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**IBM® System x™ 3650 and  
xSeries® 346: A Comparison  
of Power and Capacity  
Utilization Running  
Microsoft® Windows®  
Terminal Services**

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## Introduction

Nemertes Research ([www.nemertes.com](http://www.nemertes.com)) recently reported an 800% increase in remote workers—workers residing in separate locations from their managers—over the past five years.<sup>1</sup>

Businesses are seeing an increase in the number of remote workers every year, and the advantages of a remote workforce—reduced facility costs, centralized software and systems management, troubleshooting and support, and increased business agility—clearly outweigh the disadvantages and added complexities introduced by a remote workforce to an organization.

To meet the increasing demands of the growing remote workforce, businesses need a centralized, robust server-based solution to provide reliable, responsive, and sustainable connectivity.

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<sup>1</sup> “The Virtual Workplace: Leveraging Real-Time Communications in the Enterprise,” Nemertes Research, ([www.nemertes.com](http://www.nemertes.com)).

## The 64-Bit Advantage

The new 64-bit processors provide superior performance to 32-bit processors. Because of this, 64-bit processors are presently the best foundation for servers aimed at creating, sustaining, and growing a large remote workforce.

The key benefits of running Microsoft® Windows® Server 2003 Terminal Server in a 64-bit environment include:

- The theoretical limit for the number of users is much higher on a 64-bit system than it is on a 32-bit system. The reason is that 64-bit architecture removes the kernel virtual address space limitations of 32-bit systems.
- Multi-core Intel® Xeon® processor-based systems equipped with large amount of memory can support more Terminal Server users.
- The 64-bit systems provide I/O throughput and processor power that are superior to that of 32-bit systems. A large number of users on a single system cause a significant amount of disk, processor, and I/O activity on the system; therefore, a robust storage system is required to handle the increased disk and I/O traffic from both the operating system and from applications.

## The IBM Solution

The IBM System x3650, running Microsoft Windows Server 2003 Enterprise x64 Edition and Microsoft Windows Server 2003 Terminal Server, allows remote workers to access Microsoft Windows-based applications remotely from a computer using any member of the Microsoft Windows XP or Windows Server 2003 family of operating systems.

In addition, the IBM System x3650, running Microsoft Windows Server 2003 Enterprise x64 Edition, takes full advantage of the Microsoft Terminal Server enhancements for the 64-bit environment.

Running a simulated Terminal Server benchmark on an IBM System x3650 with two Dual-Core Intel Xeon 5160 processors allowed us to support up to 300 simultaneously connected, working users—a **50% increase** over the number of users supported on the older IBM eServer™ xSeries® 346.

Running a simulated Terminal Server benchmark on an IBM System x3650 with two Quad-Core Intel Xeon X5355 processors allowed us to support up to 350 simultaneously connected, working users—a **75% increase** over the number of users supported on the older IBM eServer™ xSeries® 346.

In addition to the x3650's superior performance, the x3650 with Dual-Core processors consumes approximately **16% less power** than the x346. With Quad-Core processors, the x3650 consumes about **4% less power** than the x346, while serving **75% more users**.

In a typical 24/7 server environment, reduced power consumption can save thousands of kilowatt-hours per year, per server.

This white paper presents the results of power consumption and performance tests conducted on the x3650 and the x346 servers. In addition, you will also find system recommendations for running Windows Terminal Services on x64-based versions of Windows Server 2003 on the IBM System x3650 platform.

The following two sections present the key features standard on the x3650 and x346 servers. The system configurations used in the tests are also described.

## Standard Features of IBM x346 and x3650 Servers

Table 1 summarizes the standard features of the IBM x346 and the x3650 with both Dual- and Quad-Core configurations.

Description	x346	x3650 Dual/Quad Core
<b>Form Factor/height</b>	Rack/2U	Rack/2U
<b>Processor</b>	Single-core Intel Xeon Processor up to 3.8 GHz and 800 MHz front-side bus	<b>Dual Core:</b> Intel Xeon Processor 5160—up to 3.0 GHz and 1333 MHz front-side bus <b>Quad-Core:</b> Intel Xeon Processor X5355, 2.66 GHz and 1333 MHz front-side bus
<b>Number of processors</b>	1 standard, 2 maximum	1 standard, 2 maximum
<b>L2 cache</b>	Up to 2MB L2 per processor core	2x4MB
<b>Memory</b>	512MB, 1GB, or 2GB/16GB PC2-3200 DDR2 via 8 DIMM	1GB standard, Up to 48GB Fully Buffered DIMMs 667 MHz via 12 DIMM slots
<b>Expansion slots</b>	4xPCI-E or 2xPCI-X and 2xPCI-Express	4xPCI-E or 2xPCI-X and 2xPCI-Express
<b>Disk bays</b>	6 total, 6 hot-swappable	8 total, 8 hot-swappable
<b>Maximum internal storage</b>	1.8 Terabyte Ultra320 SCSI	1.8 Terabyte hot-swap SAS
<b>Network interface</b>	Integrated dual Gigabit Ethernet	Integrated dual Gigabit Ethernet
<b>Power supply (std/max)</b>	Up to 2x625W	Up to 2x835W
<b>Hot-swap components</b>	Power supply, fans and hard disk drives	Power supply, fans and hard disk drives
<b>RAID support</b>	Integrated RAID-0, -1, Optional RAID-5	Integrated RAID-0, -1, -10, Optional RAID-5, -6
<b>Operating system</b>	Supported: Microsoft Windows Server 2003, Windows 2000/Advanced Server, Red Hat Linux, SUSE Linux, Novell NetWare, VMware ESX Server 2.5	<b>Supported:</b> Microsoft Windows Server 2003, Windows 2000/Advanced Server, Red Hat Linux, SUSE Linux, Novell NetWare, VMware ESX Server 2.5

**Table 1: Standard features of the x346, Dual-Core x3650, and Quad-Core x3650**

## x346 and x3650 Server Test Configurations

Table 2 summarizes the test configurations of the x346, the Dual-Core x3650, and the Quad-Core x3650.

Description	x346	Dual-Core x3650	Quad-Core x3650
Form Factor/height	Rack/2U	Rack/2U	Rack/2U
Processor	3.6 GHz, 800 MHz front-side bus	3.0 GHz, 1333 MHz front-side bus	2.66 GHz, 1333 MHz front-side bus
Number of processors	2	2	2
L2 cache	1MB	2x4MB	2x4MB
Memory	8GB PC2-3200 DDR2	12GB PC2-4200 DDR2	12GB PC2-5300 DDR2
Expansion slots	512MB, 1GB, or 2GB/16GB PC2-3200 DDR2 via 8 DIMM	4xPCI-E or 2xPCI-X and 2xPCI-Express	4xPCI-E or 2xPCI-X and 2xPCI-Express
Disk bays	4xPCI-E or 2xPCI-X and 2xPCI-Express	8 total, 8 hot-swappable	8 total, 8 hot-swappable
Maximum internal storage	36.4GB RAID-1 2 HDDs for Terminal Server, 5 HDDs for power analysis	136GB RAID-1E 8 HDDs	340GB RAID-5 6 HDDs
Network interface	Integrated dual Gigabit Ethernet	Integrated dual Gigabit Ethernet	Integrated dual Gigabit Ethernet
Power supply (std/max)	2x625w	2x835w	2x835w
Hot-swap components	Power supply, fans and hard disk drives	Power supply, fans and hard disk drives	Power supply, fans and hard disk drives
RAID support	Integrated RAID-0, -1, Optional RAID-5	Integrated RAID-0, -1, -10, Optional RAID-5, -6	Integrated RAID-0, -1, -10, Optional RAID-5, -6
Operating system	Windows Server 2003 x64 Enterprise Edition	Windows Server 2003 x64 Enterprise Edition	Windows Server 2003 x64 Enterprise Edition

**Table 2: Test configurations for the x346, Dual-Core x3650, and Quad-Core x3650**

## Test Objective

The objective of these tests was to compare the maximum number of users that could log in to the test servers before performance degraded to an unacceptable level. Two test scripts—the Knowledge Worker script and the Data Entry Worker script—were used for the tests.

Server capacity was defined as the maximum number of users that could be logged in to the terminal server with acceptable server response times. Server response time (in milliseconds) was measured for a variety of simulated user actions—for example, opening a file in Microsoft Excel, or inserting a file attachment into an e-mail composed in Microsoft Outlook®.

Exceeding the maximum number of users caused server response times to increase, at which point the server being tested became unresponsive. For our tests, an unacceptable server response time was defined as any response time exceeding 1000 milliseconds (one second) for a particular user action.

In addition to the remote worker load tests, power consumption data was collected when the servers were idle, and when they were carrying the maximum number of users that they could service before becoming unresponsive. During the maximum user load test, data was collected from the beginning of the test until 30 minutes after the maximum number of users was reached.

Technical details of the tests can be found in appendixes A–D. Appendix A describes the test scripts, test setup and configuration. Appendix B describes the systems settings. Appendix C describes test parameters. Appendix D describes power measurement tools and collection methods used to obtain power consumption data.

For more information about the Terminal Server kit used for these tests, see:

<http://www.microsoft.com/windowsserver2003/techinfo/overview/tsscaling.mspix>



## Test Results and Observations

The following table summarizes the number of users that each system was able to support for the type of test script used. Microsoft engineers also examined the data and confirmed the results.

System	Knowledge Worker	Data Entry Worker
x346	200 users	450 users
Dual-Core x3650	300 users	750 users
Quad-Core x3650	350 users	1000 users

**Table 3: Maximum number of users Supported on the Knowledge Worker and Data Entry Worker Scripts**

## Processor Usage

Processor usage was monitored during the tests to determine the maximum number of users the server could support before the CPU became unresponsive.

Figures 1-2 illustrate the increase in processor usage for the x3650 systems as the number of users logged in to the system increases.

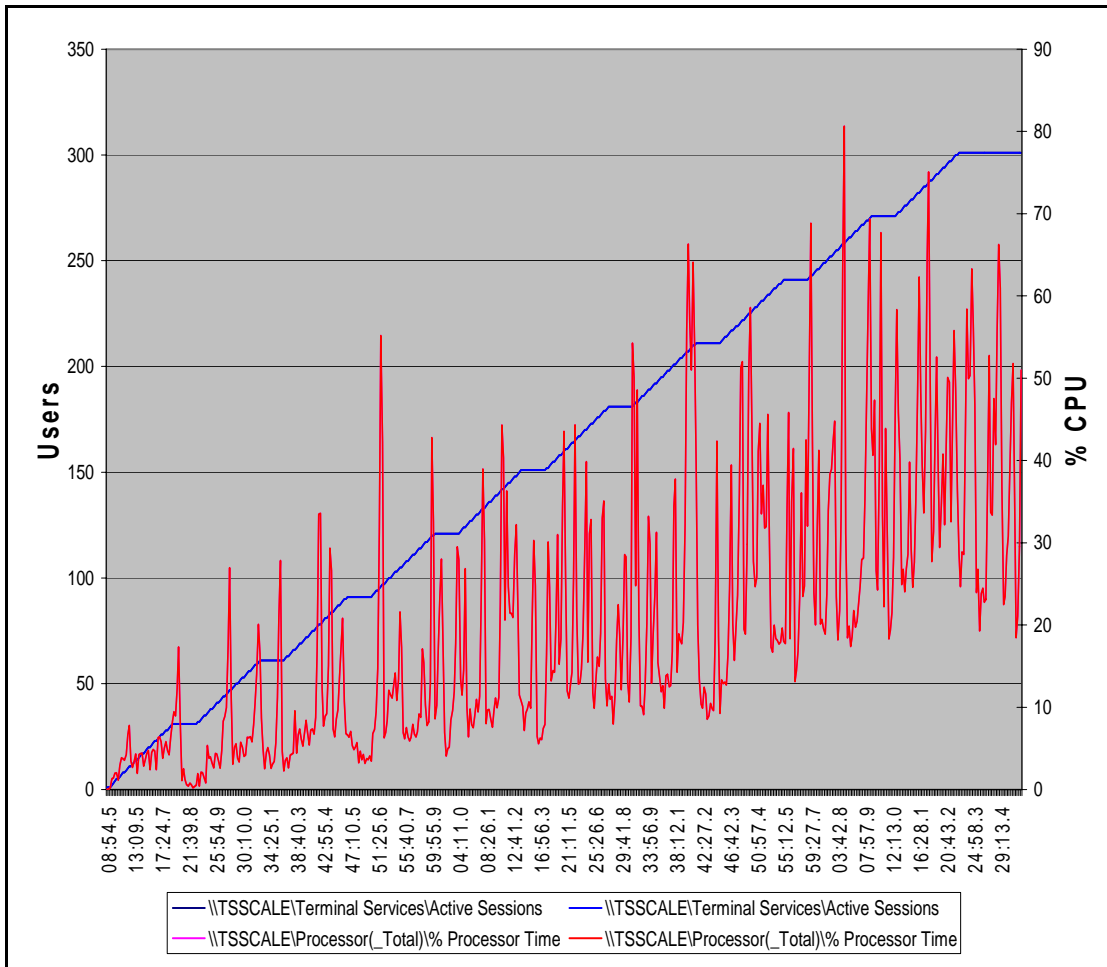


Figure 1: Dual-Core x3650—Active Sessions vs. Total CPU Usage—300 Users

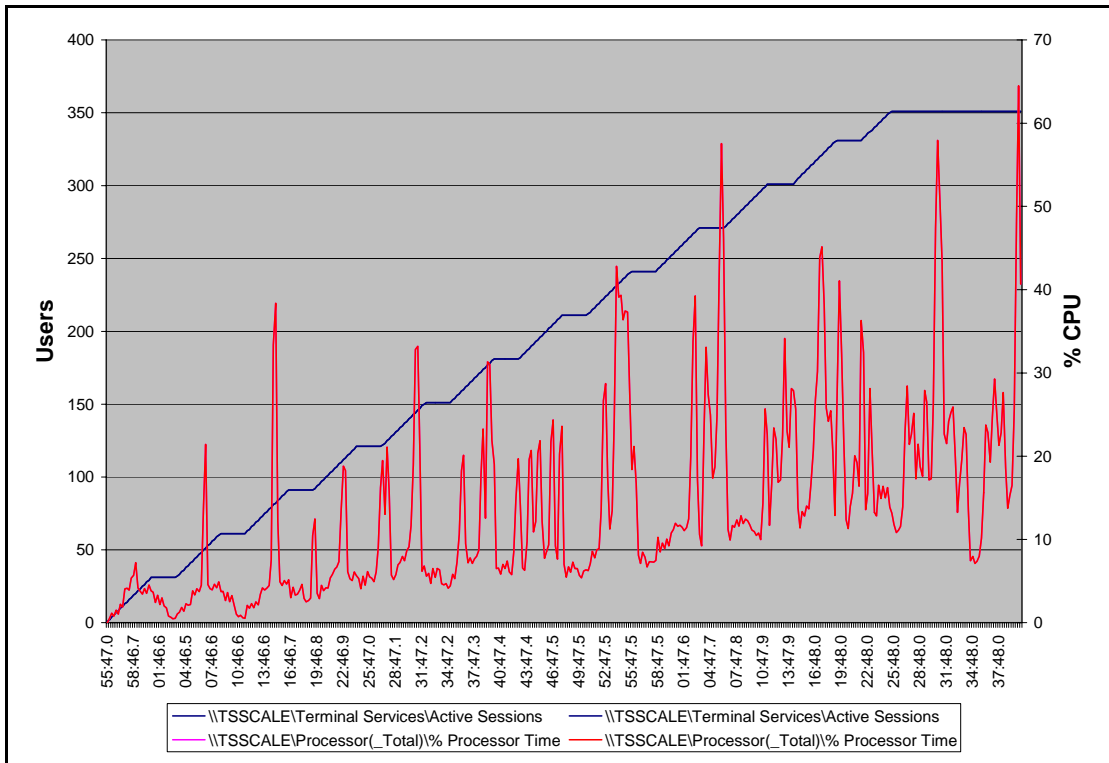
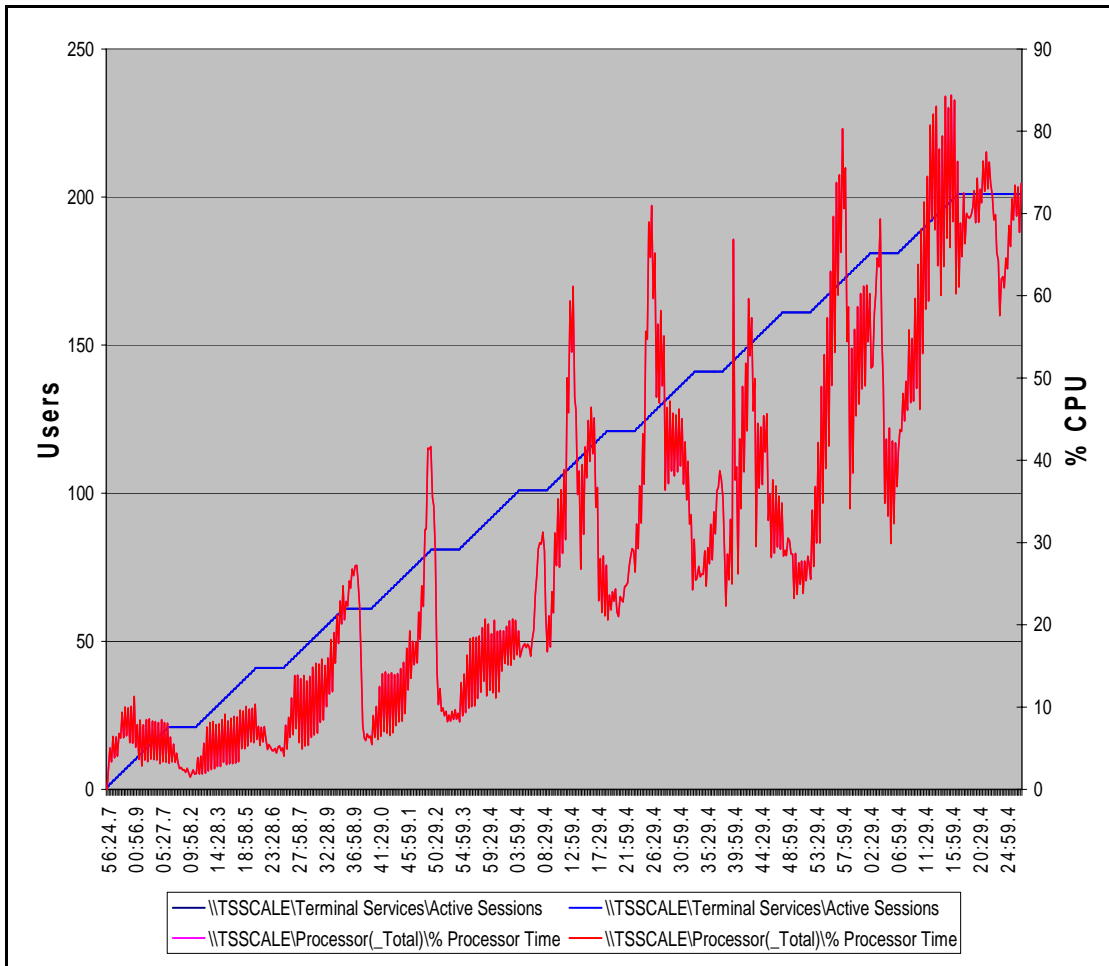


Figure 2: Quad-Core x3650—Active Sessions vs. Total CPU Usage—350 Users

Figure 3 shows the behavior of the x346 processor as the number of users logged in to the system increases.



**Figure 3: x346—Active Sessions vs. Total CPU Usage—200 Users**

As shown in Figures 1 and 2, ample processing power (i.e., CPU cycles) is still available at maximum user loads.

## Response Time

The amount of time (in milliseconds) required for a terminal server to respond to user actions was also measured to identify the point at which a server reached its maximum user load. Figures 4–9 on the following pages illustrate the relationship between server response times and the number of users logged in to the system.

The point immediately preceding an unacceptable increase in response times was considered the maximum number of users that the system can support. Additional tests were also conducted with the maximum number of users loaded to confirm that the response times fell within the acceptable range.

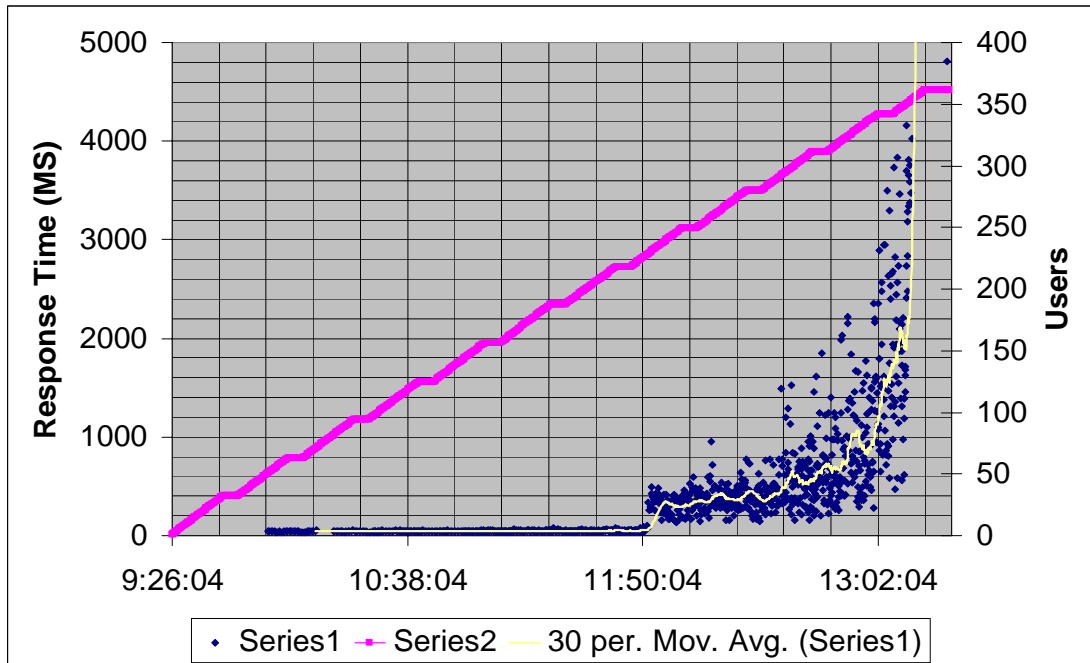
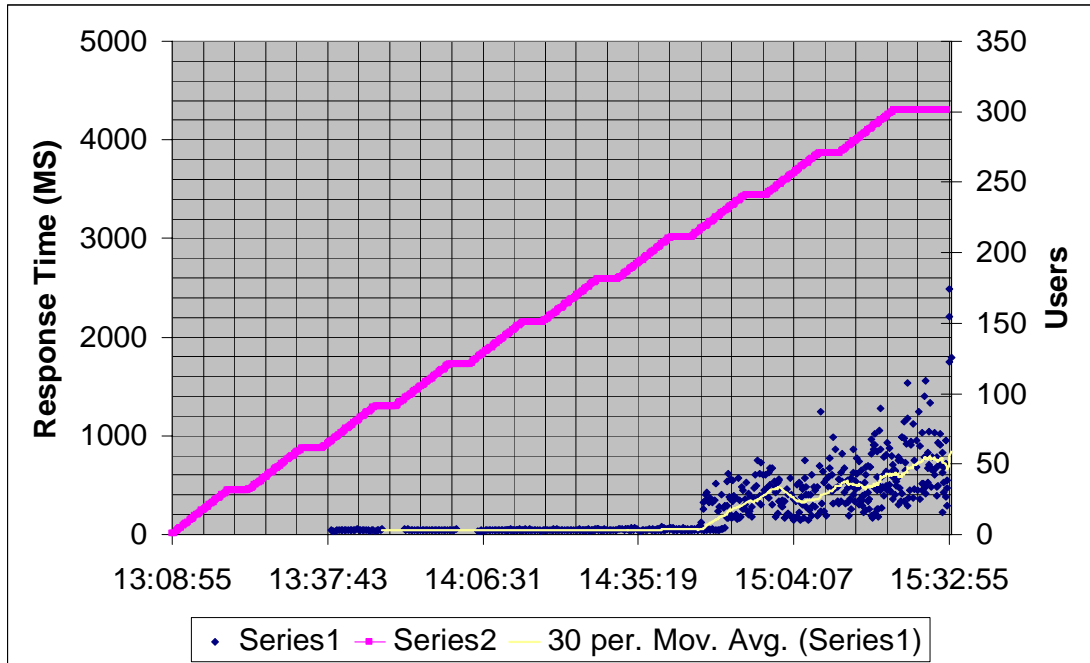


Figure 4: Dual-Core x3650—Response Time—360 Users (Excel Save as Dialog)



**Figure 5: Dual-Core x3650—Response Time—300 Users (Excel Save as Dialog)**

Figure 4 shows that the response times for the Dual-Core x3650 system rose to an unacceptable level after 360 users were logged in to the system. Compare those results with the results illustrated in Figure 8, which show the x346 becoming unresponsive after 250 users are logged in to the system.

Comparing Figure 5 with Figure 9, the data clearly shows that the Dual-Core x3650 system provides a 50% improvement over the x346 with respect to the number of users the server can support.

Comparing Figures 7 and Figure 9, the data clearly shows that the Quad-Core x3650 system provides a 75% improvement over the x346 with respect to the number of users the server can support.

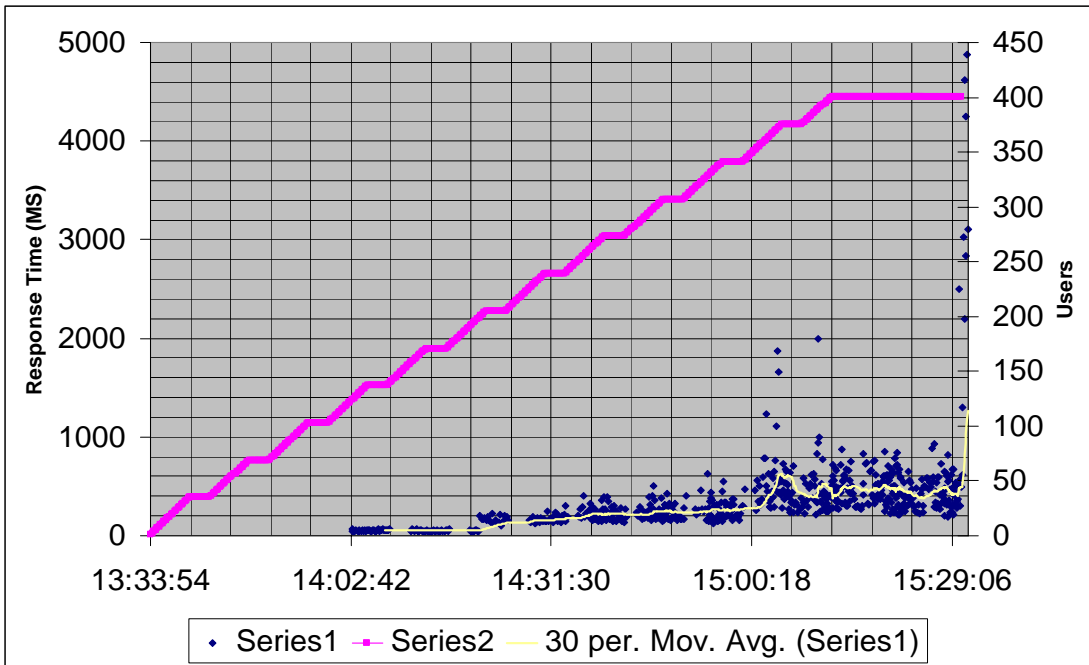


Figure 6: Quad-Core x3650—Response Time—400 Users (Excel Save as Dialog)

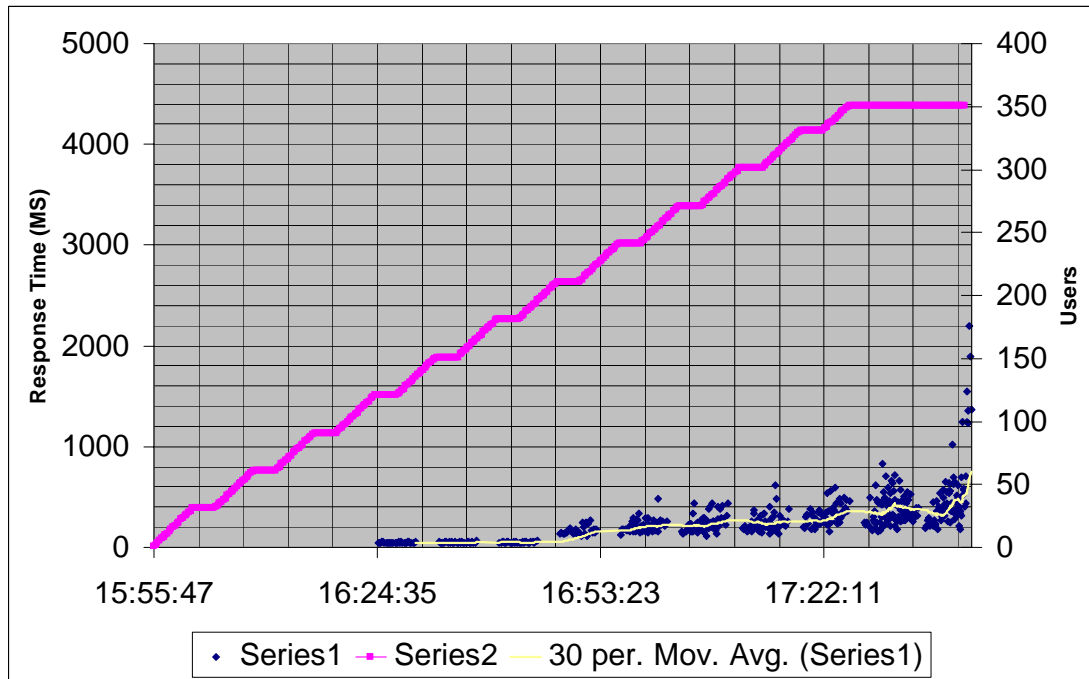


Figure 7: Quad-Core x3650—Response Time—350 Users (Excel Save as Dialog)

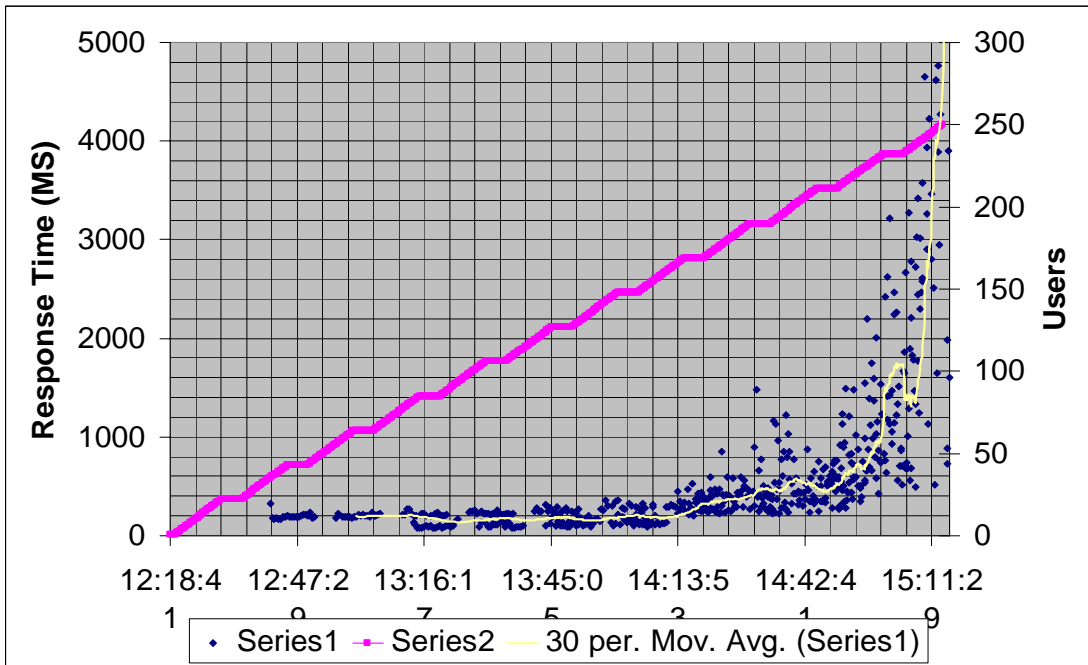


Figure 8: x346—Response Time—250 Users (Word Print Dialog)

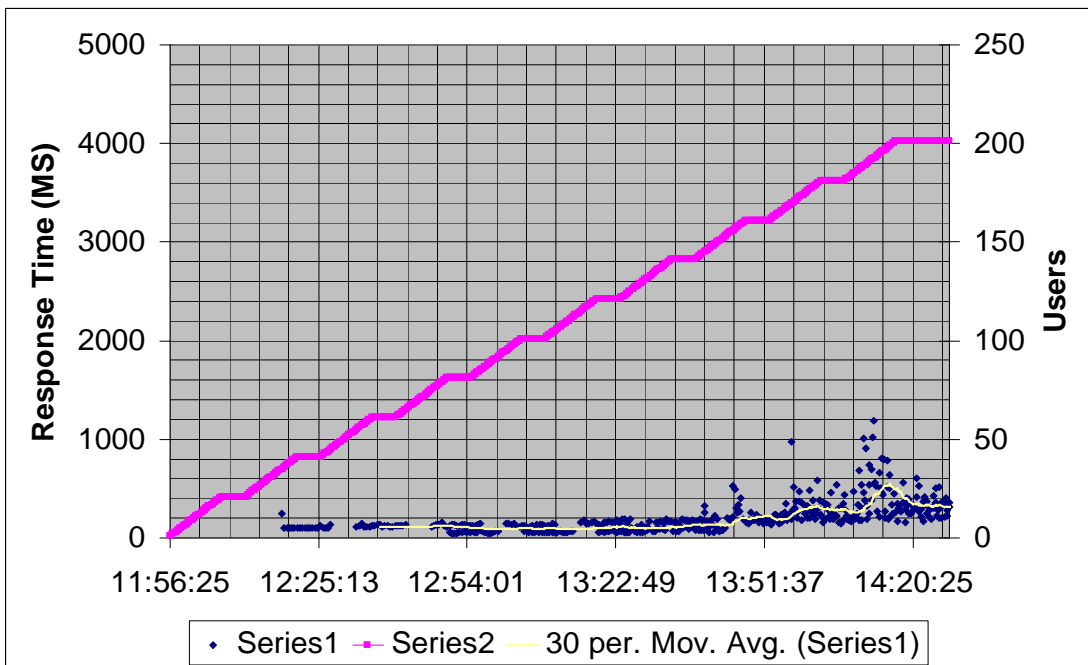


Figure 9: x346—Response Time—200 Users (Word Print Dialog)



## Response Time Results Summary

The data illustrated in Figures 4–9 can be summarized as follows:

- The response times for the Dual-Core x3650 slowed to an unacceptable level after 360 users were logged in to the system. (See Figure 4.)
- The response times for the Quad-Core x3650 started to degrade after 350 users were logged in to the system. (See Figure 6.) The system's physical memory resources are nearly exhausted at this point also. (See Figure 11.)
- The x346 became unresponsive after 250 users were logged in to the system. (See Figure 8.)
- The Dual-Core x3650 provides a 50% improvement over the x346 with respect to the number of users the server can support.
- The Quad-Core x3650 provides a 75% improvement over the x346 with respect to the number of users the server can support.

## Memory Tests

Memory usage was measured during the tests. Pages Input/sec is a measurement of the number of memory “pages” read from the hard disk when the requested data is no longer stored in the server's physical (RAM) memory. This counter also includes pages read from disk when the server's cache memory accesses data for applications.

Because reading data from the hard disk is slower than reading data from physical memory, an increase in the number of Pages Input/sec indicates that the server is becoming less responsive to the users logged in to the server.

The x346 system experienced severe spikes in the Pages Input/sec metric when 230 users logged in to the server. For the x3650 systems, similar spikes were experienced when 340 users were logged in to the Dual-Core server and when 365 users were logged in to the Quad-Core server.

In addition, the x346 system's total CPU usage rose to 100% when 230 users were logged in to the system. The Dual-Core x3650 system's total CPU usage rose to 90+% when 340 users were logged in to the system.

The spikes in the Pages Input/sec metric and the greatly increased processor usage caused a significant increase in response times—and, therefore, significantly reduced performance—for both servers.

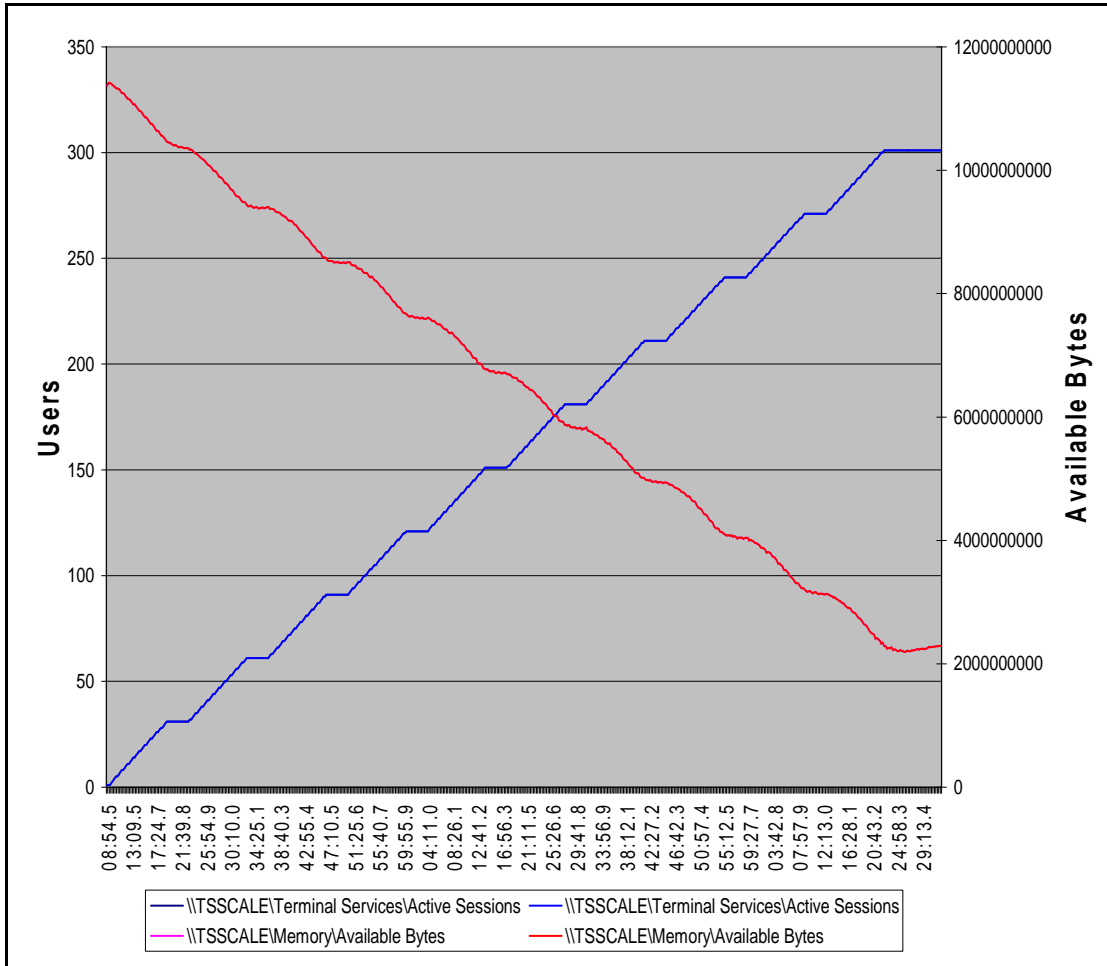


Figure 10: Dual-Core x3650—Active Sessions vs. Available Memory—300 Users

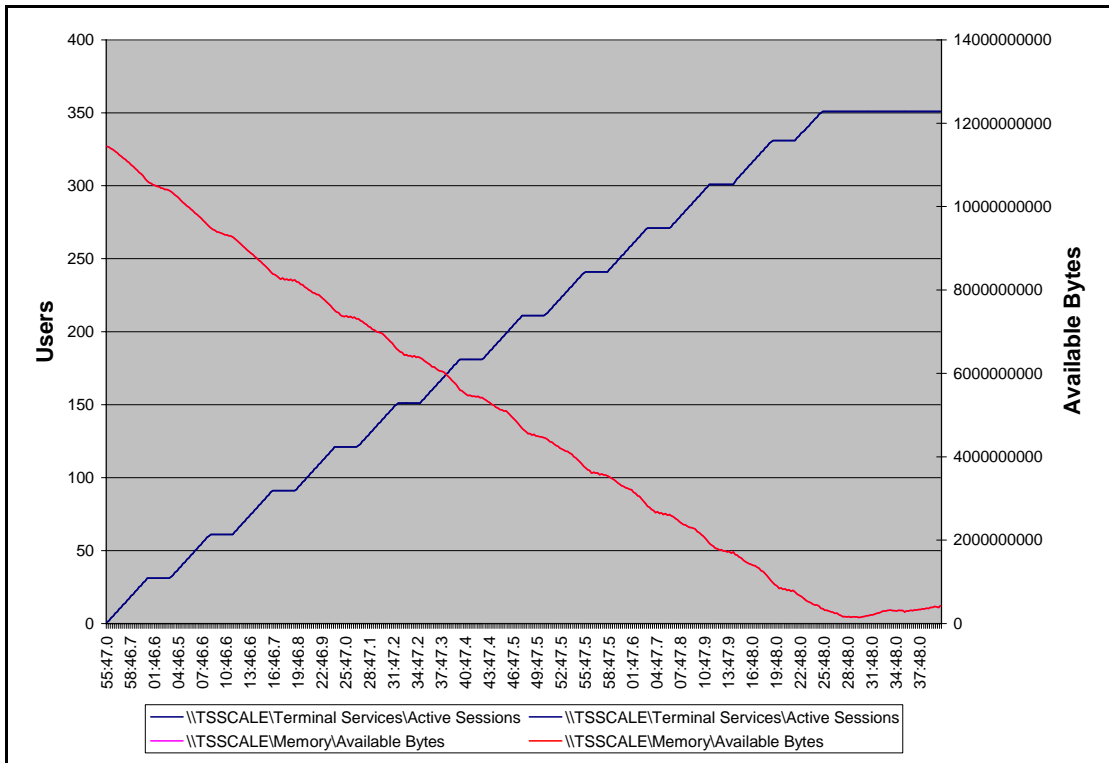


Figure 11: Quad-Core x3650—Active Sessions vs. Available Memory—350 Users

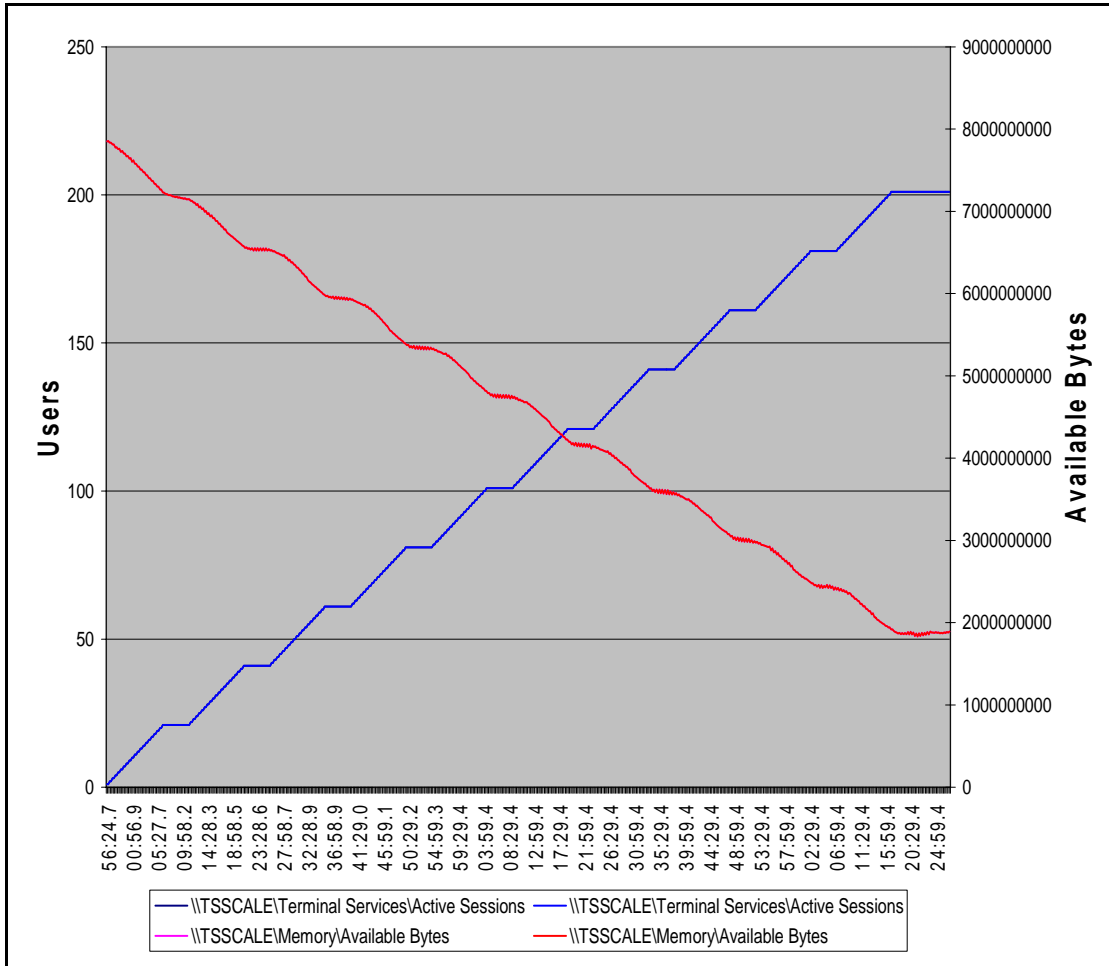


Figure 12: x346—Active Sessions vs. Available Memory—200 Users

## Memory Usage Results Summary

- The Dual-Core x3650 had ample physical memory available with 300 Knowledge Script users logged in at the end of the test. (See Figure 10.)
- The Quad-Core x3650 was close to running out of physical memory after 350 Knowledge Script users were logged into it. The Windows Virtual Memory Manager subsystem can reclaim some physical memory from other processes and allow additional users to log on. However, system performance was degraded at this point. See Figure 11.)
- The x346 still had ample physical memory available with 200 Knowledge Script users logged in at the end of the test. (See Figure 12.)

## Power Consumption Test

The following table illustrates the maximum amount of power in watts used by each system when it was idle, and when it was running with the maximum number of users connected to it with the Knowledge Worker script.

System	Idle	At Maximum Load
x346	353 Watts	481 Watts
Dual-Core x3650	338 Watts	415 Watts
Quad-Core x3650	380 Watts	460 Watts

**Table 4: Maximum Power Consumption with Maximum Users Logged In**

For more information about how power consumption data was collected, see **Appendix D: Power Consumption Test—Technical Details**.

## Conclusion

The manageability, serviceability and flexibility of an enterprise network and its systems are critical to the success of individual employees and the corporate enterprise. Centralizing software and systems management with Microsoft's Terminal Services to empower a remote workforce can reduce a company's overhead costs while increasing the speed, flexibility and efficiency at which the business can operate. Fast, powerful, scalable servers and software are critical to achieving a powerful remote workforce.

As shown by our tests, the x3650, equipped with either two Dual-Core or two Quad-Core Intel Processors, provides a 50–75% capacity and performance improvement over the IBM eServer x346.

In addition, the x3650 fits into the same 2U rack space used by the x346, making the IBM System x3650 server an **ideal replacement for the IBM eServer x346**.

The Dual-Core x3650 and Quad-Core x3650 power and performance characteristics can be summarized as follows:

- A single IBM System x3650 server, equipped with two **Dual-Core** Intel Xeon Processors 5160 and 12GB of memory, is ideally suited to support a medium-sized business with **up to 300 remote users**.
- The x3650 running two Dual-Core processors uses **16% less power** than an x346 equipped with a less powerful, single-core processor. In a typical 24/7 server environment, this can mean saving thousands of kilowatt-hours per year, per server.
- The x3650 running two Quad-Core processors uses about **4% less power** than the x346 while serving **up to 75% more capacity**.
- A single IBM System x3650 server, equipped with two **Quad-Core** Intel Xeon Processors X5355 and 12GB of memory, is ideally suited to support a medium-sized business with **up to 350 remote users**.

## **Additional References**

Terminal Services Scaling and Performance on x64-Based Versions of Windows Server® 2003:

<http://www.microsoft.com/downloads/details.aspx?familyid=9B1A8518-D693-4BBB-9AF8-B91BBC0D2D55&displaylang=en>

This paper used materials from the IBM White Paper, "IBM System x3950 and Microsoft Windows Terminal Server Performance Analysis," by Vinay Kulkarni, Conor Flynn, and Susan Goodwin.

<http://www-03.ibm.com/servers/eserver/xseries/benchmarks/index.html>

## Appendix A: Test Environment—Technical Specifications

Figure 13 illustrates the test environment used to run the Terminal Server benchmark and is described below:

- Twelve client machines were used to simulate multiple users. Each client was an IBM eServer x336 with up to 6GB of memory.
- The Domain Controller was an IBM eServer x306 with 2.5GB of memory.
- The Exchange server was an IBM eServer x365 with 8GB of memory.
- The two Terminal Server test machines were an IBM System x3650 with 12GB of memory and an IBM eServer x346 with 8GB of memory.

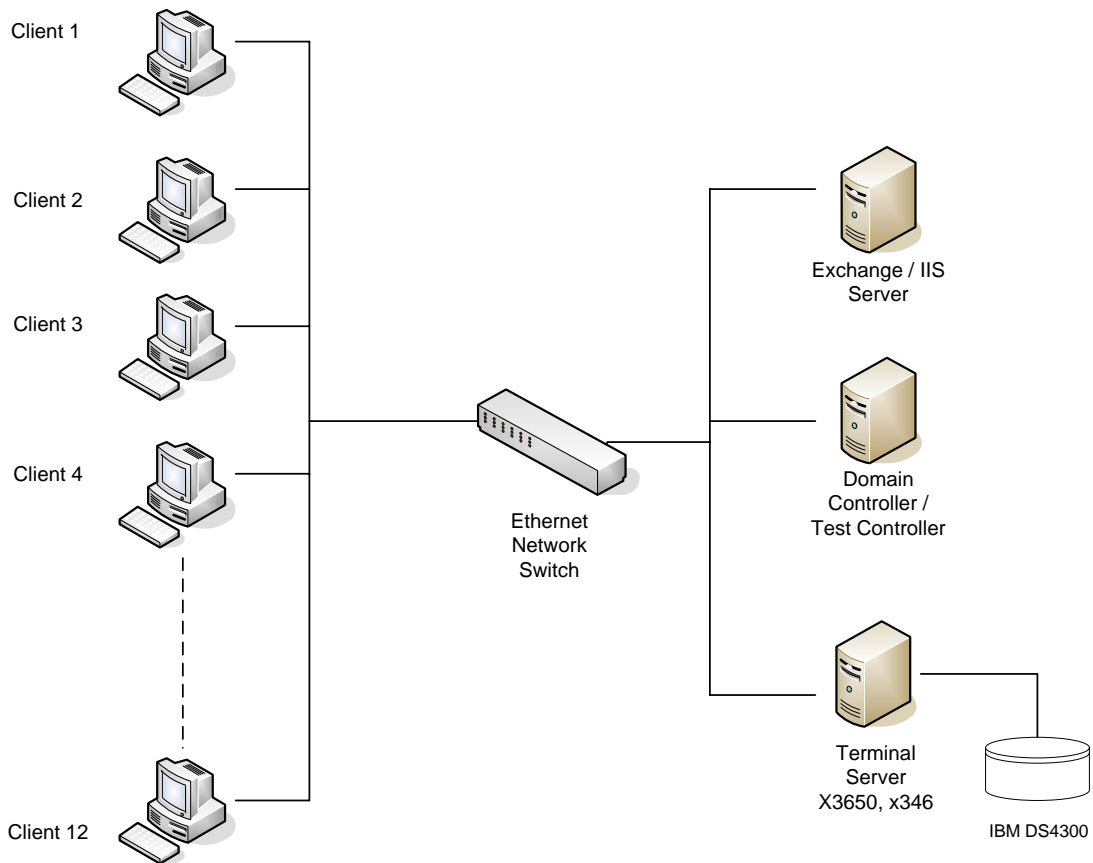


Figure 13: Test Environment



## Domain Controller

The domain controller was an IBM eServer x306 running Microsoft Windows Server 2003 Enterprise Edition with Service Pack 1. DHCP, WINS and DNS services were enabled on this server. It was also the test controller that managed the client systems used in the test.

## Exchange Server

The Exchange server was an IBM eServer x365 running Microsoft Windows Server 2003 Enterprise Edition with Service Pack 1 and Microsoft Exchange Server 2003 with Service Pack 1. This system also functioned as the Web server.

## Client Systems

Each client system was an IBM eServer x336 machine running Microsoft Windows Server 2003 Enterprise Edition. For the client machines with less than 3GB of memory, up to 50 user sessions were run. For the client machines with 6GB of memory, up to 100 user sessions were run.

## Storage System

The IBM TotalStorage® DS4300 storage expansion unit contained fourteen 18.2GB, 15K RPM SCSI disk drives. The DS4300 was connected to the Terminal Server with a QLogic QLA2350 HBA. Four 16GB LUNs were created and used as swap files. A single 164GB LUN was created to store the user profiles.

## Test Tools and Software

Microsoft Terminal Services Scalability Planning Tools were used to run the tests. These tools are part of the Windows Server 2003 Resource Kit and consist of the following executable files:

- **Robosrv.exe:** Runs on the test controller (the domain controller) and controls the rate at which Terminal Server sessions log in to the Terminal Server. It also runs a script to load the Terminal Server on each client.
- **Robocli.exe:** Runs on each client system and connects to the test controller to run the scripts ordered by Robosrv.exe.
- **Qidle.exe:** Runs on the Terminal Server machine. It monitors the connections during the test and keeps a log of any Terminal Server sessions that have been idle for more than a specified amount of time.
- **Tbscript.exe:** A script interpreter that drives the client-side load simulation. It executes Visual Basic scripts and supports specific extensions for controlling the Terminal Server client.

## **Appendix B: Test Parameters**

Each client was connected to the Terminal Server using the Windows Remote Desktop client (mstc.exe). These sessions on the Terminal Server were run via the Remote Desktop (RDP) protocol.

### **Test Script Description**

The Knowledge Worker script used for this test was developed by Microsoft and is based on Gartner Group specifications. This script switches between Microsoft Word, Microsoft Excel, Microsoft Outlook, and Internet Explorer® to send and receive e-mail, edit office documents, and access Web pages. The script also records the response time for each of the simulated user actions.

The Data Entry Worker script used for this test was written by Microsoft. It simulates data entry workers who input data (e.g., transcription, typing, order entry) into a computer system. The Data Entry Worker script was tested in a dedicated mode, in this case, running Microsoft Excel exclusively.

More information about Microsoft Terminal Services Scalability Planning Tools is available at:

<http://www.microsoft.com/windowsserver2003/techinfo/overview/tsscaling.mspx>

## **Terminal Server Configuration**

- Microsoft Windows Server 2003 x64 Enterprise Edition (build 3790) and Microsoft Office 2003 with Service Pack 1 were both installed on the Terminal Server.
- An IBM DS4300 storage expansion unit with fourteen 18.2GB SCSI disk drives was connected to the Terminal Server through a QLogic QLA2350 HBA.
- Four 16GB LUNs were created and used as swap files. A single 164GB LUN was created to store the user profiles.
- The x3650 system was configured to use four network printers. (See the Exchange Server Configuration section for additional information.)
- The x346 system was configured to use an HP LaserJet 6P printer installed on the system's NULL port as a local printer.

Adjustments recommended by the Microsoft Terminal Services Scalability Planning Tools document were also applied to the Terminal Server environment.

## **Exchange Server Configuration**

- Microsoft Exchange Server 2003 with Service Pack 1 was installed on an IBM eServer x365 system.
- Microsoft Internet Information Services 6.0 was installed on the Exchange Server.
- Four HP LaserJet 6P printers were installed on the NULL port of the Exchange Server machine and shared as HPLaserJ1, HPLaserJ2, HPLaserJ3 and HPLaserJ4. Each printer was configured as a network printer on the x3650 Terminal Server.
- User connections were added in a round-robin manner to the Terminal Server to distribute print jobs evenly among the four printers.

## **Client Configuration**

- Each client machine was running Microsoft Windows Server 2003 Enterprise Edition with Service Pack 1.
- The robocli.exe tool was copied from the test control server (domain controller) for communication with the Roboserv.exe program.

## Appendix C: System Settings for the x3650 and x346

Table 5 summarizes the BIOS settings used for the x3650 and the x346 in our tests.

x3650 BIOS Settings	x346 BIOS Settings
<ul style="list-style-type: none"><li>• Hyper-Threading Enabled</li><li>• System Cache Type Write Back</li><li>• Prefetch Queue Enabled</li><li>• Flat Memory Configuration</li></ul>	<ul style="list-style-type: none"><li>• Hyper-Threading Enabled</li><li>• System Cache Type Write Back</li><li>• Prefetch Queue Enabled</li><li>• Execute Disable Bit Disabled</li></ul>

**Table 5: x3650 and x346 BIOS settings summary**

### Drivers Used

The latest driver for the QLogic HBA QLA2350 was downloaded from [www.qlogic.com](http://www.qlogic.com).

### Operating System Performance Settings

The following adjustments were made under the System Properties for each system:

- Adjust for Best Performance was selected for Visual Effects.
- Processor Scheduling was optimized for Programs.
- Memory Usage was optimized for System Cache.
- Virtual Memory was changed to add paging files on four 16GB Logical Volumes that were created on the DS4300 external storage arrays.

Memory usage was optimized for system cache by modifying the registry entry LargeSystemCache at HKLM\SYSTEM\CurrentControlSet\Control\Session Manager\Memory Management and setting it to 1.

## **Appendix D: Power Consumption Test—Technical Details**

### **Measurement Tools**

A Watts Up? Pro power analyzer manufactured by EED, Inc., was used to collect data for both the x3650 and the x346 systems. Each server was connected to a power strip and tested separately for power consumption. Both power supplies for the system being tested were plugged into the power strip. The power strip was plugged into the Watts Up? Pro for the duration of the tests.

The Watts up? Pro power analyzer includes memory storage and the ability to download the data to a PC for analysis. Starting with a sampling rate resolution of one second, 1023 data points are stored in memory. The sample rate resolution increases over time (sample rate equals total time divided by 1023), so data are accurately recorded independently of the test duration. A serial cable and software program allows the data to be quickly downloaded to a PC for creating usage charts. A Data Table is included in the software, in addition to Charting and Payback Analysis. The data can also be exported in a comma-delimited format to popular spreadsheet programs for further analysis.

## Data Collection

Power consumption data was collected for each system, from the beginning of the test until 30 minutes after the maximum number of users had logged in. Users are simulated by the Knowledge Worker script. Power data was also collected for both systems when they were idle. Power data was collected for 30 minutes.

- For the Dual-Core x3650 system, the maximum number of users logged in to the server was 300. The total time of data collection was approximately 4 hours.
- For the Quad-Core x3650 system, the maximum number of users logged in to the server was 350. The total time of data collection was approximately 4 hours.
- For the x346 system, the maximum number of users logged in to the system was 200. The total time of data collection was approximately 3 hours.



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