated Pool: An automated pool contains one or more virtual desktops which are automatically created and modified via the View Manager. These machines are based on a template which is managed in the Virtual Center Server. Access management is also via the View Client.

Automated desktops can be dedicated or floating desktops. Dedicated desktops: the user is automatically assigned to a specific vClient. Floating desktops: the user is given any one of the available desktops. This can be a different vClient with each log-in.

So-called linked clones can be used with automated desktop pools. A linked clone is a special version of the normal clone. The normal full clone is the entire copy of a virtual machine and is completely separate. A linked clone is a reference to an existing vClient - the so-called master image - and thus clearly uses less disk space in comparison to a full clone. However, this also means that the linked clone is always dependent on the master image which must be available. The entire vClient is not changed by the operation of a linked clone; read rights for the master image are sufficient in operation. The necessary write events are in the linked clone directory. Each linked clone once created is started independently and acts like a self-sufficient vClient in operation.

³ Sources: <http://www.citrix.de/products/schnellsuche/xendesktop/>

Manual Pool: A manual desktop pool consists of a mix of virtual and physical desktops. These desktops can always be differentiated and are not based on a standardized original image. The administration and access management is via the View Client.

The manual desktop pools also have dedicated and floating desktops. You thus have a mix of individual and automated pools with a different original basis.

Terminal Services Pool: These are systems based on Microsoft Terminal Services which can also be managed by View Manager. This type of desktop pools was not considered in the test.

As far as VMware is concerned, applications can be contained either directly in the basic image of the virtual machine or the template. Alternatively, applications can also be provided via Terminal Services or via ThinApp (application virtualization).

ThinApp is a very attractive solution option. However, this is rather impractical in its current status regarding the management of applications and the distribution. There is no management console or anything comparable via which the administrator can distribute the applications to specific users either centrally or in an automated manner. Solutions for this problem must currently be provided manually in other ways, for example via scripting.

Description of the load test infrastructure

Structure of load environment

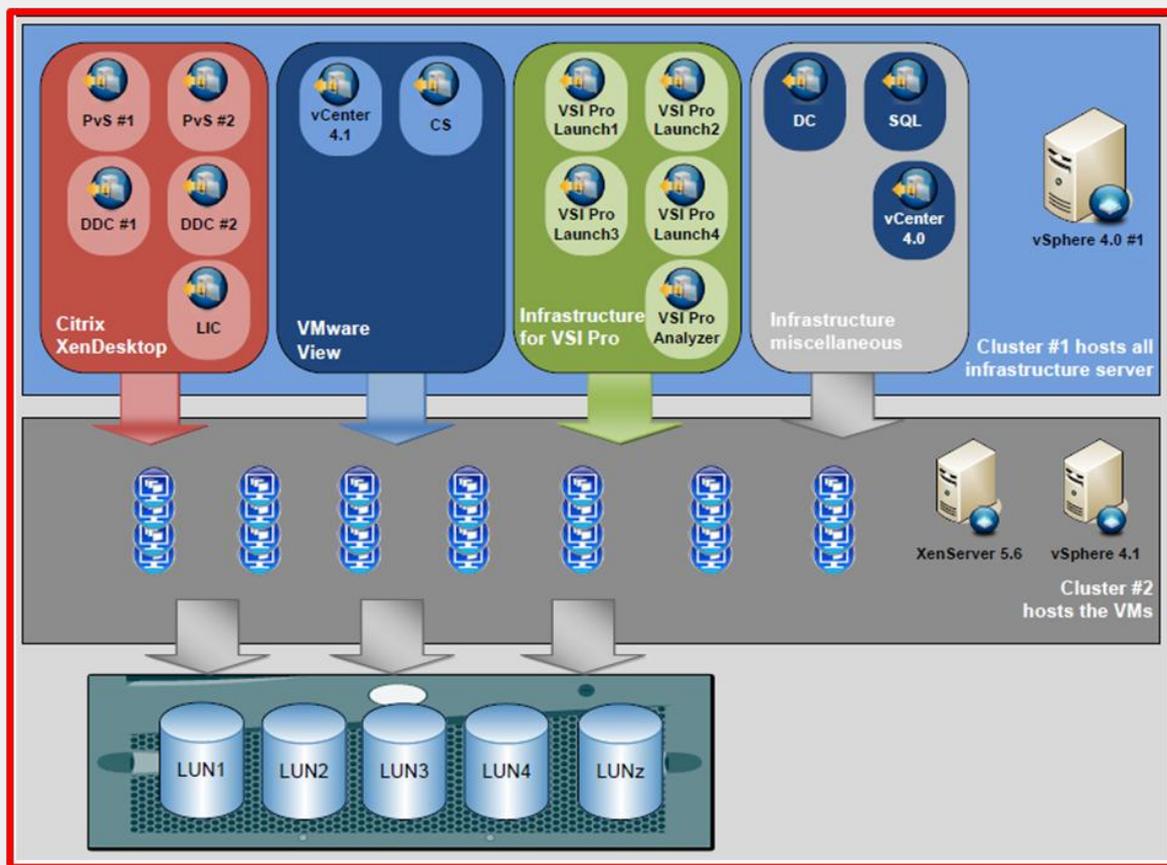


Figure 4: Structure diagram

All infrastructure servers are hosted on cluster #1 in order to minimize any possible affect on the load tests. The vSphere 4.0 ESX host with separate vCenter (vCenter 4.0) used in previous tests was still used.

Only a server with VMware vSphere 4.1 Hypervisor for the VMware View tests is used for the load test measurements of the VMs or a server with XenServer 5.6 FP1 as Hypervisor for the XenDesktop tests. A physical provisioning server was also in operation in order to fully exploit the performance capability of the Citrix solution.

For details, see table 2 – Infrastructure server.

Description of the load test tool

In order to achieve comparable results with the different technologies it is necessary to use an independent tool (as much as possible) to create and simulate user-similar load situations. The tool VSI Pro from the company Login Consultants was thus chosen.

At the moment of the test VSI Pro was the only known tool to support all three Hypervisor technologies to be supported; Citrix XenServer, VMware ESX and Microsoft Hyper-V 2.0. Furthermore, VSI Pro offers numerous access options so that - in addition to the RDP protocol - the ICA protocol can also be used. The load can be directly created on one or more targets.

Please note that VSI Pro merely initiates the connection set-up via different protocols and initiates the load test. The actual operation load is then created locally on the test target system.

Additional optimization with the protocols (PCoIP, ICA, RDP) are thus not taken into account within the VSI Pro tests. Further advantages can be obtained with a terminal in practical operations, for example by moving CPU calculations from the Hypervisor to the terminal (e.g. Thin Client). There are a lot of free publications about the tool VSI-Pro. In particular, <http://projectvrc.nl> is a good source of information.

VSI Pro supports many load profiles which can create various high operation loads. The two VSI-Pro load profiles "Medium" and "Heavy" were used to create this White Paper.

Measurements with up to 1,000 physical Windows XP based rich clients showed a general degree of load which corresponds to the "Medium" load profile, while taking the extra load into consideration caused by the planned operating system change from Windows XP (32-bit) to Windows 7 (64-bit).

The following section describes the different load profiles of VSI Pro⁴ in its original version.

Medium workload

The medium workload is the default workload in VSI.

- This workload emulated a medium knowledge worker using Office, IE and PDF.
- Once a session has been started, the medium workload will repeat every 12 minutes.
- During each loop, the response time is measured every 2 minutes.
- The medium workload opens up to 5 applications simultaneously.
- The type rate is 160 ms per character.
- The medium workload in VSI 2.0 is approximately 35% more resource-intensive than in VSI 1.0.
- Approximately 2 minutes of idle time is included to simulate real-world users.

Each loop will open and use:

- Outlook 2007, browse 10 messages.
- Internet Explorer, one instance is left open (BBC.co.uk), one instance is browsed to Wired.com, Lonelyplanet.com and heavy flash app gettheglass.com (not used with MediumNoFlash workload).
- Word 2007, one instance to measure response time, one instance to review and edit document.
- Bullzip PDF Printer & Acrobat Reader, the word document is printed and reviewed to PDF.
- Excel 2007, a very large randomized sheet is opened.
- PowerPoint 2007, a presentation is reviewed and edited.
- 7-zip: using the command line version the output of the session is zipped.

Heavy workload

This workload simulates a power user.

- It is based on the medium workload.

Difference in comparison to the medium workload:

- Type rate is 130 ms per character.
- Idle time total is only 40 seconds.
- The heavy workload opens up to 8 applications simultaneously.

⁴ Source: VSI Pro Admin Guide

Implemented measurements Citrix XenServer 5.6 FP1 and Citrix XenDesktop 4.0

Measurements Citrix XenServer 5.6 FP1 and Citrix XenDesktop 4.0

- Number of vClients with load profile "Medium"⁵
- Number of vClients with load profile "Heavy"
- Number of virtual terminal servers (vTS) with medium load profil
- Number of vTS load profile "Heavy"

Measurements VMware vSphere 4.1 and VMware View 4.5

- Number of vClients with load profile "Medium"
- Number of vClients with load profile "Heavy"
- Number of vTS with load profile "Medium"
- Number of vTS load profile "Heavy"

Hardware of the test environment

In addition to the integrated network and SAN infrastructure components, the following hardware was used for the load test:

- 2 Blade servers with the following configuration
 - 2x Intel Xeon X5670 2.93GHz
 - 12x8GB RAM
- 2 Blade servers with the following configuration
 - 2x Intel Xeon X5650 2.66GHz
 - 24x8GB RAM
- SAN storage subsystem
 - Type: EMC CX4-480
 - FastCache 185 GB
 - Powerpath (4 paths, 2 of which are active in the round robin)
 - 3x RAID 5 (9x 300GB FC HDDs, 3 LUNs each with 2.4 TB capacity)
 - 1x RAID 5 (5x 300GB FC HDDs, 1 LUN each with 1.2 TB capacity)
 - 1x RAID 5 (5x 100GB SATAII EFD HDDs, 1 LUN with 400 GB capacity)

Name and function	IP address	Operating system
DC1: Domain Controller	130.250.224.1	Windows Server 2008 EE R2 x64
VC2: VMware vCenter 4.0	130.250.224.2	Windows Server 2008 EE R2 x64
SQL: Database Server MS SQL 2008 EE	130.250.224.3	Windows Server 2008 EE R2 x64
DDC1: Desktop Delivery Controller (DDC)	130.250.224.7	Windows Server 2003 EE 32bit
DDC2: Desktop Delivery Controller (DDC)	130.250.224.8	Windows Server 2003 EE 32bit
PVS1: Provisioning Server PvS 5.6	130.250.224.9	Windows Server 2008 EE R2 x64
PVS2: Provisioning Server PvS 5.6	130.250.224.10	Windows Server 2008 EE R2 x64
PVS3: Physical Provisioning Server PvS 5.6	130.250.224.33	Windows Server 2008 EE R2 x64
LIC1 : Citrix License Server Lic 11.9	130.250.224.11	Windows Server 2003 EE 32bit
VC3: VMware vCenter 4.1, View 4.5	130.250.224.20	Windows Server 2008 EE R2 x64
CS3: VMware Connection Server CS 4.5	130.250.224.21	Windows Server 2008 EE R2 x64
VSI-XA6-000: XenApp6-Server Master and Web Interface	130.250.224.30	Windows Server 2008 EE R2 x64

Table 2: Infrastructure Servers

⁵ The medium workload of Citrix vClients could - for time reasons - only be determined in another load environment with older hardware, but not in the load test environment described here.

Test results from the workload test environment

All measurement results shown are consolidated in an Excel table. See also **Error! Reference source not found.**

Citrix XenServer 5.6 FP1 and Citrix XenDesktop 4 / 5

As the VSI Pro load tests only use the virtual covers on the XenServer and the provisioning server is also unchanged with XenDesktop 5, the results can also be used on XenDesktop 5 in combination with Pvs 5.6. The measurements of the vClients in the medium load profile could no longer be carried out due to the test time limits. However, previous measurements in another load test environment permit relatively exact calculations and estimates.

Configuration vClient

- OS: Windows 7 (x64)
- CPU: 1 vCPU
- RAM: 1536 MB⁶
- HDD: 30 GB vDisk (Thick⁷) + 3 GB vDisk with 2 GB Pagefile

Configuration vTS

- OS: Windows 2008 R2 (x64) with extension Citrix XenApp6
- CPU: 4 vCPU
- RAM: 24576 MB, of which 8196 MB is as "Write Cache in RAM"⁸
- HDD: 8 GB vDisk with 4 GB Pagefile, 30 GB vDisk (Thick) as OS partition on provisioning server
- Number: 6

⁶ Citrix sets the RAM minimum size recommended by Microsoft for all templates to 2 GB for Windows 7 (x64). This lower limit must thus be changed in order to use less RAM and the Dynamic Memory Control Feature. This occurs via the following commands within the XenServer console:

- 1) `xe vm-list`
 - a) Note uuid of the VM to be modified
- 2) `xe vm-memory-static-range-set uuid=db5d28e6-039a-d10e-e38e-9550c1c32678 min=1024MiB max=2048MiB`
- 3) `xe vm-memory-dynamic-range-set uuid=db5d28e6-039a-d10e-e38e-9550c1c32678 min=1024MiB max=2048MiB`

⁷ There are always two modes when assigning storage capacity:

Thick = the entire allocated capacity is already initially reserved on storage for the VM, irrespective of how much actual data is in the VM partition; optimal performance

Fast or Thin = the assigned capacity is always available for the VM, but on storage only the capacity is used which is filled with data; optimal capacity usage but reduced performance

⁸ The provisioning server 5.6 uses internal 32-bit addressing with the option Write Cache in RAM. Consequently, a maximum of 4 GB RAM per OS is thus sensible.

Number of vClients with heavy workload

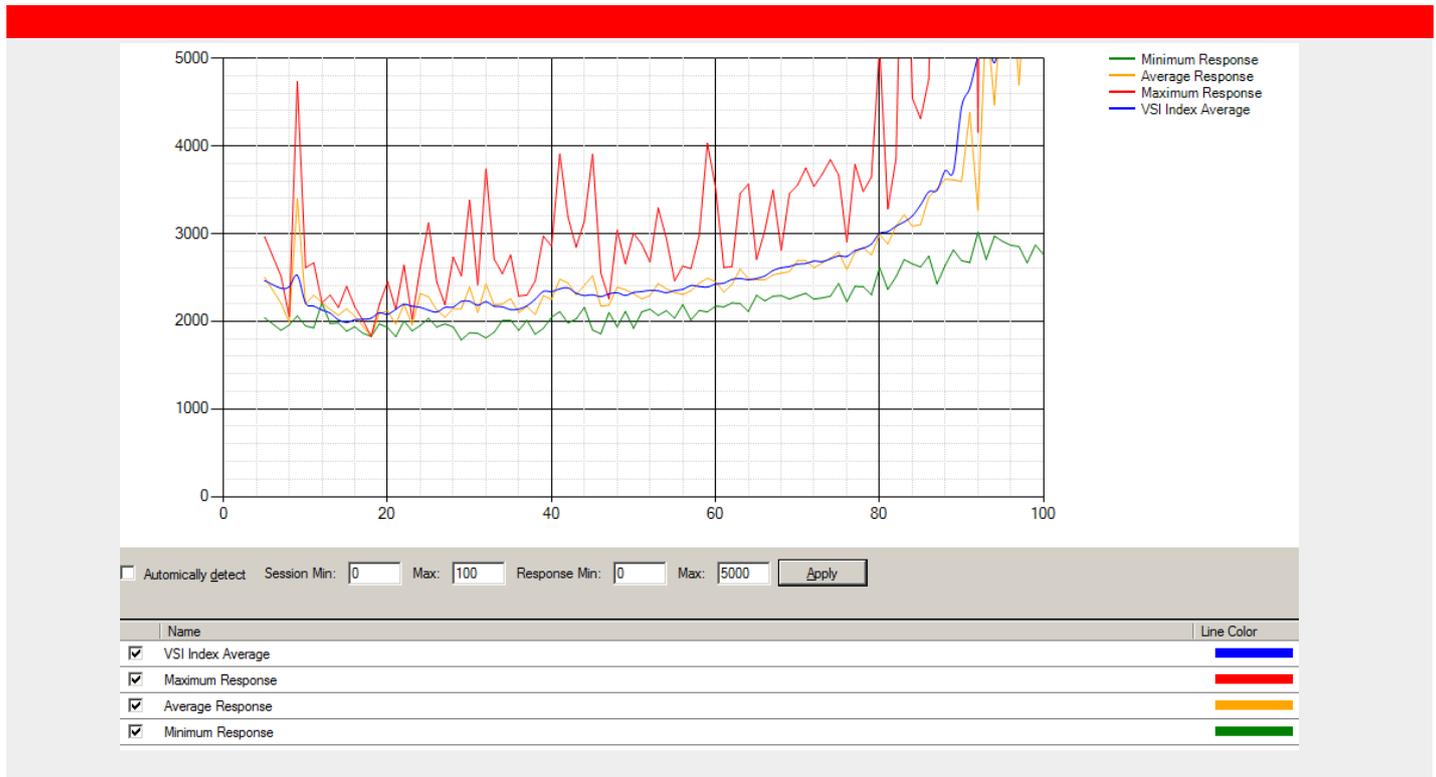


Figure 5: VSI-max vClients with heavy workload

The VSI-max was reached according to the calculation⁹ with a density of **91 vClients**. Please note that the configuration of the storage subsystems has not been optimally configured after transferring the provider VCE. In particular, the cache and path settings had to be subsequently modified during the measurements. As a consequence already implemented tests had to be repeated which showed a slight increase in performance by ~ 5%. However, two load tests after this optimization could no longer be run again due to schedule. The results listed thus mirror the results without storage optimization. The two load tests with storage optimization were:

- Citrix XenDesktop 4 with vClients in the medium load profile
- Citrix XenDesktop 4 with vClients in the heavy load profile

It is expected that the result Citrix XenDesktop 4 with vClients in heavy load profile increases to 95 - 100. Protocol-dependent optimization when using special physical terminals (e.g. FUTRO Thin Clients) were not taken into account, but this would result in an increase in density.

More information about the various optimization using special protocols (e.g. PCoIP, ICA) is not included in this White Paper.

⁹ VSI_{max} is triggered if Baseline (here 2000ms) + 2500ms (= 4500ms) is broken by the "VSI Index Average". Definition of baseline, see table 16: List of abbreviations.

Sizing vClients with heavy workload

XenServer 5.6 FP1 and XenDesktop 4.0 Load profile "Heavy" vClients					
CPU type	CPU number	Standardized performance	Recommended number of sessions "Heavy"	Recommended RAM capacity Hypervisor Server	Recommended performance SAN (Backend Disk IOPS)
Intel Xeon E5504	2	39%	36	57 GB	615
Intel Xeon E/L5520	2	57%	52	82 GB	903
Intel Xeon X5550	2	70%	64	100 GB	1103
Intel Xeon W5590	2	79%	72	112 GB	1244
Intel Xeon E5507	2	45%	41	65 GB	703
Intel Xeon E/L5640	2	70%	64	99 GB	1098
Intel Xeon X5650	2	100%	91	141 GB	1571
Intel Xeon X5670	2	105%	96	147 GB	1649
Intel Xeon X5680	2	110%	100	154 GB	1722
Intel Xeon E7540	4	158%	144	219 GB	2478
Intel Xeon X7560	4	222%	202	307 GB	3483

Table 3: Sizing vClients with heavy workload

Explanation:

Only the red highlighted line was measured on physical hardware. All other values were theoretically calculated based on the CPU performance values. The basis for the "standard performance" was the determined CPU benchmark values of the SPECint_rate_base2006.

The "recommended capacity RAM" contains - in addition to the configurable RAM per vClient or per vTS - the Hypervisor RAM (4096 MB) required for operation.

Number of vTS with medium workload

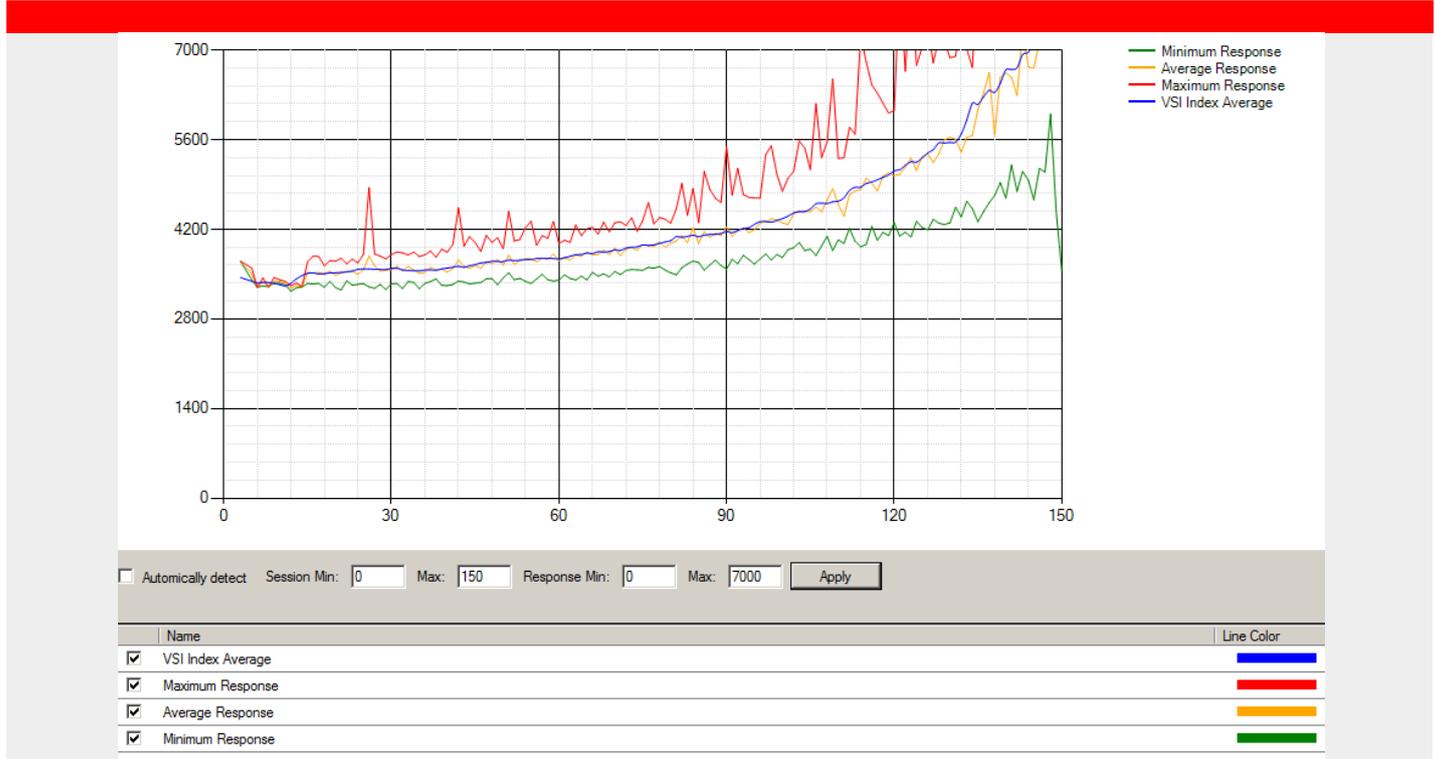


Figure 6: VSI-max vTS with medium workload

The VSI-max was reached according to the calculation¹⁰ with a density of 136 sessions.

All logical processors (in our case 24 logical CPUs) must be used in order to reach the maximum CPU load on XenServer 5.6 FP1! 6 virtual XenApp 6 servers each with 4 vCPUs were configured for the top measurement. Alternatively, 3 virtual XenApp6 servers each with 8 vCPUs can be used, for example to save license costs for the operating system. However, there were no measurements with 8 vCPUs for comparability reasons with the tests from the load test environment as well as comparability with Hyper-V.

Protocol-dependent optimization when using physical terminals (e.g. FUTRO Thin Clients) were not taken into account, but this would result in an increase in density.

¹⁰ VSI_{max} is triggered if Baseline (here 3700ms) + 2500ms (=6200ms) is broken by the "VSI Index Average" (blue line). Definition of baseline, see table 16: List of abbreviations.

vTS sizing with medium workload

XenServer 5.6 FP1 & XenDesktop 4.0 Medium load profile vTS					
CPU type	CPU Number	Standardized performance	Recommended number of sessions "Medium"	Recommended RAM capacity Hypervisor Server	Recommended performance SAN (Backend Disk IOPS)
Intel Xeon E5504	2	39%	53	44 GB	12
Intel Xeon E/L5520	2	57%	78	63 GB	18
Intel Xeon X5550	2	70%	95	76 GB	22
Intel Xeon W5590	2	79%	108	85 GB	25
Intel Xeon E5507	2	45%	61	50 GB	14
Intel Xeon E/L5640	2	70%	95	75 GB	22
Intel Xeon X5650	2	100%	136	106 GB	31
Intel Xeon X5670	2	105%	143	111 GB	33
Intel Xeon X5680	2	110%	149	116 GB	34
Intel Xeon E7540	4	158%	215	165 GB	49
Intel Xeon X7560	4	222%	302	230 GB	69

Table 4: vTS - Sizing with medium workload

Explanation:

Only the red highlighted line was measured on physical hardware. All other values were theoretically calculated based on the CPU performance values. The basis for the "standard performance" was the determined CPU benchmark values of the SPECint_rate_base2006.

The virtual terminal servers were provided via a physical provisioning server.

There are thus very few reads on the storage subsystem as read inquiries can usually be made from the provisioning server RAM. The setting "Cache in device RAM" could also reduce the number of writes to almost 0. A higher work memory configuration of the virtual terminal server was not required in the test environment.

This operating mode no longer has hardly any measureable IO workload on the storage subsystem. Operation with local hard disks is possible.

The "recommended capacity RAM" contains - in addition to the configurable RAM per vClient or per vTS - the Hypervisor RAM (4096 MB) required for operation.

Number of vTS with heavy workload

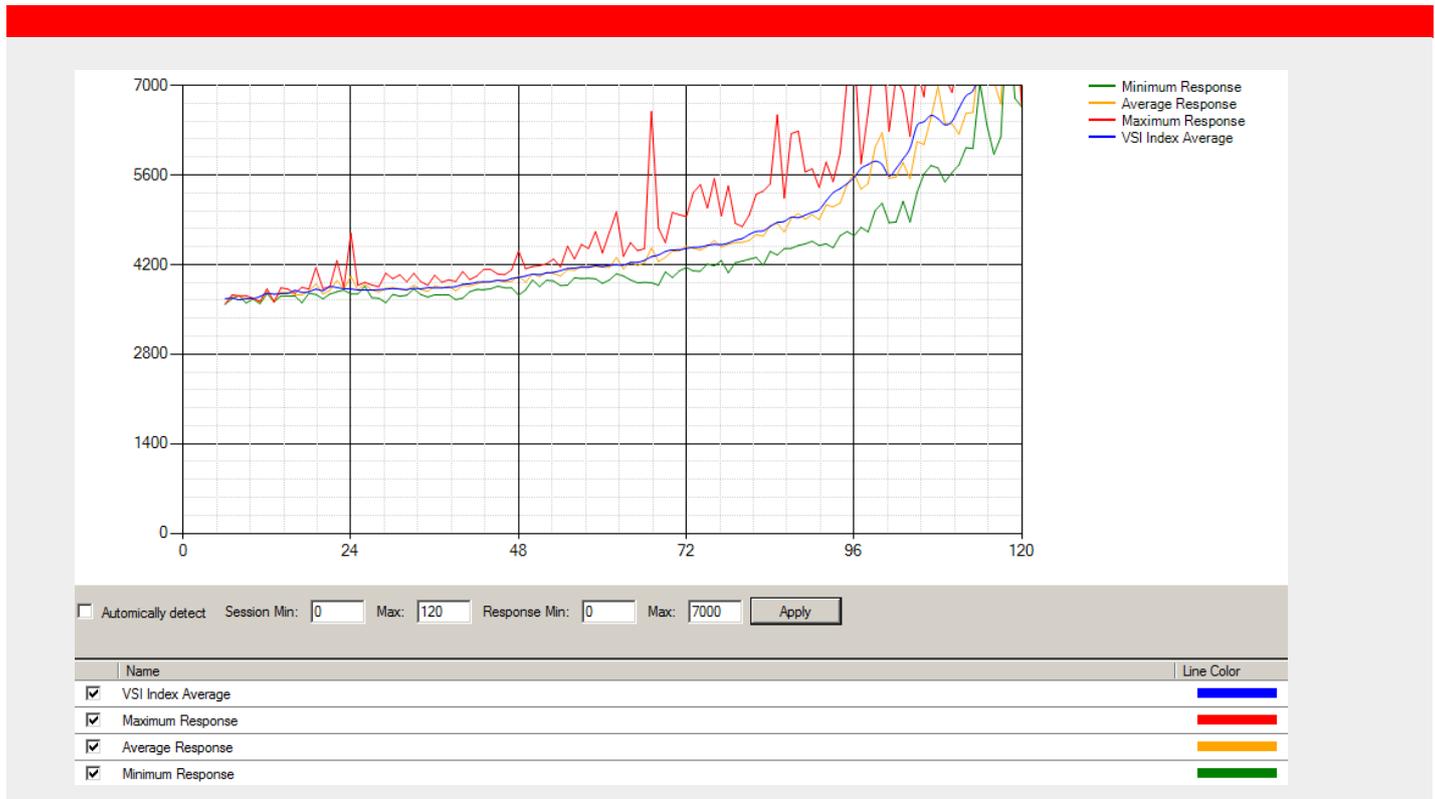


Figure 7: VSI-max vTS with heavy workload

The VSI-max was reached according to the calculation ¹¹ with a density of **105 sessions**. All logical processors (in our case 24 logical CPUs) must be used in order to reach the maximum CPU load on XenServer 5.6 FP1! 6 virtual XenApp 6 servers each with 4 vCPUs were configured for the top measurement. Alternatively, 3 virtual XenApp6 servers each with 8 vCPUs can be used, for example to save license costs for the operating system. However, there were no measurements with 8 vCPUs for comparability reasons with the tests from the load test environment as well as comparability with Hyper-V.

Protocol-dependent optimization when using special physical terminals (e.g. FUTRO Thin Clients) were not taken into account, but this would result in an increase in density.

¹¹ VSI_{max} is triggered if Baseline (here 3700ms) + 2500ms (= 6200ms) is broken by the "VSI Index Average" (blue line). Definition of baseline, see table 16: List of abbreviations.

vTS sizing with heavy workload

XenServer 5.6 FP1 & XenDesktop 4.0 Heavy load profile vTS					
CPU type	CPU Number	Standardized performance	Recommended number of sessions "Heavy"	Recommended RAM capacity Hypervisor Server	Recommended performance SAN (Backend Disk IOPS)
Intel Xeon E5504	2	39%	41	35 GB	15
Intel Xeon E/L5520	2	57%	60	49 GB	22
Intel Xeon X5550	2	70%	74	59 GB	27
Intel Xeon W5590	2	79%	83	66 GB	30
Intel Xeon E5507	2	45%	47	39 GB	17
Intel Xeon E/L5640	2	70%	73	59 GB	27
Intel Xeon X5650	2	100%	105	83 GB	38
Intel Xeon X5670	2	105%	110	87 GB	40
Intel Xeon X5680	2	110%	115	90 GB	42
Intel Xeon E7540	4	158%	166	128 GB	60
Intel Xeon X7560	4	222%	233	179 GB	85

Table 5: vTS - Sizing with heavy workload

Explanation:

Only the red highlighted line was measured on physical hardware. All other values were theoretically calculated based on the CPU performance values. The basis for the "standard performance" was the determined CPU benchmark values of the SPECint_rate_base2006. The virtual terminal servers were provided via a physical provisioning server.

There are thus very few reads on the storage subsystem as read inquiries can usually be made from the provisioning server RAM. The setting "Cache in device RAM" could also reduce the number of writes to almost 0. A higher work memory configuration of the virtual terminal server was not required in the test environment.

This operating mode no longer has hardly any measureable IO workload on the storage subsystem. Operation with local hard disks is possible.

The "recommended capacity RAM" contains - in addition to the configurable RAM per vClient or per vTS - the Hypervisor RAM (4096 MB) required for operation.

VMware vSphere 4.1 and VMware View 4.5

In addition to the general optimization of the Windows 7 image for the vClient, the vSphere 4.1 ESX host was optimized via the extended settings – as recommended by VMware¹² – as follows:

CPU/HaltingIdleMsecPenalty: 2,000
HaltingIdleMsecPenaltyMax: 80,000

Configuration vClient

- OS: Windows 7 (x64)
- CPU: 1 vCPU
- RAM: 1536 MB
- HDD: 30 GB vDisk (Fast¹³) + 3 GB vDisk with 2 GB Pagefile

Configuration vTS

- OS: Windows 2008 R2 (x64) with extension Citrix XenApp6
- CPU: 4 vCPU
- RAM: 24576 MB
- HDD: 30 GB vDisk (Thick) + 8 GB vDisk (Thick) with 4 GB Pagefile
- Number: 4

¹² Details can be found here as well:

http://kb.vmware.com/selfservice/microsites/search.do?language=en_US&cmd=displayKC&externalId=1020233

¹³ There are always two modes when assigning storage capacity:

Thick = the entire allocated memory is already initially reserved on storage for the VM, irrespective of how much actual data is in the VM partition; optimal performance

Fast or Thin = the assigned memory is always available for the VM, but on storage only the capacity is used which is filled with data; optimal capacity usage but reduced performance

Number of vClients with medium workload

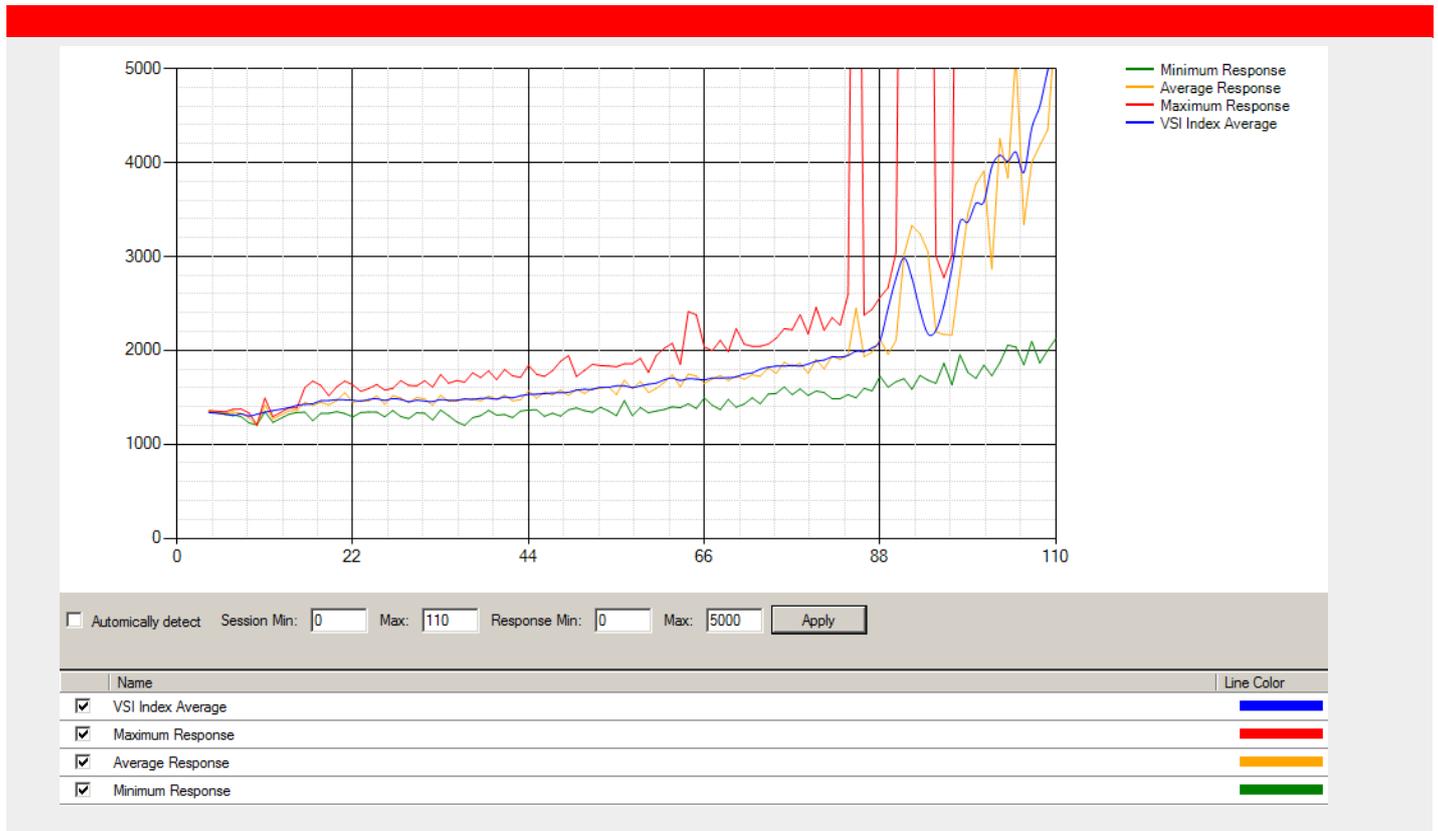


Figure 8: VSI-max vClients with medium workload

The VSI-max was reached according to the calculation¹⁴ with a density of 103 vClients. Protocol-dependent optimization when using physical terminals (e.g. FUTRO Thin Clients) were not taken into account, but this would result in an increase in density.

¹⁴ VSI_{max} is triggered if Baseline (here 1300ms) + 2500ms (= 3800ms) is broken by the "VSI Index Average". Definition of baseline, see table 16: List of abbreviations.

Sizing vClients with medium workload

VMware vSphere 4.1 & VMware View 4.5 Load profile "Medium" vClients					
CPU type	CPU Number	Standardized performance	Recommended number of sessions "Medium"	Recommended RAM capacity Hypervisor Server	Recommended performance SAN (Backend Disk IOPS)
Intel Xeon E5504	2	39%	40	64 GB	1228
Intel Xeon E/L5520	2	57%	59	93 GB	1803
Intel Xeon X5550	2	70%	72	112 GB	2203
Intel Xeon W5590	2	79%	82	126 GB	2486
Intel Xeon E5507	2	45%	46	73 GB	1404
Intel Xeon E/L5640	2	70%	72	112 GB	2193
Intel Xeon X5650	2	100%	103	159 GB	3139
Intel Xeon X5670	2	105%	108	166 GB	3295
Intel Xeon X5680	2	110%	113	173 GB	3441
Intel Xeon E7540	4	158%	162	248 GB	4952
Intel Xeon X7560	4	222%	228	347 GB	6960

Table 6: Sizing vClients with medium workload

Explanation:

Only the red highlighted line was measured on physical hardware. All other values were theoretically calculated based on the CPU performance values. The basis for the "standard performance" was the determined CPU benchmark values of the SPECint_rate_base2006.

The "recommended capacity RAM" contains - in addition to the configurable RAM per vClient or per vTS - the Hypervisor RAM (4096 MB) required for operation.

Number of vClients with heavy workload

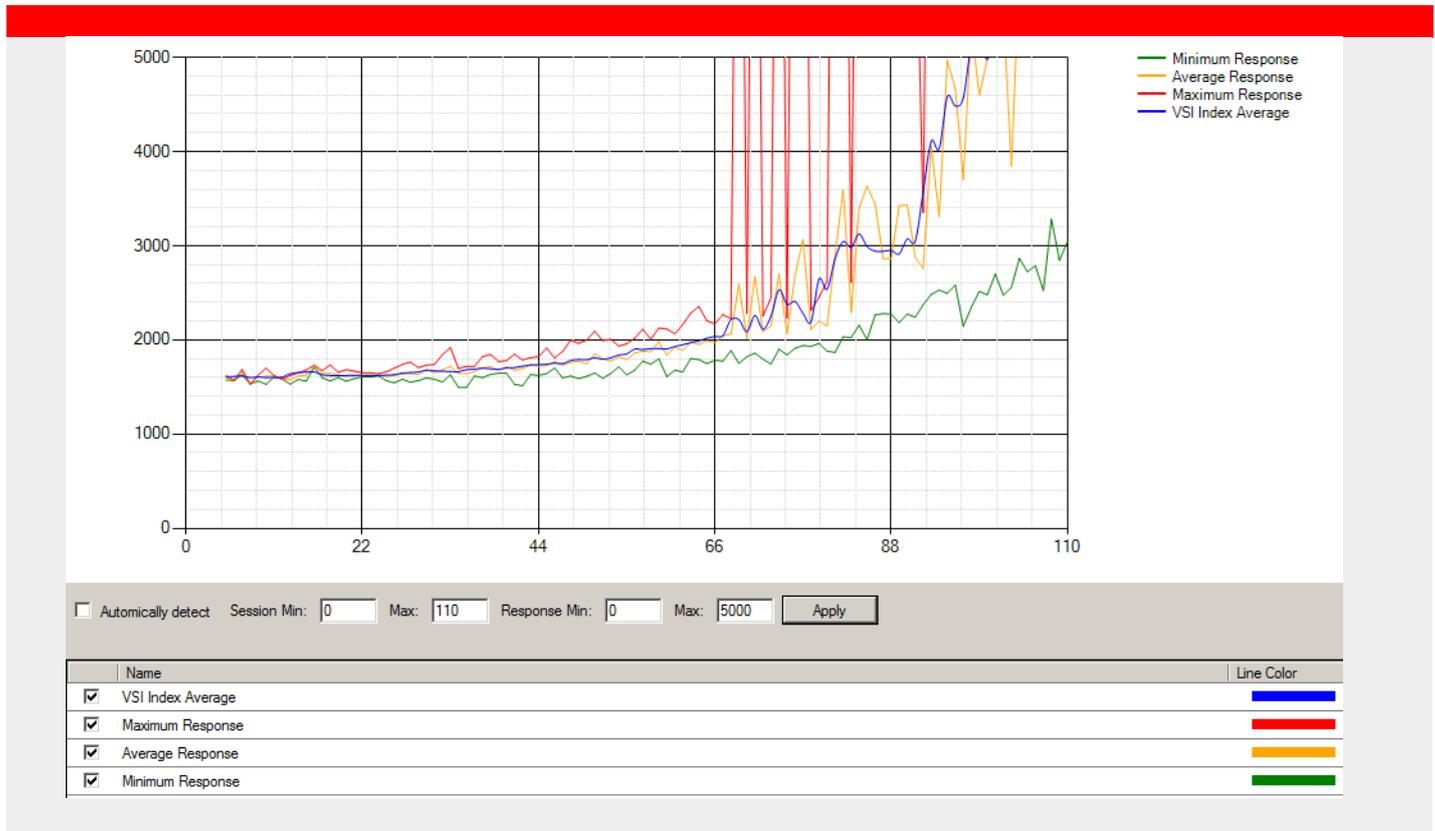


Figure 9: VSI-max vClients with heavy workload

The VSI-max was reached according to the calculation ¹⁵ with a density of 95 vClients.

Protocol-dependent optimization when using physical terminals (e.g. FUTRO Thin Clients) were not taken into account, but this would result in an increase in density.

¹⁵ VSI_{max} is triggered if Baseline (here 1600ms) + 2500ms (= 4100ms) is broken by the "VSI Index Average". Definition of baseline, see table 16: List of abbreviations.

Sizing vClients with heavy workload

**VMware vSphere 4.1 & VMware View 4.5
Load profile heavy vClients**

CPU type	CPU Number	Standardized performance	Recommended number of sessions "Heavy"	Recommended RAM capacity Hypervisor Server	Recommended performance SAN (Backend Disk IOPS)
Intel Xeon E5504	2	39%	37	60 GB	1190
Intel Xeon E/L5520	2	57%	55	86 GB	1747
Intel Xeon X5550	2	70%	67	104 GB	2134
Intel Xeon W5590	2	79%	75	117 GB	2407
Intel Xeon E5507	2	45%	42	68 GB	1360
Intel Xeon E/L5640	2	70%	66	104 GB	2124
Intel Xeon X5650	2	100%	95	147 GB	3040
Intel Xeon X5670	2	105%	100	154 GB	3191
Intel Xeon X5680	2	110%	104	160 GB	3333
Intel Xeon E7540	4	158%	150	229 GB	4796
Intel Xeon X7560	4	222%	211	320 GB	6741

Table 7: Sizing vClients with heavy workload

Explanation:

Only the red highlighted line was measured on physical hardware. All other values were theoretically calculated based on the CPU performance values. The basis for the "standard performance" was the determined CPU benchmark values of the SPECint_rate_base2006.

The "recommended capacity RAM" contains - in addition to the configurable RAM per vClient or per vTS - the Hypervisor RAM (4096 MB) required for operation.

Number of vTS with medium workload

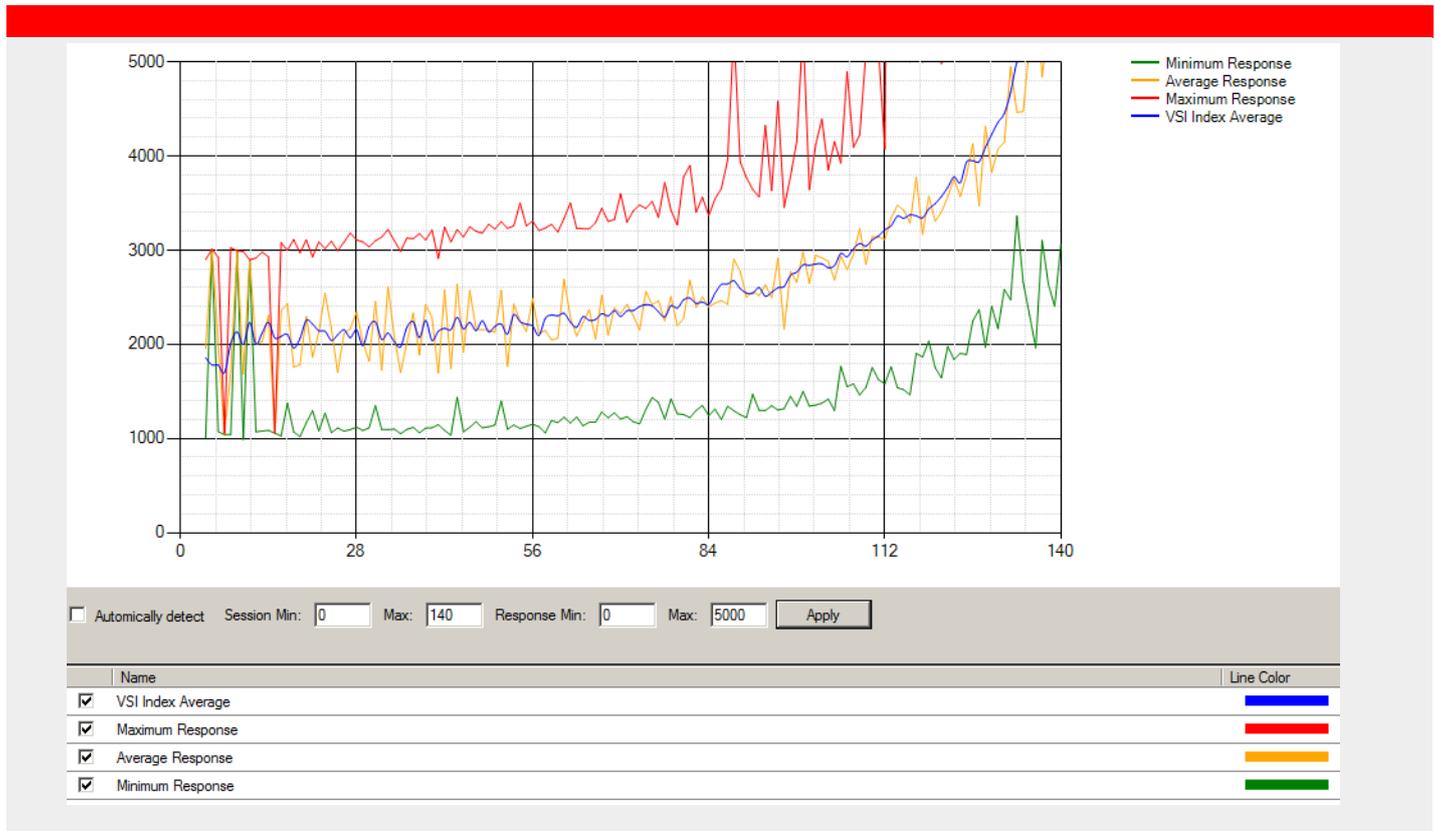


Figure 10: VSI-max vTS with medium workload

The VSI-max was reached according to the calculation ¹⁶ with a density of **132 sessions**.

Not all the logical processors (in our case 24 logical CPUs) have to be used in order to reach the maximum CPU load and user density on vSphere v4.1! 4 virtual XenApp 6 servers each with 4 vCPUs were configured for the top measurement. A larger number of vTS did not create a bigger number of possible sessions. Alternatively, two or three virtual XenApp6 servers each with 8 vCPUs can also be used. However, there were no measurements with 8 vCPUs for comparability reasons with the tests from the load test environment as well as comparability with Hyper-V.

Protocol-dependent optimization when using physical terminals (e.g. FUTRO Thin Clients) were not taken into account, but this would result in an increase in density.

¹⁶ VSI_{max} is triggered if Baseline (here 2100ms) + 2500ms (= 4600ms) is broken by the "VSI Index Average" (blue line). Definition of baseline, see table 16: List of abbreviations.

vTS sizing with medium workload

VMware vSphere 4.1 & VMware View 4.5 Load profile "Medium" vTS					
CPU type	CPU Number	Standardized performance	Recommended number of sessions "Medium"	Recommended RAM capacity Hypervisor Server	Recommended performance SAN (Backend Disk IOPS)
Intel Xeon E5504	2	39%	52	43 GB	258
Intel Xeon E/L5520	2	57%	76	61 GB	379
Intel Xeon X5550	2	70%	93	73 GB	463
Intel Xeon W5590	2	79%	105	82 GB	523
Intel Xeon E5507	2	45%	59	48 GB	295
Intel Xeon E/L5640	2	70%	92	73 GB	461
Intel Xeon X5650	2	100%	132	103 GB	660
Intel Xeon X5670	2	105%	139	108 GB	693
Intel Xeon X5680	2	110%	145	113 GB	724
Intel Xeon E7540	4	158%	208	160 GB	1041
Intel Xeon X7560	4	222%	293	224 GB	1463

Table 8: vTS - Sizing with medium workload

Explanation:

Only the red highlighted line was measured on physical hardware. All other values were theoretically calculated based on the CPU performance values. The basis for the "standard performance" was the determined CPU benchmark values of the SPECint_rate_base2006.

The virtual terminal servers were created via a previously created template manually on the Hypervisor Server as VMware View currently does not start the automated provisioning of server operating systems.

Significantly lower IO workloads can be reached on the storage subsystem by using terminal server technology.

The "recommended capacity RAM" contains - in addition to the configurable RAM per vClient or per vTS - the Hypervisor RAM (4096 MB) required for operation.

Number of vTS with heavy workload

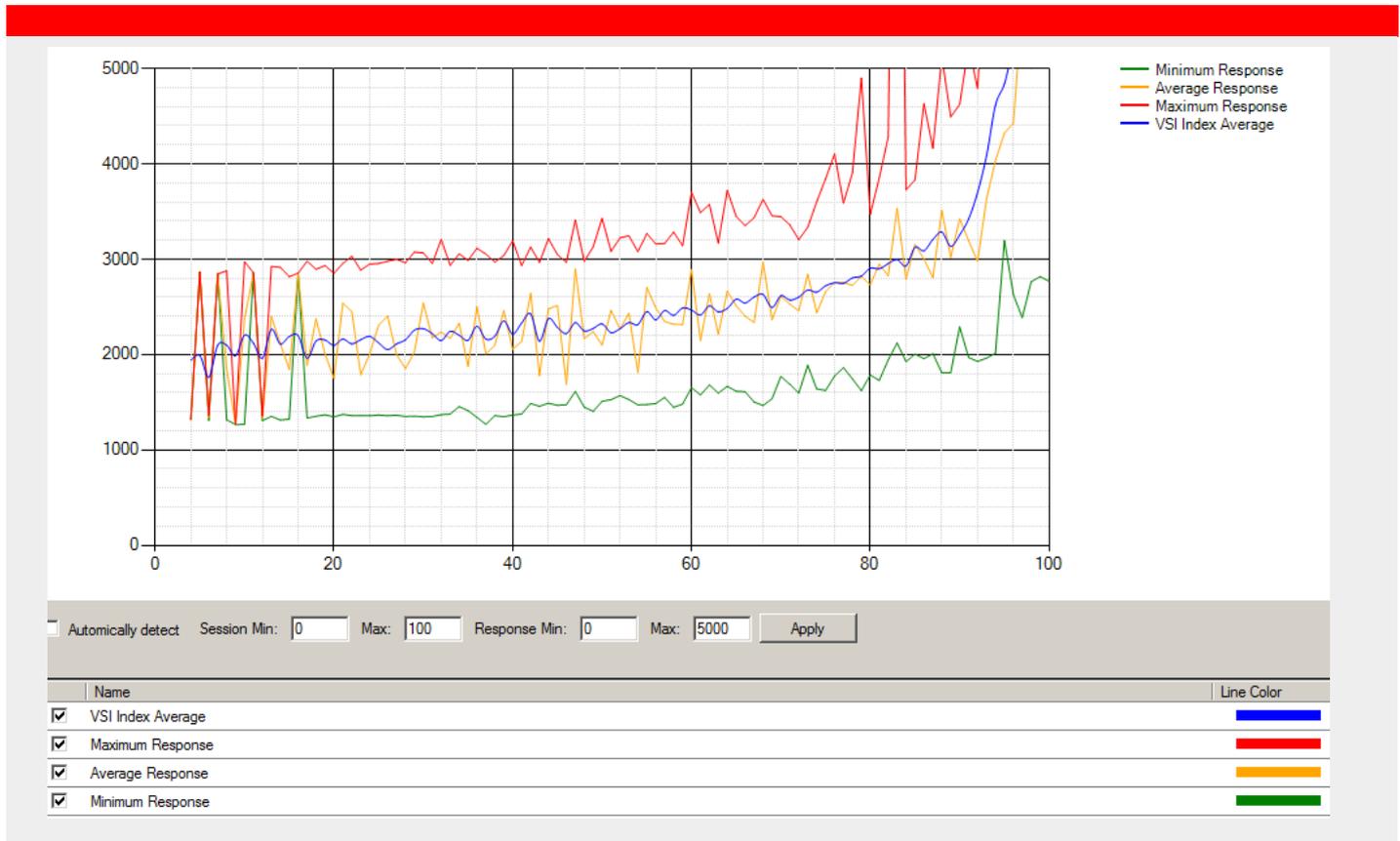


Figure 11: VSI-max vTS with heavy workload

The VSI-max was reached according to the calculation¹⁷ with a density of 95 sessions.

Not all the logical processors (in our case 24 logical CPUs) have to be used in order to reach the maximum CPU load and user density on vSphere v4.1! Four virtual XenApp 6 servers each with 4 vCPUs were configured for the top measurement. A larger number of vTS did not create a bigger number of possible sessions. Alternatively, two or three virtual XenApp6 servers each with 8 vCPUs can also be used. However, there were no measurements with 8 vCPUs for comparability reasons with the tests from the load test environment as well as comparability with Hyper-V.

Protocol-dependent optimization when using physical terminals (e.g. FUTRO Thin Clients) were not taken into account, but this would result in an increase in density.

¹⁷ VSI_{max} is triggered if Baseline (here 2100ms) + 2500ms (= 4600ms) is broken by the "VSI Index Average" (blue line). Definition of baseline, see table 16: List of abbreviations.

vTS sizing with heavy workload

VMware vSphere 4.1 & VMware View 4.5 Load profile "Heavy" vTS					
CPU type	CPU Number	Standardized performance	Recommended number of sessions "Heavy"	Recommended RAM capacity Hypervisor Server	Recommended performance SAN (Backend Disk IOPS)
Intel Xeon E5504	2	39%	37	32 GB	223
Intel Xeon E/L5520	2	57%	55	45 GB	327
Intel Xeon X5550	2	70%	67	54 GB	400
Intel Xeon W5590	2	79%	75	60 GB	451
Intel Xeon E5507	2	45%	42	36 GB	255
Intel Xeon E/L5640	2	70%	66	54 GB	398
Intel Xeon X5650	2	100%	95	75 GB	570
Intel Xeon X5670	2	105%	100	79 GB	598
Intel Xeon X5680	2	110%	104	82 GB	625
Intel Xeon E7540	4	158%	150	116 GB	899
Intel Xeon X7560	4	222%	211	162 GB	1264

Table 9: vTS - Sizing with heavy workload

Explanation:

Only the red highlighted line was measured on physical hardware. All other values were theoretically calculated based on the CPU performance values. The basis for the "standard performance" was the determined CPU benchmark values of the SPECint_rate_base2006.

The virtual terminal servers were created via a previously created template manually on the Hypervisor Server as VMware View currently does not start the automated provisioning of server operating systems.

Significantly lower IO workloads can be reached on the storage subsystem by using terminal server technology.

The "recommended capacity RAM" contains - in addition to the configurable RAM per vClient or per vTS - the Hypervisor RAM (4096 MB) required for operation.

vClients - Overview IO workload storage subsystem

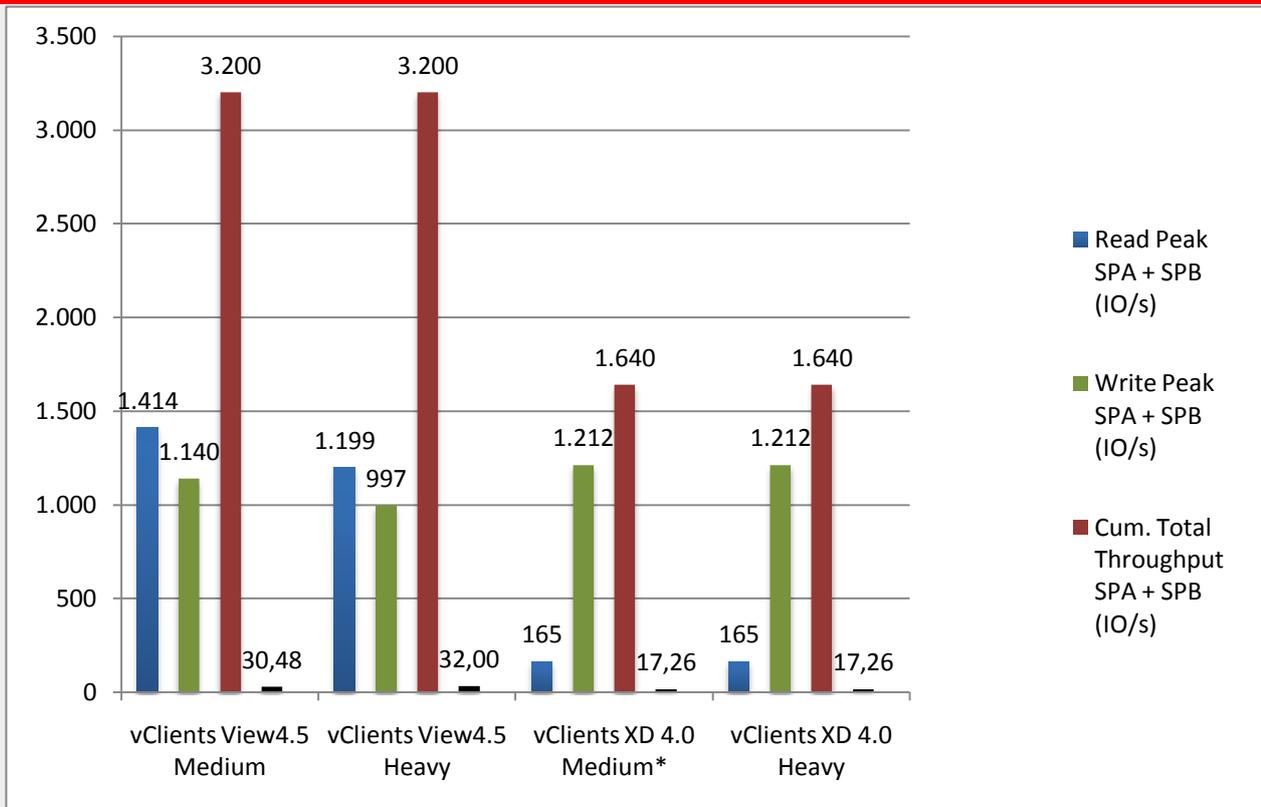


Figure 12: vClients overview IO workload

*= Column "vClients XD4.0 Medium" contains estimated values and were not measured! PvS was operated with "WC in SAN" option.

Further details, see also **Error! Reference source not found.**

vTS - Overview IO workload storage subsystem

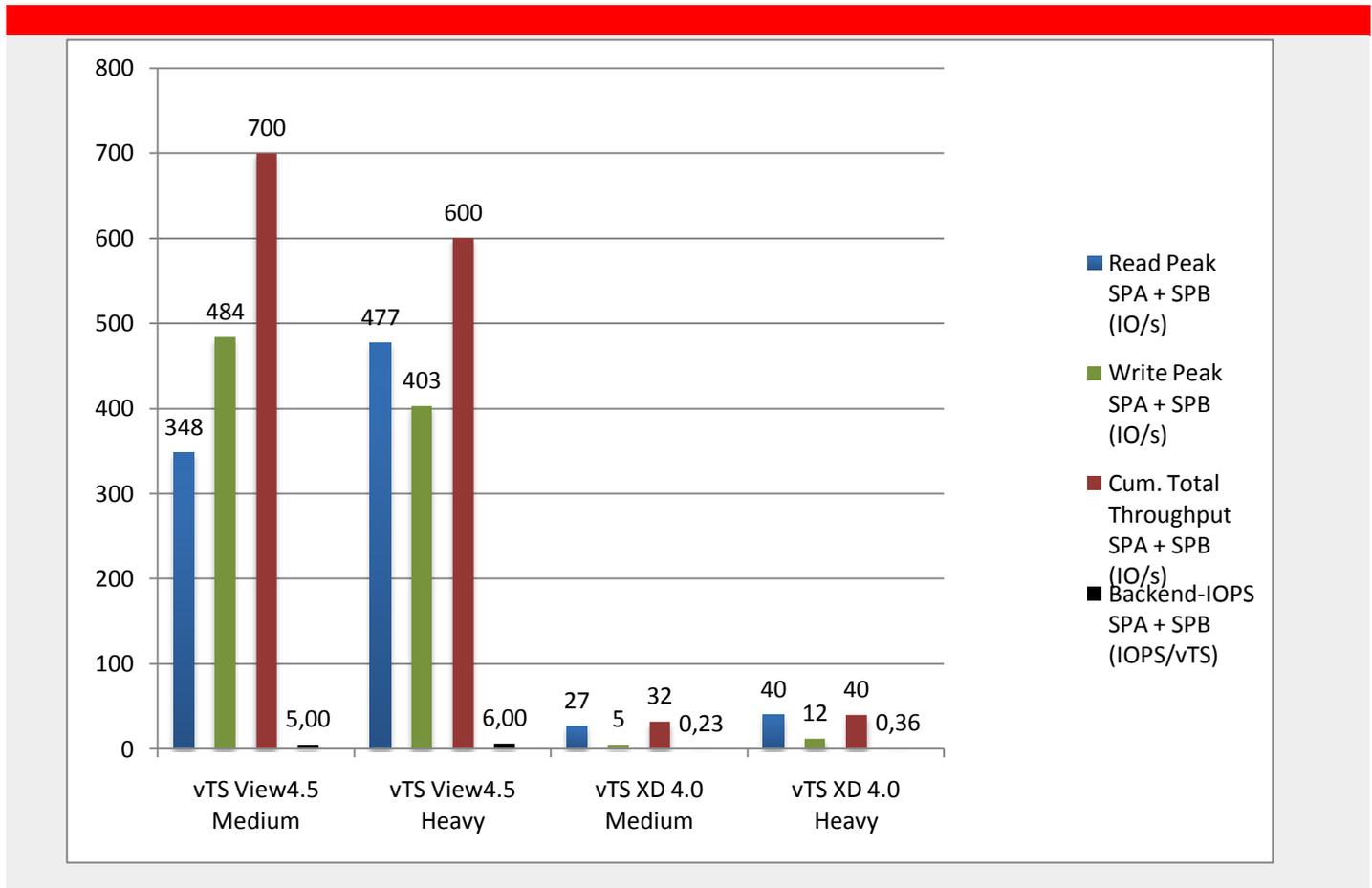


Figure 13: vTS overview IO workload

For further details, see **Error! Reference source not found.**

Conclusion

The tested solutions are of a similar level regarding the user density of vClients. A noticeable difference can be seen at most in the user density of vTS:

With activated hyper-threading of the Hypervisor CPUs and use a 64-bit server operating system (e.g. Windows Server 2008 R2) the Citrix Hypervisor acts more powerfully than that of VMware. With the user density measurements Citrix XenServer 5.6 FP1 10-15% could provide more sessions performant than VMware ESXi vSphere 4.1. For provisioning and operating a mere vClient environment the two solutions - VMware View 4.5 and XenDesktop 4 - are equally good. Both solutions offer advantages and disadvantages as can be seen in table 12 – Advantages/disadvantages.

An increased use of virtual terminal servers (vTS) is recommended in a VDI environment, in particular when there is an average medium, or light when load profile of users exist. On the one hand, because up to 30% more desktops can be provided; on the other hand, because the performance requirements for the central SAN storage subsystem can be clearly lower.

As VMware View does not support the provisioning of server operating systems, the following options are offered with mixed environments of vClients and vTS:

- VMware ESXi vSphere / VMware View / Dinamiqs VirtualStorm¹⁸
- Citrix XenServer / Citrix XenDesktop
- VMware ESXi vSphere / Citrix XenDesktop¹⁹

Furthermore, when analyzing the IO workload, it was seen that the Citrix provisioning server option of placing the write cache in the target device RAM is an additional option. There are thus almost no read and write IO operations on the central SAN storage subsystems when using this option. However, the Hypervisor server RAM must be sized large enough accordingly.

This option is also suitable for a local solution without SAN in order to implement a centralized VDI environment. See the summary evaluation for the above solution combinations on the next page.

Medium load profile							
Test Description	Client type	CPU type	CPU number	Recommended RAM capacity / Session	Recommended RAM capacity Hypervisor Server	Recommended number of sessions	Recommended performance SAN (Backend Disk IOPS)
Citrix XenServer 5.6 XenDesktop 4	vClients	Intel Xeon X5650	2	1,536 MB	159 GB	103	31* / 1,571
Citrix XenServer 5.6 XenDesktop 4	vTS	Intel Xeon X5650	2	768 MB	106 GB	136	31* / 700
VMware vSphere 4.1 VMware View 4.5	vClients	Intel Xeon X5650	2	1,536 MB	159 GB	103	3139
VMware vSphere 4.1 VMware View 4.5	vTS	Intel Xeon X5650	2	768 MB	103 GB	132	660
VMware vSphere 4.1 XenDesktop 4	vClients	Intel Xeon X5650	2	1,536 MB	159 GB	103	31* / 1,571
VMware vSphere 4.1 XenDesktop 4	vTS	Intel Xeon X5650	2	768 MB	106 GB	136	31* / 700

= Results of the highlighted line were not determined but mirror the solution results to be expected!

* = Configuration: Provisioning Server WriteCache in RAM (second value = WriteCache in SAN)

Table 10: Summary sizing medium workload

The manufacturers Citrix and VMware took part in the installation, configuration and implementation of the respective load tests and confirmed the correctness of the load test results.

¹⁸ More information about VirtualStorm can be found at <http://www.dinamiqs.com/>

¹⁹ This combination was technically optimal at the moment of the test; the economic viability must be checked separately.

Heavy load profile							
Test Description	Client type	CPU type	CPU Number	Recommended RAM capacity / Session	Recommended RAM capacity Hypervisor Server	Recommended Number of sessions	Recommended performance SAN (Backend Disk IOPS)
Citrix XenServer 5.6 XenDesktop 4	vClients	Intel Xeon X5650	2	1,536 MB	141 GB	91	38* / 1,571
Citrix XenServer 5.6 XenDesktop 4	vTS	Intel Xeon X5650	2	768 MB	83 GB	105	38* / 600
VMware vSphere 4.1 VMware View 4.5	vClients	Intel Xeon X5650	2	1,536 MB	147 GB	95	3139
VMware vSphere 4.1 VMware View 4.5	vTS	Intel Xeon X5650	2	768 MB	75 GB	95	570
VMware vSphere 4.1 XenDesktop 4	vClients	Intel Xeon X5650	2	1,536 MB	147 GB	95	38* / 1,571
VMware vSphere 4.1 XenDesktop 4	vTS	Intel Xeon X5650	2	768 MB	83 GB	105	38* / 600

= Results of the highlighted line were not determined but mirror the solution results to be expected!

* = Configuration: Provisioning Server WriteCache in RAM (second value = WriteCache in SAN)

Table 11: Summary sizing heavy workload

The manufacturers Citrix and VMware took part in the installation, configuration and implementation of the respective load tests and confirmed the correctness of the load test results.

Criterion	Citrix XenDesktop 4	VMware View 4.5
Number of required infrastructure servers	-	+
Complexity in installation and initial operation	o	+
Create user-defined name conventions	+	+
License costs	o	o
Administration expenditure for managing up to 160,000 vClients	o	o
51 maximum pool size	65,000	512
Speed (new) provisioning	+	-
SAN requirements	+	-
LAN requirements	-	+
Provisioning server operating systems	+	-

Table 12: Advantages/disadvantages

Explanation:

+ = Advantage

o = Neutral

- = Disadvantage

Appendix

Abbreviations / glossary

Name	Meaning
Baseline	Average response time of first 15 vClients or vTS in ms. The base response time of Published Desktops (vTS) via Terminal Server is always greater than that of the VDI solution desktops (vClients).
CS	Abbreviation for VMware Connection Server. Fulfils the function of a connection broker
DDC	Abbreviation for the Citrix Desktop Delivery Controller. Fulfils the function of a connection broker
EFD	Abbreviation for Enterprise Flash Disks; high-value Solid State Disks (SSD)
OS	Operating system
PvS	Abbreviation for the Citrix provisioning server.
SAN	Abbreviation for Storage Area Network.
vClient	Abbreviation for: virtual client or virtual machine (VM).
VDI	Abbreviation for Virtual Desktop Infrastructure. Describes the infrastructure required to operate virtual clients.
VM	Abbreviation for virtual machine, This can be both a virtual client (vClient) as well as a virtual server
vTS	Abbreviation for virtual terminal server or virtual terminal server session.

Table 133: List of abbreviations