Virtual Reality Check

Project VRC: Phase III

Windows XP and Windows 7 on ‘Red Bull®’

Author(s): Jeroen van de Kamp, Ruben Spruijt
Version: 1.0
Date: September 2010
# DOCUMENT OVERVIEW

## HISTORY

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## REVIEWERS

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1. SUMMARY

More and more organizations are planning a move to VDI. Experience in many VDI projects has proven so far that the performance and sizing issues are still a major hurdle to overcome. Often, VDI results are disappointing because the VDI environment is not properly sized and tuned. In practice, storage remains the number one challenge in today’s VDI deployments.

In this whitepaper Windows XP and Windows 7 are extensively compared. Specifically, the I/O behavior of Windows XP and Windows 7 is investigated in detail. By evaluating the different phases of a desktop workload, completely new insights are given.

Windows 7 has a much bigger disk footprint and consumes more memory than Windows XP. It would be reasonable to expect that Windows 7 requires more resources than Windows XP. Although this is certainly true, several tests in this whitepaper prove that Microsoft managed to optimize Windows 7 disk I/O behavior in specific phases of a desktop workload in comparison to Windows XP.

Many best practices are available to optimize Windows 7. Project VRC performed tests with the default optimizations configured by VSI (referred in this document as ‘VSI optimizations’) and additional optimization best practices that are specific to Windows 7 (referred as ‘VRC optimizations’). Both from an I/O and VSI max (maximum capacity) perspective, these ‘VRC optimizations’ proved to have a significant positive impact.

Project VRC also investigated the performance impact of topics like ‘Page file configuration’, ‘Address Space Layout Randomization’, ‘VM logging’, ‘ESXTOP’, ‘1 vs 2 vCPU’s’, ‘ESX 4.0u2 vs ESX 4.1’, and ‘Overcommitting Memory’. There are many lessons to be learned here, but the impact of disabling ASLR was striking. It is difficult to blindly recommend disabling such an important security feature, but the impact is large enough to consider it.

All tests were performed with either vSphere 4.0 U2 or 4.1 as the hypervisor and all VDI tests were performed using View 4.0. Apart from specific recommendations for vSphere, all Windows related conclusions are valid for any kind of hypervisor or VDI solution.

The ‘Project VRC phase II version 2.0’ whitepaper evaluated the impact of configuring a higher HaltingIdleMsecPenalty value on vSphere with Terminal Server workloads. This setting improved hyper-threading performance considerably for vSphere under high loads. Although no specific hints were given by VMware or the community, Project VRC investigated if a higher HaltingIdleMsecPenalty value would benefit VDI workloads. Surprisingly, a significant performance increase was witnessed for both Windows 7 and Windows XP workloads. The difference was so high that Project VRC internally started to call this the ‘Red Bull setting’.

Project VRC highly recommends to evaluate the data in this document carefully. Project VRC realizes there are always valid reasons not to use a specific settings mentioned in this paper. Real world VDI environments will always be different from the test-setup in the Project VRC labs. More importantly, Project VRC must emphasize that it is crucial to test and validate these optimizations in your own VDI deployment.
2. INTRODUCTION PROJECT VRC

Welcome to “Project: Virtual Reality Check (VRC)”!

If you are looking for an independent advise and a ‘Reality Check’ in relation to Virtualizing Terminal Server and Desktop workloads, if you are curious about the impact of different hypervisors and the performance differences with various hardware and if you are searching for best practices for your virtual Desktops ... Project VRC whitepapers are a must read!

PQR and Login Consultants started this unbiased and independent R&D project early 2009. The goal of Project VRC is to analyze the developments in the Application- and Desktop Virtualization market and to objectively present the results. All together over 650 tests have been carried out (Q3-2010).

In the haze of extreme innovation rate in the virtualization market and corresponding marketing promises this information is appreciated.

Therefore we published our methods and conclusions in various whitepapers which can be downloaded on [www.projectvrc.com](http://www.projectvrc.com).

2.1 PROJECT VRC OBJECTIVES

The overall goal of Project VRC is to investigate, validate and give answers to the following questions and much more:

- What is the true impact of innovations on a hardware and hypervisor level?
- Which performance optimization on the host and guest virtualization level can be configured, and what is the impact of these settings on user density?
- With the introduction of the latest hypervisor technologies, can we now recommend running large scale TS/CTX workloads on a virtualization platform?
- How does a VDI infrastructure scale in comparison (virtualized) Terminal Server?
- How do various Microsoft Windows Client OS’s scale as a virtual desktop?
- How do x86 and x64 TS platforms compare in scalability on bare metal and virtualized environments?
- What is the best way to partition (memory and vCPU) the Virtual Machines the hypervisor host, to achieve the highest possible user density?
- What is the impact of the latest and greatest hardware on (virtualized) terminal servers and desktops?

Project VRC is not finished, and probably never will be. We look forward to evaluate new innovations in the hypervisor arena, hardware level, Application Virtualization and Remoting Protocols.

Project VRC publishes their findings on [www.projectvrc.com](http://www.projectvrc.com).

2.2 INTENDED AUDIENCE

This document is intended for IT Managers, Architects, (Performance) Analysts, System Administrators and IT-Pro’s in general who are responsible for and/or interested in designing, implementing and maintaining virtualized Terminal Server and Virtual Desktop Infrastructures.
2.3 BETTER TOGETHER

“..The two largest and most focused competitors in the Dutch Virtualization and Application Delivery market space are working together on project: Virtual Reality Check...” PQR and Login Consultants started this joined-venture to share insights with the virtualization community with Project: Virtual Reality Check. There are several reasons for PQR and Login consultants to execute this project together:

- The Project leaders, Ruben Spruijt and Jeroen van de Kamp know each other for a long time from the virtualization community and share the same passion for these technologies.
- Project VRC is a huge undertaking, PQR and Login consultants individually do not have the resources, or time, to execute this project on their own. Thus is it logical to cooperate, share the workload and deliver the results together;
- Both organizations share the same technical vision, which is critically important in complicated projects like these.

2.4 VENDOR INVOLVEMENT

All major vendors whose products are covered by Project: Virtual Reality Check, such as VMware, Microsoft and Citrix have been approached in advance to create awareness of Project VRC and discuss the results.

2.5 CONTACT

All information about Virtual Reality Check can be found at www.projectvrc.com. Contact details are:

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We try to provide accurate, clear, complete and usable information. We appreciate your feedback. If you have any comments, corrections, or suggestions for improvements of this document, we want to hear from you! Please send e-mail to Jeroen van de Kamp (j.kamp@loginconsultants.nl) or Ruben Spruijt (rsp@pqr.nl). Include the product name and version number, and the title of the document in your message.

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3. ABOUT THE AUTHORS

3.1 ABOUT LOGIN CONSULTANTS

Login Consultants (Login) is an international IT-service provider specialized in virtualization, migration, desktop-deployment and application-delivery. In this field, we are recognized as the experts in the technologies of Microsoft, Citrix, VMware, RES, AppSense en Symantec/Altiris.

Technical innovation, like virtualization, of end-user infrastructures can bring significant benefits in the areas of costs, flexibility, safety, stability, and license management. As a result of the rapid technological advances and the technical complexity of implementations, only the very best specialists in this field are able to fully realize the business advantages of these innovations.

Login has an experienced team of more than 100 consultants in The Netherlands, Belgium and Germany. Our consultants have been accredited by Microsoft (4 MVP’s) and Citrix (2 CTP’s). Our specialists are well-regarded as speakers at (inter)national technical seminars. They are active in technical blogs and involved as experts in several IT-publications.

Login’s passion for technology and innovation is also materialized in our successful suite of point solution virtualization software tools in use by thousands of organizations around the world.

The service portfolio of Login Consultants is grouped around our three core service areas: consulting, projects and managed services. With our services we support our customers with the deployment of traditional and hosted desktops, with application virtualization and server virtualization.

In our role of independent advisor we support our customers with their selection of the architecture and software products that will best address their specific needs. Next to this role our specialists help with the design, implementation, migration and management of innovative desktop- and application infrastructures. We are in this business for more than 7 years.

Login Consultants has over 100 customers in The Netherlands, Germany and Belgium. Especially large and midsized organizations benefit of our expertise. We have a very large customer base in healthcare, government, financial services, transport, industry and references in all other verticals.

3.2 ABOUT PQR

PQR is THE specialist for professional ICT infrastructures with a focus on server & storage, virtualization and application & desktop delivery.

PQR stands for simplicity, freedom and professionalism. We provide our clients with innovative ICT solutions that ensure that application availability and manageability are optimal. We have demonstrable references and a wide range of expertise in the field, as witnessed by our many high partner statuses and certifications.

As a Trusted Advisor we inform our clients about new technologies that keep their ICT environments running even easier, creating optimal performance and information accessibility from any location or device. This not only applies to system administrators but also to users. By using application and desktop virtualization, for example, users experience the ease and speed of accessing applications and the associated data that they need. We therefore offer our clients an ICT environment that is manageable and well-organized and, above all, entails significant cost decreases, not only in management but also in energy consumption. In addition, these solutions contribute to a remarkable reduction of CO2 emissions. In this way PQR provides medium and enterprise companies and institutions with an ICT infrastructure that is stable, flexible and ready for the future.

PQR also has extensive experience in designing and implementing storage environments. Large storage environments have been our specialty for quite some time, and this ensures that we work efficiently. Our approach is clear for all processes. We begin with an inventory of needs and a preliminary examination. We carefully map out what is required in terms of functionality - naturally, taking future plans into consideration - and we give advice regarding necessary and feasible changes. During the entire project, from design to implementation, PQR takes responsibility for on-time delivery of (sub-
projects and for the end result. We usually do this fixed price with the associated guarantees. We call this ‘simplicity in ICT’. And that is the PQR approach that delivers success - and has been doing so since the company’s founding in 1990.

PQR is headquartered in De Meern, The Netherlands, and counts over 100 employees. In fiscal year 2008/2009 the company posted sales of € 84.6 million and a net after tax profit of € 4.2 million. PQR’s clients can be found in all sectors of society. A significant part of our sales is realized in non-profit organizations, the health care industry, education and local and federal government.

3.3 TEAM MEMBERS

Jeroen van de Kamp, CTO Login Consultants

As Chief Technology Officer, Jeroen van de Kamp is responsible for defining and executing the technical strategy for Login Consultants. From the start, Jeroen has played a critical role in the technical growth and accreditation Login has accumulated over the years. He has developed several core solutions which allow Login Consultants to easily differentiate in the infrastructure consulting market.

Jeroen is also responsible for several well-known publications like the Flex Profile Kit, TCT templates & “The black hole effect”. Because of his contribution to the technical community Van de Kamp is recognized as a thought-leader in the application delivery industry and has become a residential speaker for seminars like BriForum, Citrix Solution Summit and many others. He is one of the 25 members worldwide who participate in the exclusive "Citrix Technology Professional" program.

Jeroen is still engaged with strategic key accounts for Login Consultants, defining and realizing an all-encompassing strategy for the application, desktop and server delivery infrastructures. Previous to his position as CTO at Log*in Consultants Jeroen held positions as Infrastructure Architect at Login Consultants; IT Consultant at QFace ICT and IT specialist at ASG de Veer. To contact Jeroen send an email to j.kamp@loginconsultants.nl or follow him on www.twitter.com/thejeroen.

Ruben Spruijt, Technology Officer PQR

Ruben Spruijt, born in 1975, studied Computer Science and started his career as a Systems Engineer at A-Tree Automatisering. He has been working as a Solutions Architect at PQR since 2002.

Focusing on Server and Storage, Virtualization and Application Delivery solutions, PQR implements and migrates advanced ICT-infrastructures and has achieved the highest certifications of its most important partners: HP Preferred Partner Gold, Microsoft Gold Certified Partner, Citrix Platinum Solution Advisor, VMware Premier and Consultancy Partner.

In his job, Ruben is primary focused on Application and Desktop Delivery, hardware and software Virtualization. He is a Citrix Certified Integration Architect (CCIA), Citrix Certified Enterprise Administrator (CCEA) as well as Microsoft Certified Systems Engineer (MCSE+S). Ruben has been awarded the Microsoft Most Value Professional (MVP), Citrix Technology Professional (CTP), VMware vExpert and RES Software Value Professional (RSVP) titles.

At various local and international conferences Ruben presents his vision and profound knowledge of ‘Application and Desktop Delivery’ and Virtualization solutions. He is initiator of PQR’s conceptual modes of ‘Application and Desktop Delivery solutions’ and ‘Data and System Availability solutions’ and originator of www.virtuall.eu, the solutions showcase of PQR. He has written several articles that have been published by professional magazines and informative websites. To contact Ruben directly send an email to rsp@pqr.nl. Follow Ruben on www.twitter.com/rspruijt.
Sven Huisman, Consultant PQR

Sven Huisman (1977) studied Information Management in Utrecht. He started his career as system engineer and meanwhile he has over 10 years of experience in the IT business. He is one of PQR’s technical Consultants, focusing on Application and Desktop Delivery, hardware and software virtualization.

In addition he is a member of the VRC team and has been analyzing several tests of Terminal Services (TS) and hosted VDI workloads running on the latest generation hardware and hypervisors.

Sven advises, designs, implements and migrates advanced ICT-infrastructures. Having achieved the highest certifications of its most important partners, Sven is a Citrix Certified Enterprise Administrator (CCEA), a Microsoft Certified Systems Engineer (MCSE) and a VMware Certified Professional (VCP). Sven is blogging about virtualization on various websites, among which PQR’s showcase environment www.virtuall.nl and was awarded as VMware vExpert in 2009 and 2010

*Personal note from Jeroen and Ruben: we would like to give special thanks to Sven Huisman, who simply did an incredible job in setting up and performing the tests for phase III whitepaper. The amount of effort and private time spend in the VRC labs by Sven is extraordinary, and Sven never complained if we thought it was a good idea to redo some boring tests to (double-)check new insights... Thanks!*
4. THE LOGIN VSI BENCHMARK

For Project VRC, the Login Virtual Session Indexer (Login VSI 3.0) methodology was used. Login VSI is a benchmarking methodology which calculates index numbers based on the amount of simultaneous sessions that can be run on a single physical machine, running either bare metal or virtualized operating systems. To keep the results representative it is imperative that identical tests are run on different types of systems. Therefore Login VSI does not allow any customization of the load scripts.

Login Virtual Session Indexer can be downloaded from: www.loginvsi.com.

The philosophy behind VSI is different from conventional benchmarks. In general, most system benchmarks are steady state benchmarks. These benchmarks execute one or multiple processes, and the measured execution time is the outcome of the test. Simply put: the faster the execution time or the bigger the throughput, the faster the system is according to the benchmark.

Login VSI is different. VSI is specifically not a steady state test. VSI, a solution for benchmarking TS or VDI workloads, loads the system with simulated user workloads. VSI focuses on how many users can run on the system while maintaining acceptable response times. VSI is similar to investigating the maximum amount of seats on the bus, airplane or lifeboat by trial and error. This is the “Virtual Session Index (VSI_{max})”. With Virtual Desktop Infrastructure (VDI) and Server Based Computing (SBC) with Remote Desktop Services (RDS) workloads this is very valid and useful information. This index simplifies comparisons and makes it possible to understand the true impact of configuration changes on hypervisor host or guest level.

For Login VSI the choice has been made to execute the scripts completely on the server side with AutoIT. This is the only practical and platform independent solution for a benchmark like Login VSI. Also the relative overhead and footprint AutoIT is small enough (1-5% range) for Login VSI’s purposes.

4.1 LOGIN VSI OVERVIEW

Login VSI 3.0 consists of 4 components:

- AD Domain controller for user accounts and standard policies
- A file share for central configuration and logging
- Launcher workstations (Master and Slaves) to initiate the sessions
- Target platform (VDI or SBC) where the user load script are installed and performed
4.2 WHAT’S NEW IN LOGIN VSI 3.0

While the phase I whitepaper used VSI 1.x, the phase II whitepaper used 2.x, this whitepaper uses Login VSI 3.0.

New standard workload called VSI, based on the original Medium workload:

- Alternating between 2 medium workloads: one is with Flash video, the other without. Once one workload is finished, the other will start, alternating throughout the test.
- The flash app GetTheGlass is replaced by the “Kick-Ass” 480p movie trailer in flash format (.flv)
- Random start delay of max 15 second, to prevent workload synchronization
- Automatic loop length adjustments: when the load is higher, normally the total loop length increases: now automatically the pauses are decreased so the total loop length stays the same, even when the system approaches saturation.
- FreeMind (an open source JAVA application) is added to the medium workload.
- Updated the light, heavy & multimedia workloads to include all changes mentioned above

Completely revised logging structure:

- No more VSI_Log.xxxx, but SESSIONNUMBER_USERNAME_COMPUTERNAME.log
- The Log files are now using comma delimited CSV formatting
- Logfiles are now stored in VSI Share\ActiveTestName\Results
- Active sessions are not based on sessions launched, but truly active (logged on) sessions

Completely new analyzer, based on the MSchart add-on for .Net 3.5 sp1

- Fully automatic analysis (including stuck sessions)
- Dynamic charting (right click on the chart to set axis)
- Result selection and highlighting (similar to perfmon: right click in the lower window)
- Detailed charting
- Export Chart to PNG (other formats will follow)
- Local Access database to cache analysis
- The highest and lowest scores: the 2% top and bottom results will be removed from VSI max calculation to lower noise in the results

4.3 LOGIN VSI 3.0 WORKLOAD

The standard VSI workload is the only workload available in VSI Express and also available in VSI PRO.

- This workload emulates a medium knowledge worker using Office, IE, PDF and FreeMind.
- Once a session has been started the workload will repeat every 14 minutes.
- During each loop the response time is measured every 2-3 minutes.
- The medium workload opens up to 5 apps simultaneously.
- The type rate is 160 ms for each character.
- Approximately 3 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 a YouTube style video (Kick-Ass 480p trailer) is opened once every two loops.
- 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.
- Freemind, a java mind mapper application

4.4 INTERPRETING PROJECT VRC RESULTS

Project VRC uses the product independent Login Consultants VSI 3.0 benchmark to review, compare and analyze desktop workloads on TS and VDI solutions. The primary purpose of VSImax is to allow sensible and easy to understand comparisons between different configurations.

The data found within Project VRC is therefore only representative for the VDI & TS workloads. Project VRC results cannot and should never be translated into any other workloads like SQL, IIS, Linux, Unix, Domain Controllers, Network, etc… Also, the “VSImax” results (the maximum amount of VSI users), should never be directly interpreted as real-world results. The VSI workload has been made as realistic as possible, but, it always remains a synthetic benchmark with a specific desktop workload. Real world TS and VDI performance is completely dependent on the specific application set and how these applications are used. To include specific applications or customize the VSI 3.0 workload, VSI PRO can be used.

4.5 VSImax 3.0

With VSI 2.0, a new index VSImax was introduced which replaced the OPI of VSI 1.0.

VSI 2.0 updated VSImax to 2.1 which improved accuracy (e.g. VSImax is reached when CPU is around 100%)

VSI 3.0 updated VSImax to respond better to disk I/O related bottlenecks.

In VSI 3.0 seven operations are measured to determine VSImax:

- Copy new doc from the document pool in the homedrive
  - This operation will refresh a new doc to be used for measuring the response time. This activity is mostly a file-system operation.

- Starting Microsoft Word
  - This operation will measure the responsiveness of the Operating System and the file-system. Word is started and loaded into memory, also the new doc is automatically loaded into Word. When the disk I/O is extensive or even saturated, this will impact the file open dialogue considerably. This operation is relatively heavy in comparison to other measured operations. To balance the response time, 50% of measured time is added to VSImax. (This is a relative long activity, the result of this response time is divided by 2, to ensure that this activity does not dominate the total response time.)

- Starting the “File Open” dialogue
This operation is handled in small part by Word and in large part by the operating system. The file open dialogue uses generic subsystems and interface components of the OS. The OS provides the contents of this dialogue.

- Starting "Notepad"
  - This operation is handled by the OS (loading and initiating notepad.exe) and by the Notepad.exe itself through execution. This operation seems instant from an end-user’s point of view.

- Starting the “Search and Replace” dialogue
  - This operation is handled within the application completely; the presentation of the dialogue is almost instant. Serious bottlenecks on the application level will impact the speed of this dialogue. (This is a relative short activity, the result of this response time is multiplied by 5, to ensure this activity affects the total response time.)

- Starting the “Print” dialogue
  - This operation is handled in small part by Word and in large part by the OS subsystems, as the print dialogue is provided by the OS. This dialogue loads the print subsystem and the drivers of the selected printer. As a result, this dialogue is also dependent on disk performance.

- Compress the document into a zip file with 7-zip command line
  - This operation is handled by the command line version of 7-zip. The compression will very briefly spike CPU and disk I/O.

The measured operations with VSI hit considerably different subsystems such as CPU (user and kernel), Memory, Disk, the OS in general, the application itself, print, GDI, etc. These operations are specifically short by nature. When such operations are consistently long: the system is saturated because of excessive queuing on any kind of resource. As a result, the average response times will then escalate. This effect is clearly visible to end-users. When such operations consistently consume multiple seconds the user will regard the system as slow and unresponsive. $VSI_{max}$ is reached when the average of the total response time exceeds 4000ms consistently.
5. THE VRC PLATFORM

Login Consultants and PQR have built the benchmark platform for Project VRC at PQR in a datacenter in Amsterdam, The Netherlands. Login VSI 3.0 was used to create transparent, reproducible and stable performance tests on Server Based Computing (SBC) and virtualized desktop (VDI) workloads. To effectively demonstrate the scalability of the Hypervisor platforms the benchmark environment has been built with the latest hardware- and software technologies.

For the tests in this whitepaper both ESX 4.0 update 2 and ESX 4.1 are used. To perform VDI tests VMware View 4.0 is used and RDP is used to connect to the desktop.

5.1 HARDWARE CONFIGURATION

All tests were performed VMware vSphere 4.0 update 2 and vSphere 4.1. on the following server hardware:

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<tr>
<td>BIOS version</td>
<td>P62 07/24/2009</td>
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<tr>
<td>CPU</td>
<td>2 x Intel Quad core <a href="mailto:x5550@2.67GHz">x5550@2.67GHz</a></td>
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<td>CPU cache</td>
<td>1Mb L2, 8Mb L3</td>
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<tr>
<td>Memory</td>
<td>96GB; 1333MHz</td>
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<tr>
<td>Disk</td>
<td>8 x 146Gb, 820.2Gb, dual port 10.000RPM Serial SCSI</td>
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<td>RAID level</td>
<td>RAID-5 with online spare (25% Read / 75% Write)</td>
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<td>HP Smart Array P400i, with 512Mb and Battery Backed Write Cache</td>
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<td>Integrated Lights Out (iLO) v2</td>
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5.2 Launcher Configuration

All the VSI launchers are installed and configured within Virtual Machines which are running on VMware. All the VSI launchers have been installed on Windows Server 2008 x86 Enterprise Edition SP2 with 2vCPU and 3GB memory. The Microsoft Remote Desktop Client (v6.0.6001) is included in the OS, no special configuration settings are applied. The View 4.0 client was used in the VDI tests.

The RDP connection to the target machines was set to:

- 1024x786 Resolution
- 16 Bit Color Depth
- Speed Screen accelerators are disabled
- Client Drives are disabled
- Client Printing is disabled
- Clear Type is not configured

5.3 Test Approach

Unless mentioned otherwise, Project VRC consistently used these methodologies to perform their tests:

- Before each test is started, the server host and launcher infrastructure are completely restarted to ensure the test is not influenced by previous tests.
- In all tests the VM’s are pre-booted, as a result the logon interval is always 30 seconds, both with SBC and VDI workloads.
- To ensure vSphere’s Transparent Page Sharing (TPS) can free memory resources, each test is initiated at least 20 minutes after the last VM has been started.
- All tests are performed at least twice and the average result is reported in this document (both I/O and VSI max).
- All VSI max tests are performed with ESXTOP running in the background with a 60 second interval.
- I/O tests are performed on a single VM, the I/O data is retrieved using ESXTOP.
- All I/O tests are performed with an 10 second collection interval.
- All test are performed using local storage.
- For the VDI tests, VMware View Composer is used to create the VM’s.
- Typically, Windows 7 tests are performed with 1GB memory and Windows XP with 768MB. Both OS’s in this setup have roughly an equal amount of about 600-700MB of free memory available, which is more than enough for the VSI workload.
6. **VSI- VS VRC-OPTIMIZATIONS**

One of the main goals of Project VRC is to investigate best-practices and how they impact performance. The first Phase III tests done by project VRC were run only with the default optimizations configured through Login VSI. When reviewing VSI max scores and ESXTOP disk I/O results, it became clear additional optimizations and best-practices needed to be evaluated. This was especially visible when Windows 7 tests were reviewed, as they showed some erratic and sometimes disappointing results.

In this white paper tests are performed with two types of configurations: only with the default optimization within Login VSI (referenced as ‘VSI optimizations’ which are mostly tailored to Windows XP), and with additional optimizations and best practices. These additional best practices are referenced as ‘VRC optimizations’ in this document. Note that not all optimizations are performance related, and that the list does not cover every single best-practice being shared by the community.

Except ‘disk alignment’ and ‘disable VM logging’ all settings are configured within the Windows guest. In this document the impact of using the VSI optimizations only, and using all VRC optimizations are evaluated in many comparisons.

In the table below the differences between default Windows 7 configuration, the VSI optimizations and the additional VRC optimization are specified in detail:

<table>
<thead>
<tr>
<th>Description of optimization</th>
<th>Win7 default</th>
<th>Win7 VSI opt</th>
<th>Win7 VRC opt</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM Properties&gt;Options&gt;General&gt;Enable Logging -&gt; Uncheck</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Aligned disk</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disable Offline Files</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disable Autoupdate</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disable Background Defrag</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disable Last Access Timestamp</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disable Hibernate</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disable Bug Check Memory Dump</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disable Move to Recycle Bin</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reduce Event Log Size to 64k</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Advanced System settings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance&gt;Visual effects&gt;Best</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Startup and Recovery&gt;write debugging information&gt;None</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardware&gt;Device installation settings&gt;Never install driver software</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Protection&gt;Configure&gt;Turn off system protection</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remove Windows components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tablet PC Components</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Print and Document services&gt;Windows Fax and Scan</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows Gadget Platform</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XPS Services and Viewer</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remote Differential Compression</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User Accounts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>User Accounts Control Settings&gt;Never notify</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action Center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn off all messages</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Reporting Settings&gt;Never check</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Options (Create a plan)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never turn off display</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never put computer to sleep</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never turn off harddisk</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Description of optimization

<table>
<thead>
<tr>
<th>Description</th>
<th>Win7 default</th>
<th>Win7 VSI opt</th>
<th>Win7 VRC opt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disable services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application Experience</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Base Filtering Engine</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Background Intelligent Transfer service</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Diagnostic Policy service</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Function Discovery Resource Publication</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Offline files</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Superfetch</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Themes</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Windows Defender</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Windows Search</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Windows Update</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Windows Firewall</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>WLAN Autoconfig</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Windows media player Network Sharing Service</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Routing and remote Access</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>HomeGroup Provider</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Internet Connection Sharing</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Media Center Extender Service</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Net.Tcp Port Sharing Service</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Registry tweaks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HKLM\SYSTEM\CurrentControlSet\Services\Tcpip\Parameters DWORD DisableTaskOffload=1</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HKLM\SYSTEM\CurrentControlSet\Control ServicesPipeTimeout=120000</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HKLM\SOFTWARE\Microsoft\Windows\CurrentVersion\Run Delete VMware Tools key</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>HKLM\SYSTEM\Current Control\Session Manager\Memory Management\PrefetchParameters EnablePrefetcher=0 (disabled)</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Disabled Scheduled tasks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\Microsoft\Windows\Defrag\ScheduledDefrag</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\Diagnosis\Scheduled</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\DiskDiagnostic\DataCollector</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\Maintenance\WinSAT</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\Power Efficiency Diagnostics\AnalyzeSystem</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\Registry\RegIdleBackup</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\SystemRestore\SR</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\Backup\ConfigNotification</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows\Defender\MP Scheduled Scan</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>\Microsoft\Windows Defender\MPIdleTask</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

**Recommend reading on Windows 7 optimizations:**

- Optimizing Window 7 guide by VMware:

- Blog article by Citrix:
  [http://community.citrix.com/display/ocb/2010/01/15/Optimizing+Windows+7+for+FlexCast+Delivery](http://community.citrix.com/display/ocb/2010/01/15/Optimizing+Windows+7+for+FlexCast+Delivery)

- Windows 7 optimization tool by Microsoft’s Jonathan Bennett:

Although not specifically researched in this whitepaper, it is always recommended to consult applications vendors, since specific application optimizations can have a significant positive performance impact in real world VDI deployments.
7. UNDERSTANDING I/O

This whitepaper is completely focused on VDI workloads. Especially with VDI workloads, disk I/O proves to be a bottleneck if the storage solution is not designed and optimized for VDI. To understand how I/O behaves with Windows XP and Windows 7, many different configurations have been tested by running a single VM using the VSI workload, and reviewing the ESXTOP data.

I/O is investigated during the following phases; boot & logon, the first VSI loop, the second VSI loop, idle with 6 applications running, idle with no other applications running.

7.1 BOOT & LOGON

The total boot I/O’s (including the logon of a VSI test user with a locally cached roaming profile) of Windows XP and Windows 7 is shown in the chart below. For Windows 7 different configurations are measured. Windows 7 is tested with 1 or 2 GB memory, with VSI and VRC optimizations, and the page file has been set to automatic and fixed.

Legend chart raw tests results (average of at least two test runs):

- XP / W7: Windows XP or Windows 7
- 768MB / 1GB / 2GB: Memory configured
- PFAUT / PF2GB: Page file on automatic or fixed to 2GB
- ASRLOFF: ASLR is disable
- VRCOPT / VSIOPT: VRC optimizations or VSI optimizations
When all this raw data is averaged and normalized, the following comparison can be made between Windows XP (100%), Windows 7 with VSI optimizations only and Windows 7 with the VRC optimizations as shown in the chart below:

It is interesting to see how Windows XP and Windows 7 compare. With only the VSI optimizations Windows 7 shows a 118% higher total disk I/O than Windows XP. When the VRC optimizations are applied, Windows 7 shows a 83% higher disk I/O than Windows XP.

It is not surprising that Windows 7 has a higher boot I/O footprint than Windows XP since Windows 7’s disk space footprint is considerably larger. More importantly, Windows 7 is two generations younger than Windows XP and offers considerably more functionality, so a higher boot I/O footprint is reasonable and to be expected. Using VRC optimizations resulted in a 20% lower boot I/O in comparison to using the VSI optimizations only.

7.1.1 Read vs Write I/O

In the next consolidated chart, the read and write I/O’s are compared for the boot and logon process of Windows XP, Windows 7 VSI optimizations, and Windows 7 with VRC optimizations:

As expected, the read I/O’s are considerably higher than the write I/O’s during boot for both Windows XP and Windows 7. When reviewing the write I/O results, a remarkable conclusion can be made. As expected, Windows XP clearly has a lower read and total I/O in comparison to Windows 7. However, the XP’s write I/O’s are more than 200% higher than those of Windows 7. This is caused by the inclusion of the logon process of a VSI user with roaming profiles (which are cached on from previous logon attempts within the VM). The Windows 7 logon process is more efficient from an I/O perspective than Windows XP.
7.1.2 Logon I/O

In the comparison below, the total I/O's during logon are measured: this includes the VSI 3.0 logon script. This logon is performed while the roaming profile was cached by a previous logon attempt:

Looking at the chart above, it is clear that Windows 7 outperforms Windows XP when it comes to write I/O's. Windows 7 is considerably more effective than Windows XP from an I/O point of view: especially when considering the fact that a Windows 7 profile is larger than a Windows XP profile.

7.2 FIRST VSI LOOP

For the I/O tests in this white paper, Login VSI 3.0 is used to simulate a desktop workload. This ensures that every configuration tested is executing exactly the same workload. In this section the first loop of VSI (loop 1), which is based on the Medium workload without a flash movie (MediumNoFlash), is evaluated.

In Login VSI 3.0 a loop takes close to 14 minutes to finish, after that all applications are closed and the loop is repeated. Every loop opens several Internet Explorer pages, and applications like Outlook, Word, Excel and Powerpoint from the Microsoft Office 2007 suite, Adobe Reader and the Java mindmap application Freemind. The first loop represents the phase within the desktop when applications are started for the first time. Similar to the boot I/O discussion, different configurations were tested for both Windows XP and Windows 7. In the next chart the raw result in total I/O's are displayed:
When these tests are averaged and normalized for Windows XP, Windows 7 with VSI optimizations and Windows 7 with the VRC optimizations, the following comparison can be made:

![Comparison chart]

In comparison to Windows XP (100%), Windows 7 with VSI optimization requires 34% more I/O’s. When the VRC optimizations are applied, Windows 7 only generates 18% more I/O in total for the first loop.

### 7.2.1 Read vs Write I/O

The read and write I/O are compared for the first loop in this consolidated chart below for Windows XP, Windows 7 VSI optimizations, and Windows 7 with VRC optimizations:

![Consolidated chart]

It is clear that read I/O’s are considerably higher than the write I/O’s. On average a 65% read – 35% write ratio is visible in the first loop. This is caused by the fact that applications are started for the first time and have to be read from disk.
7.3 **SECOND VSI LOOP**

After the first VSI loop is finished, a second loop is evaluated. This loop is performing exactly the same action as the first loop, there is only one fundamental difference: applications are started for the second time.

These are the raw total I/O results for the second loop in the chart below:

![I/O Results Chart](image)

When the total I/O are compared to the first loop, I/O scores are fundamentally lower in the second loop. This is caused by the fact that applications within Windows are cached in memory when they are closed. As a result, applications can be loaded from memory and do not require the same amount of disk reads when these were started for the first time. This behavior is native to Windows, and can also easily be witnessed on normal PC’s and laptops: applications start much more quickly when opened for a second time.

Again these Loop 2 I/O results are averaged and normalized in the next chart for Windows XP, Windows 7 with VSI optimization and Windows 7 with the VRC optimizations:

![Averaged I/O Results](image)

When comparing Windows XP and Windows 7, a remarkable conclusion can be made. From an I/O perspective, Windows 7 is clearly more efficient with the re-launch of applications than Windows XP (100%). When the VSI optimizations are applied, Windows 7 scores 5% lower I/O’s than Windows XP. The difference is 21% with the VRC optimizations.

While the first loop may be representative for the first hour when users start working in their desktop session, the second loop may be representative for the rest of the day, when most applications have already been started.
7.3.1 Read vs Write I/O

The read and write I/O’s are compared for the second loop in this consolidated chart for Windows XP, Windows 7 VSI optimizations, and Windows 7 with VRC optimizations in the chart below:

The read I/O’s in the second loop are considerably lower than the read I/O’s in loop 1. On average a 20% read – 80% write ratio is visible in the second loop. This is caused by the fact that applications are cached by Windows in memory, and a started application can be loaded from memory directly with minimal disk access. In comparison to the first loop, the write I/O’s are pretty consistent.

7.4 IDLE I/O WITH 6 APPLICATIONS RUNNING

In real-world VDI deployments, between 20% - 40% of all desktop sessions are running idle because users are not actively working in their desktop session. Of course this percentage highly depends on how the desktop is used, but on average a 20-40% idle desktop session count is realistic. Project VRC also investigated Windows I/O behavior when the session is idle for 20 minutes:
These Idle I/O results (with 6 running apps) are averaged and normalized for Windows XP, Windows 7 with VSI optimization and Windows 7 with the VRC optimizations:

When the VSI optimizations are applied, Windows 7 scores 97% higher I/O’s than Windows XP. However, Windows 7 with VRC optimization scores 33% lower! By disabling scheduled tasks in Windows 7 (part of the VRC optimizations), no processes to perform maintenance on Windows 7 are started in the background. These scheduled tasks are not consistent in execution behavior (their execution time depends on time of day, how long the machine has been idle and when the tasks have been executed before). As a result, large variances in I/O behavior is witnessed in each test with VSI optimizations.

### 7.4.1 Read vs Write I/O

The read and write I/O’s are compared for the 20 minute idle workload with 6 opened apps in this consolidated chart for Windows XP, Windows 7 VSI optimizations, and Windows 7 with VRC optimizations:

On all platforms, the write I/O’s are consistently dominant when a session is idle. These write I/O’s are caused by Windows moving memory blocks to the page file located on disk.
7.5 **Idle I/O with No Running Apps**

Also disk I/O is evaluated when the sessions are idle for 20 minutes, with no additional apps opened in the table below:

<table>
<thead>
<tr>
<th>Configuration</th>
<th>I/O (MB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XP_1GB_PF1.5GB</td>
<td>794</td>
</tr>
<tr>
<td>XP_768MB_PF1GB</td>
<td>463</td>
</tr>
<tr>
<td>W7_2GB_PFAUT_ASLROFF_VROPT</td>
<td>446</td>
</tr>
<tr>
<td>W7_2GB_PF2GB_ASLROFF_VROPT</td>
<td>558</td>
</tr>
<tr>
<td>W7_1GB_PFAUT_ASLROFF_VROPT</td>
<td>1039</td>
</tr>
<tr>
<td>W7_1GB_PF2GB_ASLROFF_VROPT</td>
<td>515</td>
</tr>
<tr>
<td>W7_2GB_PFAUT_ASLROFF_VSOPT</td>
<td>2126</td>
</tr>
<tr>
<td>W7_2GB_PF2GB_ASLROFF_VSOPT</td>
<td>727</td>
</tr>
<tr>
<td>W7_1GB_PFAUT_ASLROFF_VSOPT</td>
<td>1701</td>
</tr>
<tr>
<td>W7_1GB_PF2GB_ASLROFF_VSOPT</td>
<td>34654</td>
</tr>
</tbody>
</table>

When these idle I/O results (without additional applications opened) are averaged and normalized for Windows XP, Windows 7 with VSI optimization and Windows 7 with the VRC optimizations, the following comparison is possible in the next chart:

![Chart showing I/O comparison](chart.png)

Now, an extreme difference is visible: the Windows 7 with VSI optimization still has scheduled maintenance tasks enabled. One of those tasks is to defrag the disk, and this is exactly what happened in one of the tests. As a result, an extreme peak in I/O can be witnessed. When the VRC optimizations are applied, Windows 7 I/O behavior is equal to Windows XP.
### 7.5.1 Read vs Write I/O

The read and write I/O are compared for the 20 minute idle workload with no apps running, in this consolidated chart for Windows XP, Windows 7 VSI optimizations, and Windows 7 with VRC optimizations:

When the disk gets defragmented by the scheduled task in Windows 7, the read and write I/O are close to equal. This is obvious since data-blocks are moved around the disk. The defragmentation process does this by physically organizing the contents of the disk to store the pieces of each file close together and contiguously. It also attempts to create larger regions of free space using compaction to impede the return of fragmentation.

### 7.6 Fixed or Automatic Page File Size

Also the I/O impact of an automatically managed page file and a page file fixed to 2GB (a minimum of 1.5x of memory is recommended by Microsoft) within Windows 7 is compared. The chart below is based on Windows 7 with the VRC optimizations and showing the total I/O for each phase:
Configuring a fixed page file (orange) does result in less I/O for almost all phases. Especially when Windows is booting or is in an idle state, I/O is considerably lower (around 20%). It is therefore recommended to fix the page file with virtual desktop workloads, similar to Terminal Services and every other type of virtualized Windows workload.

7.7 1GB vs 2GB

Adding more memory to a VM gives users more headroom to start applications. Adding more memory can prevent excessive paging when Windows run out of memory, which will potentially create excessive I/O’s for a VM. It is therefore important to assign enough memory for desktop VM’s.

With the ‘VRC optimizations’ configured, the VSI workload runs without problems on a 1GB Windows 7 VM. Adding more memory should not give specific benefits with the VSI workload. In real world VDI deployments, the amount of memory required is completely dependent on the applications provided within the desktop and how they are used. It is therefore ill-advised to assume that Project VRC’s 1GB configuration for Windows 7 should be taken as an general recommendation.

Multiple tests were performed to investigate I/O behavior in the different phases on Windows 7 with 1GB and 2GB memory of VM memory configured. This comparison on total I/O’s is done with a fixed 2GB page file and the ‘VRC optimizations’ enabled:

Note that Windows 7 with 1GB and 2GB perform very similar. In the first and second loop, when applications are used, there is no significant I/O difference visible between the 1GB and 2GB configurations. This is logical, since both with 1GB and 2GB memory configuration there is sufficient memory to run all applications that are part the VSI workload. Also, in the idle phase with no additional applications running, the difference in I/O is too small to be of any consequence.

However, there are two significant differences. First of all, in the boot phase, adding more memory increases total I/O. It seems that Windows is more aggressive in loading DLL’s and services when 2GB is configured during boot. Secondly, in idle phase with 6 applications open, the 2GB configuration requires less I/O than 1GB. Because of the additional memory, Windows is less aggressive in paging, resulting in a lower I/O behavior.
7.8 **AVERAGE I/O’s**

The average I/O behavior is compared for all phases in these consolidated charts for Windows XP, Windows 7 with VSI optimizations, and Windows 7 with VRC optimizations. The differences are similar to the comparisons based on total I/O’s. Nonetheless, the average I/O results help identifying the I/O capacity needed when deciding on a storage platform:

**Average I/O Boot and Logon:**

![Average I/O Boot and Logon Chart]

**Average I/O Loop 1:**

![Average I/O Loop 1 Chart]
Average I/O Loop 2:

- **Win XP**: Avg Reads/sec 1,6, Avg Writes/sec 5,0, Avg IO/sec 6,6
- **Win 7 VSI opt**: Avg Reads/sec 1,2, Avg Writes/sec 5,1, Avg IO/sec 6,3
- **Win 7 VRC opt**: Avg Reads/sec 0,9, Avg Writes/sec 4,3, Avg IO/sec 5,2

Average I/O Idle + 6 Apps:

- **Win XP**: Avg Reads/sec 0,1, Avg Writes/sec 1,1, Avg IO/sec 1,2
- **Win 7 VSI opt**: Avg Reads/sec 0,8, Avg Writes/sec 1,5, Avg IO/sec 2,3
- **Win 7 VRC opt**: Avg Reads/sec 0,2, Avg Writes/sec 0,6, Avg IO/sec 0,8

Average I/O Idle no Apps:

- **Win XP**: Avg Reads/sec 0,2, Avg Writes/sec 0,4, Avg IO/sec 0,5
- **Win 7 VSI opt**: Avg Reads/sec 3,8, Avg Writes/sec 4,6, Avg IO/sec 8,4
- **Win 7 VRC opt**: Avg Reads/sec 0,1, Avg Writes/sec 0,5, Avg IO/sec 0,5
7.9 CONCLUSION I/O’s

In the first I/O comparisons Windows 7 sometimes showed disappointing results, in every phase Windows 7 scored much more I/O’s than Windows XP. However, these first tests were performed only with the default VSI optimizations, which are designed for Windows XP workloads. It is clear the additional VRC optimization have a positive impact on the I/O’s. Surprisingly, after the VRC optimizations are applied, Windows 7 behaves better from an I/O point of view in the, logon, second loop and idle phases than Windows XP.

Windows 7 generates more boot I/O’s (+83%) and in the first loop (+18%) than Windows XP. It is highly recommend to consider this when choosing on storage solution for Windows 7. During morning and peak (logon/boot) hours, Windows 7 does require a significant higher I/O capacity than Windows XP. Consequently, Windows 7 requires a considerable higher read (burst) capacity on a storage level.

Still, Microsoft managed to optimize I/O behavior of Windows 7. This is especially visible after VM’s have been booted and users have started their applications. From an average I/O perspective (measured along the day), this does have a considerable positive impact. When a desktop session is running the whole day, in general the ratio between read and write I/O will shift dramatically:

<table>
<thead>
<tr>
<th>Time</th>
<th>Reads=Blue, Writes=Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 10min Application start</td>
<td>R/W = 65/35</td>
</tr>
<tr>
<td>Production</td>
<td>R/W = 20/80</td>
</tr>
</tbody>
</table>

In the long run, the ratio between read (blue) and write (red) I/O’s can be up to 20% read and 80% write. In practice this is heavily dependent on the applications and how they are used, but expecting a lot more write I/O’s than read is completely valid and should be considered in the design of the storage solution.
8. VIRTUAL DESKTOPS ON RED BULL

The Project VRC Phase 2 version 2.0 white paper showed substantial increase in performance with Terminal Server workloads on vSphere running on Intel Nehalem with HT enabled, when the patch ESX400-201003001 (now included in ESX 4.0 Update 2 and ESX 4.1) was installed.

In addition to installing the fix or ESX update the following advanced settings were configured:

- esxcfg-advcfg --set 0 /Numa/PageMigEnable (warning: this is not recommended anymore, as test will prove later in this chapter)
- esxcfg-advcfg --set 10000 /Cpu/HaltingIdleMsecPenalty (Known as HIMP)

VMware wrote a knowledge base article about HaltingIdleMsecPenalty:

“… ESX provides fine-grained CPU scheduling that, among other things, enforces resource settings like CPU reservations, limits, and shares. Based on those settings, the scheduler determines if a VM has fallen behind in the amount of CPU time it should have received. Should the VM indeed be behind, attempts are made to help it catch up, usually by scheduling it more frequently.

If the processor has hyper-threading, however, scheduling more frequently does not guarantee that the VM will catch up. This is because the amount of CPU resources received by the vCPU is affected by the activity on the other logical processor on the same physical core. To guarantee the vCPU that is behind can catch up, ESX will sometimes not schedule VMs on the other logical processor, effectively leaving it idle.

In the case of the Intel Xeon 5500 series (and other modern hyper-threaded) processors, not scheduling on a logical processor may have a measurable impact on the overall throughput of the system. As a result, in systems that:

- have more than 50% CPU utilization, and
- are very close to exactly committed (number of vCPUs = number of pCPUs +/- 25%), and
- have particular kinds of bursty CPU usage patterns,

we have observed a throughput drop of up to 15% when this fairness algorithm takes effect.

A parameter called HaltingIdleMsecPenalty determines when this fairness algorithm should come into effect. When, across all vCPUs of the VM, the total amount of time by which a VM has fallen behind exceeds the value of this parameter (in milliseconds), the scheduler will attempt to catch up the VM using the method described above. Note that setting the parameter too high may decrease the accuracy of resource settings, especially CPU reservations and shares. Also note that in an overwhelming majority of circumstances, setting the parameter larger than the default has no performance impact.

Caution: HaltingIdleMsecPenalty is an advanced parameter and should only be changed under guidance from VMware Support or after thorough testing in the user’s environment.

To set this parameter, use the following command on the ESX service console:

```
esxcfg-advcfg --set <desired value, e.g. 100> /Cpu/HaltingIdleMsecPenalty
```

For ESXi, use the following command on a Windows or Linux machine with vSphere CLI installed:

```
vicfg-advcfg --set <desired value, e.g. 100> /Cpu/HaltingIdleMsecPenalty
```

As of patch-set ESX400-201003001 to ESX 4.0 (available now on the VMware support website) and all versions of ESX going forward, a much larger maximum value of this parameter is allowed (up to 10,000 instead of the current 100). Larger values may make sense in environments where achieving maximal aggregated throughput is more important than fair sharing of CPU resources. Internal testing shows that values greater than 2,000 show little gain in total throughput.

Starting with ESX 4.0 U2, the meaning of this parameter changes slightly. Before it is used, it is multiplied by the number of virtual CPUs. After this operation, the value is capped by the new parameter.
HaltingIdleMsecPenaltyMax (maximum allowed value is 80,000). Both parameters may be set on the command line as shown above or changed in the vSphere Client (Host > Advanced Settings > CPU). The fairness check can be disabled entirely by setting HaltingIdleMsecPenalty to 0.

Before ESX Update 2, the default value for HaltingIdleMsecPenalty was 50. With ESX 4.0 Update 2 and higher the default value for HaltingIdleMsecPenalty is now 100.

vSphere had difficulties utilizing Hyper-Threading with Terminal Server workloads. In comparison to the competitors Citrix XenServer 5.0 and Microsoft Hyper-V 2008R2, capacity did increase when Hyper-Threading was enabled on vSphere, but not in the same scale as XenServer and Hyper-V.

The patch, together with configuring HIMP to 10000, equalized performance for 2vCPU and 4vCPU Terminal Server workloads configurations on Intel Nehalem with hyper-threading enabled on vSphere in the comparisons made in the Project VRC Phase II version 2.0 whitepaper.

During the phase III tests, Project VRC wondered if HIMP does impact VDI performance in the same way as it does with Terminal Server workloads on vSphere. There were no specific indications that it would, and setting HIMP to a higher value should only work on a system where the ratio of vCPU’s is similar to the amount of logical processors available.

To satisfy curiosity, Project VRC performed tests with HaltingIdleMsecPenalty (HIMP) configured with VDI workloads.

### 8.1 WINDOWS XP

First Windows XP is compared with HaltingIdleMsecPenalty set to 100, which is the default after ESX 4.0 update 2 and 2000, the VMware recommendation as highest effective value (VMware KB 1020233).

These tests are performed on: 130 VM’s pre-booted, 768GB memory, 1vCPU per VM, 1.5GB Page file fixed and ESX 4.1:

<table>
<thead>
<tr>
<th>Setting</th>
<th>Capacity Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIMP 100</td>
<td>98</td>
</tr>
<tr>
<td>HIMP 2000</td>
<td>114</td>
</tr>
<tr>
<td>HIMP 2000 max 80k</td>
<td>120,5</td>
</tr>
</tbody>
</table>

Configuring HIMP to 2000 gave a very considerable 16% capacity increase over the default HIMP value of 100 with Windows XP. The first time this increase was witnessed, the setting became known as the ‘Red Bull setting’ within project VRC.

However, Project VRC was told by VMware that HIMP is limited to 800. By configuring HaltingIdleMsecPenaltyMax (refered in this document to HIMPmax) to 80000, the 800 limit is removed. When HIMPmax is set to 80000, now HIMP is truly 2000. This results in even bigger improvements: the difference is now 23% compared to the default HIMP value of 100 for Windows XP.
In the next chart the average ESXTOP % utilization (Physical Cpu(_Total)\% Util Time) is compared between a HIMP of 100 and a HIMP of 2000 (HIMPmax is 80000):

When comparing the HIMP of 100 (Red) and 2000 (Green), the average CPU is up to 17% higher after 40 sessions with HIMP set to 2000. Before 40 sessions the average CPU utilization is practically equal, the effect of configuring HIMP becomes clearly noticeable when the CPU hits 40%. From these results, it must be concluded that the ‘Red Bull Setting’ not only makes a difference in response times (which results in a considerable higher VSI\_max value), it also increases the effective CPU utilization for each VM. When HIMP is set to the default of 100, the scheduler service is too conservative in assigning CPU cycles to the VM’s, as a result, the utilization is too low. (Note: Physical Cpu(_Total)\% Processor Time is already maxed when VSI\_max is reached with both HIMP set to 100 or 2000.)

8.2 WINDOWS 7

Also Windows 7 is evaluated with an HIMP of 100, 2000 with default HIMPmax, 2000 and 10000 with a HIMPmax of 80000 (a HIMP value of 10000 was used in the VRC Phase II v2.0 whitepaper for TS workloads). These tests were performed with: 120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ASLR Off and ESX 4.1:

Configuring HIMP to 2000 gives an 13% performance increase with Windows 7 in comparison to the default HIMP value 100. When the HIMP=800 limit is removed by setting HIMPmax to 80000: the difference is goes up to 22%.
VMware states in their knowledge base article (VMware KB 1020233) that a HaltingIdleMsecPenalty setting higher than 2000 does not give performance improvements. This is confirmed by these tests: the minimal difference between 2000 and 10000 is too small to be considered measurable. As a result, a HaltingIdleMsecPenalty of 2000 is recommended.

### 8.3 Hyper-Threading Disabled

When the HaltingIdleMsecPenalty impact was evaluated in the Phase II version 2.0 white paper, it was clear it did not make a fundamental difference when hyper-threading was disabled. vSphere already performed on the same level as its competitors in the tests without hyper-threading enabled.

Project VRC also tested the impact of HaltingIdleMsecPenalty set to the original 50 and the recommended 2000 on the host with hyper-threading disabled (Windows 7, 120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ASLR Off):

![Graph showing performance with different HaltingIdleMsecPenalty settings](image)

With such a small difference, the impact of HaltingIdleMsecPenalty set to 2000 with hyper-threading disabled does not come close when Hyper-threading is enabled. It is clear that increasing HaltingIdleMsecPenalty is only beneficial when hyper-threading is utilized.

### 8.4 PageMigEnable

In Project VRC’s Phase II version 2.0 whitepaper also the PageMigEnable=0 setting was mentioned part of the tuning needed to optimize Intel Nehalem Hyper-Threading performance. If this option is set to 0 (default=1), the system does not automatically migrate pages between nodes to follow vCPU migrations.

Project VRC thought it was worthwhile to review this individual setting (Windows 7, 120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ASLR Off, HIMP=2000/HIMPmax=8000):

![Graph showing performance with different PageMigEnable settings](image)

These test show there is no specific performance impact measurable when PageMigEnable=0. It is therefore not recommended to change this value, since it does not bring measurable benefits with the VSI workload.
8.5 **HIMP CONCLUSION**

A little unexpected, but it is good to see that with both Windows XP and Windows 7, configuring HaltingIdleMsecPenalty to 2000 (and HIMPmax is set to 80000) gives a considerable performance boost on a host with Intel’s hyper-threading enabled. It has not been tested on other CPU architectures, however, the test with disabled Hyper-Threading shows it is very likely that setting HIMP to a value of 2000 does not bring the same benefits to systems with AMD or the previous generation Intel processors.

Configuring HIMP can affect fairness of the assigned CPU cycles between VM’s. This has not been specifically witnessed with the tests executed by Project VRC, but there remains a slight chance that configuring HIMP can lead to an unbalance between VM’s. It is therefore highly recommend to always first evaluate and test HIMP tuning in your own VDI deployment.

The previous recommendation (from the Project VRC Phase II version 2.0 whitepaper) to configure PageMigEnable does not seem to make a difference for the VSI workload. Nevertheless, it is difficult not to recommend tuning HIMP with both VDI and RDS workloads running on vSphere on Intel Nehalem hosts.
9. VSIMAX COMPARISONS

Project VRC performed many comparisons utilizing Login VSI 3.0 to analyze the relative performance impact of different settings and configurations:

- ASLR; Address Space Layout Randomization
- VM logging
- ESXTOP
- VSI vs VRC optimizations
- 1 vs 2 vCPU’s
- Overcommitting Memory
- VMware vSphere 4.0 Update 2 vs VMware vSphere 4.1

9.1 ASLR

In the ‘Virtual Reality Check Phase II version 2.0’ white paper a 4% performance increase was measured on Windows 2008 Terminal Services by disabling ASLR. Although a relative small impact, the test showed the desktop capacity of a server could be increased by disabling ASLR.


“Address space randomization hinders some types of security attacks by making it more difficult for an attacker to predict target addresses. For example, attackers trying to execute return-to-libc attacks must locate the code to be executed, while other attackers trying to execute shellcode injected on the stack have to first find the stack. In both cases, the related memory addresses are obscured from the attackers. These values have to be guessed, and a mistaken guess is not usually recoverable due to the application crashing.”

Although Microsoft states that ASLR does not have an performance overhead, this can be different in Terminal Server workloads which are typified by hundreds of processes, thousands of threads and tens-of-thousands context switches per seconds. ASLR does not measurably affect a single user/OS systems. Nonetheless, in multiuser environments it does have an impact on server capacity.

It must be noted that Project VRC does not blindly recommend disabling ASLR. This is an important security feature, and it is enabled by default since Windows Vista and Windows 2008 server (Windows XP and Windows server 2003 do not support ASLR). However, with VDI workloads, the impact could be potentially larger. Every desktop session is running an individual desktop OS instance. In comparison to Terminal Services, a VDI workload runs a magnitude of OS’s more to serve desktops to end-users. Potentially the performance impact of ASLR could be larger.

Project VRC evaluated the impact of ASLR on a Windows 7 desktop workload (120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ESX 4.0 Update 2, HIMP=100):

![Bar chart showing comparison between Win 7 ASLR ON and Win 7 ASLR OFF]

By disabling ASLR, the VSImax score was 16% higher. In comparison to the 4% increase witnessed on Terminal Services, the increase in capacity with Windows 7 VDI workloads is significantly higher. This does not come a total surprise: the amount of VM’s running is also significantly higher. Although it is difficult to generally recommend disabling ASLR, the impact on Windows 7 is considerable.
ASLR can be disabled through the registry:

[HKEY_LOCAL_MACHINE\System\CurrentControlSet\Control\Session Manager\Memory Management]
"MoveImages"=dword:00000000

9.2 VM LOGGING

By default, VM logging (enabled by default on a VM level in vCenter) is enabled for each virtual machine in VMware vSphere. To investigate what performance impact VM logging potentially can have, tests were performed with logging enabled and disabled on a Windows 7 workloads (120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ASLR Off, ESX 4.0 Update 2, HIMP=100):

By disabling VM debug logging for each Windows VM, VSI max scored 4% higher. Although not significant, disabling VM debug logging in VMware vSphere for each VM does bring a measurable performance improvement. The same applies for Windows XP workloads.

9.3 ESXTOP

Every test performed by Project VRC is run with ESXTOP running in the background (with an 60 second interval, to minimize impact) on the vSphere host to record additional performance metrics. During the Phase III tests the question was raised what the overall performance impact was of gathering additional performance data.

Project VRC tested the performance impact of ESXTOP on Windows 7 VDI workloads (120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VSI optimizations only, ASLR Off, ESX 4.0 Update 2, HIMP=100)

It is clear that enabling ESXTOP does not significantly impact VSI max results. The overhead induced by the ESXTOP configuration used by Project VRC is only 1%, which is negligible and could also be the result of normal variance in tests.
9.4 **VSI vs VRC OPTIMIZATIONS**

It is already clear that configuring the VRC optimizations can dramatically reduce I/O’s in Windows 7 in comparison to only using VSI optimizations.

Project VRC tested the performance impact of the VRC optimizations on Windows 7 VDI workloads (120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, ASLR Off, ESX 4.0 Update 2, HIMP=100):

![Graph showing Win 7 VSI opt and Win 7 VRC opt with values 70 and 81.5 respectively.]

By configuring the VRC optimizations, capacity was increased by 16%. Suffice to say, extremely recommended!

9.5 **1 vCPU vs 2vCPU**

Previous Project VRC white papers showed that it is highly recommended to configure at least 2vCPU’s per VM with Terminal Server workloads. Because the system is shared by many users, having at least 2vCPU’s for each VM will dramatically improve performance. When it is the aim to maximize the users on a host, it is not recommended to overcommit on vCPU’s (total vCPU’s on a host should not exceed the available logical processors).

Project VRC investigated if moving from 1 to 2vCPU’s brings performance benefits within a VDI scenario. (105 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ASLR Off, ESX 4.0 Update 2, HIMP=100):

![Graph showing Win 7 1vCPU and Win 7 2vCPU with values 81.5 and 60 respectively.]

VDI is fundamentally different than Terminal Server workloads, as each user has its own Windows instance. As a result, the sheer amount of vCPU’s is considerably higher on each host than with Terminal Server workloads. Doubling the vCPU configuration per VM in a VDI scenario doubles the overhead required to manage the vCPU’s. As a result, configuring 2vCPU’s per VM did decrease session capacity by 26%.

Configuring 2vCPU is beneficial for performance, but only for the first users on the system. Once more users are active on the host, the average response time will increase much faster than with a 1vCPU configuration. (Note: when HIMP is set to 2000, similar results were witnessed.)
9.6 **ESX 4.0 UPDATE 2 VS ESX 4.1**

Most tests were performed with ESX 4.0 update 2. ESX 4.1 was released on July 13th 2010. Project VRC was interested to see if ESX 4.1 brings immediate performance benefits when both the host and VM’s are updated. ESX 4.0 update 2 and ESX 4.1 are compared with Windows 7 (120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, ASLR Off, HIMP=100):

![Bar Chart]

Also this comparison is made with ‘Red Bull’ enabled (HIMP=2000/HIMPmax=80000):

![Bar Chart]

The difference is too small (2-3%) to be considered significant for this test, but the difference is consistent with both HIMP set to 100 and 2000.

It must be noted that these tests were performed with identical configurations. In ESX 4.1 memory compression is enabled by default. Because 120 VM’s with 1GB are pre-booted, memory is overcommitted by approximately 30%. Running 120 VM’s with 1GB requires approximately 130GB, and the server is configured with 96GB. The slight difference visible is probably caused by memory compression.

However, this is not a test to evaluate the impact of memory compression in ESX 4.1. This purpose of this test is only to evaluate if there are direct benefits to moving ESX 4.1 with the VDI tests in VRC. Evaluation of memory compression is out of scope of this document, and requires a different testing approach.

9.7 **OVERCOMMITTING MEMORY**

Project VRC performed all VDI tests with the VM’s pre-booted on vSphere. With most Windows 7 tests 120 VM’s with 1GB of memory are pre-booted before the test is run. Without vSphere’s Transparent Page Sharing (TPS) & ballooning ability this would not have been possible. The server host has 96GB of physical memory, booting 120 VM’s with 1GB easily results in a 30% overcommit on a system with 96GB of memory. Without the ability to overcommit, roughly 85 VM’s could have been booted safely on a 96GB system (before excessive host memory swapping occurs), approximately 80MB of additional memory is required for each 1GB VM with ESX.
Before every test, the host running vSphere is always rebooted to ensure the tests are not tainted by previous tests. After the host is restarted, the View desktop pool has been configured to automatically boot the Windows VM’s in batches of ten. If a test is started immediately after the last (120th) Windows VM is booted, many logons will fail, since the host’s memory is too much under contention, causing VM’s to be less responsive. Therefore, at least 20 minutes is waited after the last (120th) VM has been booted to allow TPS to free up memory resources on the vSphere host.

While the ability to overcommit on memory is instrumental to perform tests with more than 85 1GB Windows 7 VM’s on a 96GB machine, it is difficult to predict when too much memory is overcommitted. To evaluate the impact of overcommitting VM memory, tests are performed with 1GB, 1.5GB and 2GB of memory for each VM with 120 VMs pre-booted (30s logon interval, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ASLR Off, HIMP=2000/HIMPmax=80000, ESX 4.1):

With the 1GB test, an average VSImax score of 95.5 is achieved and 120 sessions are (100%) successfully logged on. With 120 booted 1.5GB VM’s (approximately a 100% memory overcommit total on a 96GB host) an average VSImax score of 95 is achieved. However, on average only 102 of 120 sessions were successfully logged on after the test has been completed. Around 70th session launch the first logon is dropped. The host memory is under extreme contention, resulting in an average of 18 dropped sessions for the complete test. With 120 booted 2GB VM’s (approximately a 150% memory overcommit on a 96GB host) an average VSImax score of 87.5 is achieved, but only an average of 95.5 sessions are successfully logged on.

Please note: these test are not about proving it is impossible to run 1.5GB or 2GB desktop VM’s. Also this test should not be interpreted that Project VRC concludes it is possible to overcommit 100% on memory or more.

The ability to overcommit is highly valuable feature, but it is difficult to predict what happens when too much memory has been committed. TPS requires time to free memory resources. When memory is under extreme contention, the system will start paging. When the host starts paging guest memory, it will severely affect performance of the desktop VM’s and become (temporarily) unresponsive. It is therefore recommended to be conservative with overcommitting memory in a VDI scenario and review vSphere memory metrics continuously.

Under these conditions it can be helpful to greatly increase the aggressiveness of page sharing, at the cost of a small amount of CPU. This will free up memory more quickly. To increase TPS aggressiveness, look in advanced settings -> Mem for the host. There are 3 parameters to tune TPS: ShareScanGHz, ShareScanTime, ShareRateMax. The actual scan rate is the minimum of the rates calculated by the algorithms associated with each of the parameters. Review the descriptions for these settings, this will help to understand each of the rates and which one is actually limiting the scan rate.
10. VDI VS SBC

This whitepaper focuses completely on VDI workloads with Windows XP and Windows 7. Still, it is interesting to see how VDI and SBC (Remote Desktop Server / Terminal Server) workloads compare in session capacity. In the chart below the following configurations are compared:

- **VDI**
  - Windows XP (130 VM’s pre-booted, 768GB memory, 1vCPU per VM, 1.5GB Page file fixed, ASLR Off, ESX 4.0 Update 2, HIMP=2000/HIMPmax=80000)
  - Windows 7 (120 VM’s pre-booted, 1GB memory, 1vCPU per VM, 2GB Page file fixed, VRC optimizations, ASLR Off, ESX 4.1, HIMP=2000/HIMPmax=80000)

- **SBC**
  - Windows 2003 R2 x86 (4 VM’s pre-booted, 8GB memory, 4vCPU per VM, 8GB Page file fixed, ESX 4.0 Update 2, HIMP=2000/HIMPmax=80000)
  - Windows 2008 R2 x64 (4 VM’s pre-booted, 14GB memory, 4vCPU per VM, 14GB Page file fixed, ESX 4.1, ASLR Off, HIMP=2000/HIMPmax=80000)

The RDS workloads have a considerable capacity advantage in comparison to the VDI workloads. Both VDI and RDS can serve functionally identical desktops, but with RDS only 4 VM’s are shared by all users, and with VDI each user has its own desktop VM. By running so many more VM’s within VDI, there is a considerable performance overhead compared to the highly efficient Terminal Services.

Interestingly, the difference between Windows 2003 R2 (x86) and Windows 2008 R2 is smaller than Windows XP and Windows 7. This is to be expected, as the relative OS overhead of Windows 7 in comparison to Windows 2008 R2 is much higher: there many more VM’s running.

In this relative comparison SBC with (blue) is compared to VDI (red):

While VSI max is up to 40% higher with SBC, other metric show greater differences. The avg. writes are only 50% of VDI with 100 users. The reads are even lower: this is because all applications that are
started are cached in memory. If other users start these applications, no disk access is required, since the application can be loaded from memory. The disk space required to run 100 users is only 20% of VDI, which is logical because the Windows server is shared by many users. Lastly, SBC’s memory footprint is around 40% with 100 users in comparison to VDI. This is caused by the memory overhead of serving individual VM’s to each users with VDI.

Project VRC would like to emphasize that this discussion is not a general recommendation for SBC, there are clear and tangible benefits to VDI which SBC cannot deliver. In many cases VDI offers the additional flexibility of giving users access to their personal Windows VM and with VDI it is much more easier to support applications.

Nevertheless, for general purpose desktops for task workers, SBC is still the most economical choice. This is not just driven by a higher server capacity, SBC economics are strengthened by the much lower storage requirements.