CITRIX METAFRAME XPe
VMware ESX Server 1.5.2
Capacity and Scalability
of the
IBM @server xSeries x440

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Introduction

This document presents the results of performance tests done on the IBM @server x440 with VMware ESX Server 1.5.2 and Citrix Metaframe XPe Features Release 2 on Microsoft Windows 2000 Server.

On the server, eight VMware Virtual Machines were created, each hosting one instance of Microsoft Windows 2000 Server and Citrix Metaframe XPe.

The objectives of the tests were to evaluate the system performance and scalability.

To do so, injection servers were used to simulate user connections and workload, on each of the VMware Virtual Machines. The following elements have been measured:
➢ The time taken to run a reference script while the number of concurrent active users was increasing.
➢ The percentage of "*Processor Time*".
➢ The maximum number of active users connected on the server.

For all the tests, Virtual machine have been affected to server processors as follow:

CPU0	CPU1	CPU2	CPU3	CPU4	CPU5	CPU6	CPU7
VM1	VM2	VM3	VM4	VM5	VM6	VM7	VM8

Testing tools and methodology overview

The tests have been designed to reflect the activity generated by typical users of Citrix Metaframe XPe in a production environment. The test procedures have been performed using Microsoft Office 2000 (Microsoft Excel, Microsoft Access, Microsoft PowerPoint) on a Microsoft Windows 2000 platform with Metaframe XPe Features Release 2 – SP2 installed in Virtual Machines created with VMware ESX Server 1.5.2.

In order to reproduce typical user activity, we used the *Citrix Server Test Kit* software (referenced in this document as CSTK) to generate sequential user connections on each Citrix server.
The CSTK automatically launches ICA connections. Once opened, this software starts a script coded in "win batch". Then, this script starts software from the Microsoft Office 2000 product suite and simulates user interaction.

Four types of users are defined:

CPU Intensive User. This user scenario is used for simple data entry. The activity generated by this type of user is defined in the CSTK as a **normal user**. We can read the following definition in the CSTK guide: "*Normal user application scripts run one application at a time; for example, the script may write and save a letter using Microsoft Word.*" In this test, the "CPU Intensive User" scenario uses first Microsoft PowerPoint then Microsoft Word. It is based on the pre-defined scripts of the CSTK Version 2.1.

Ram/Disk Intensive User. This type of user scripts run two or more applications simultaneously and typically uses more system resources than normal users. As defined in the CSTK documentation: "(…) *for example, a power user script may open Microsoft Word and Microsoft Excel at the same time and merge an address book in Excel with a letter in Word.*" It is based on the pre-defined scripts of the *Citrix Server Test Kit* (CSTK) Version 2.1 using Microsoft Access 2000 and Microsoft Excel 2000.

Reference User. A "Reference User" was created to reflect other user activity. Depending on the test to run, it can be either a "CPU Intensive" or "Ram/Disk Intensive" user. The "Reference User" script time can be measured while the number of connections increases. The methodology used to measure the time spent to run the "Reference User" scripts is described later in this document.

Connected User. The "Connected User" scenario was intended to identify the maximum number of concurrent users on a server without any additional activity generated in the ICA session.

User Type	CSTK User Group Type	Scripts run
Connected User	*No script run*	*No script run*
CPU Intensive User	Normal User	MS PowerPoint 2000/ MS Word 2000
Ram - Disk Intensive User	Power User	MS Access 2000 / MS Excel 2000
Reference User	*Normal or Power*	*One of above*

Results Summary
Maximum number of "Active" and "Connected" Users

Max. Number of "Active Users"

An "Active User" is defined as a user that has an opened ICA session on the Metaframe server and generates workload on it. The table below summarizes the maximum number of users who were connected to the Metaframe servers and the associated number of sessions with failed scripts. The number of "Active Users" is the result of the subtraction of those two values.

Important Note:
When the scripts launched by the Citrix Server Test Kit fail, the associated ICA sessions were still active. No error was reported at the server, hardware, operating system or software level.

All the Virtual Machines were running simultaneously during the test.

User type	# Sessions opened	# Sessions with Script halted	#Active Users
Ram/Disk Intensive	307	1	**306**
CPU Intensive	284	9	**275**

For complete results, refer to: "Test 2 - Ram/Disk Intensive users - Sequential user connections" and "Test 4 - CPU Intensive users - Sequential user connections" in the chapter "Detailed Results".

Max. Number of "Connected Users"

A "connected user" generates no user activity and has only an ICA session opened on the Citrix Metaframe Server. All the Virtual Machines were running simultaneously during the test.

VM1	VM2	VM3	VM4	VM5	VM6	VM7	VM8
161	159	160	159	169	169	167	168
Total number of connected users on the IBM @server x440							**1312**

Important Note:
No error was reported at the server, hardware, operating system or software level.

User Response Time

User Response Time Variations – One VM running

The following chart shows the response time variation (percentage) when the number of active users is increasing in **one** Virtual Machine.

Because VMware uses CPU 0 extensively, the test has been done on CPU 7. The other Virtual Machines were not started.

The test was stopped when:
➢ Restarting failed scripts systematically causes failures in other ICA sessions.

For complete results, refer to: « Test1 - Ram/Disk Intensive user – One VM Running » and « Test 3 - CPU Intensive users – One VM Running" in the chapter "Detailed Results".
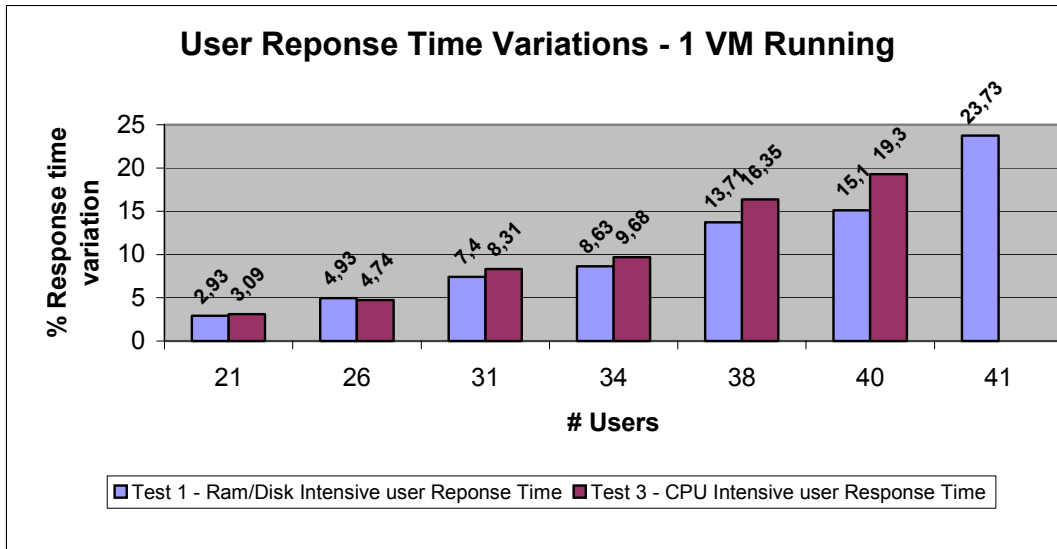
User Average Response Time Variations – Eight VMs running

The following chart shows the response time variation (percentage) when the number of active users is increasing in **all** the Virtual Machines.

The test was stopped when one of the conditions below occurred:
➢ The %Processor Time was near 90% for CPU0 (VM1).
➢ Restarting failed scripts systematically causes failures in other ICA sessions.

Important Note
When the scripts launched by the Citrix Server Test Kit end with error, the associated ICA sessions had no error message and were still active without any error message.
No error was noted at the server, hardware, operating system and software level.
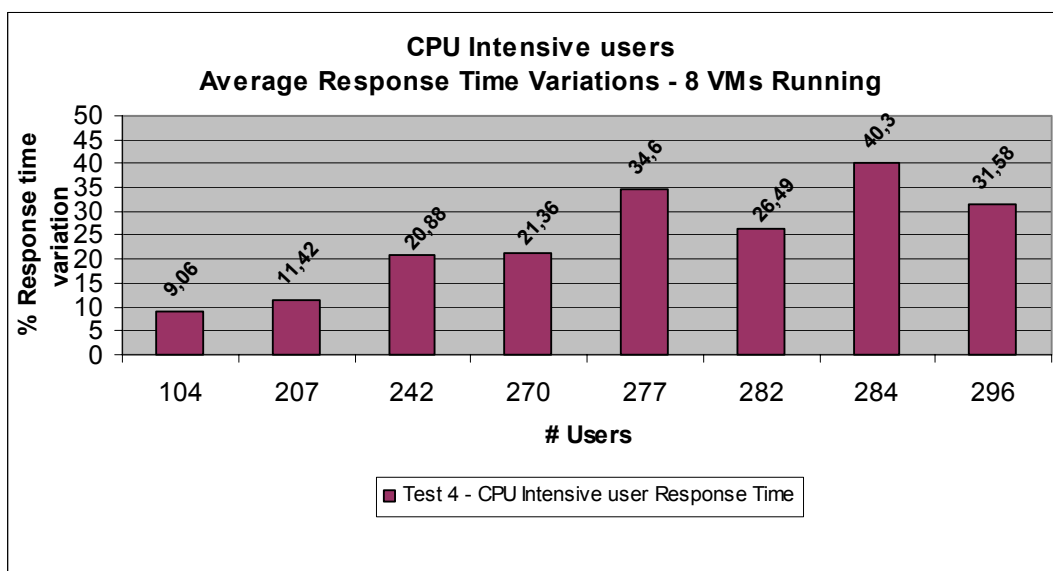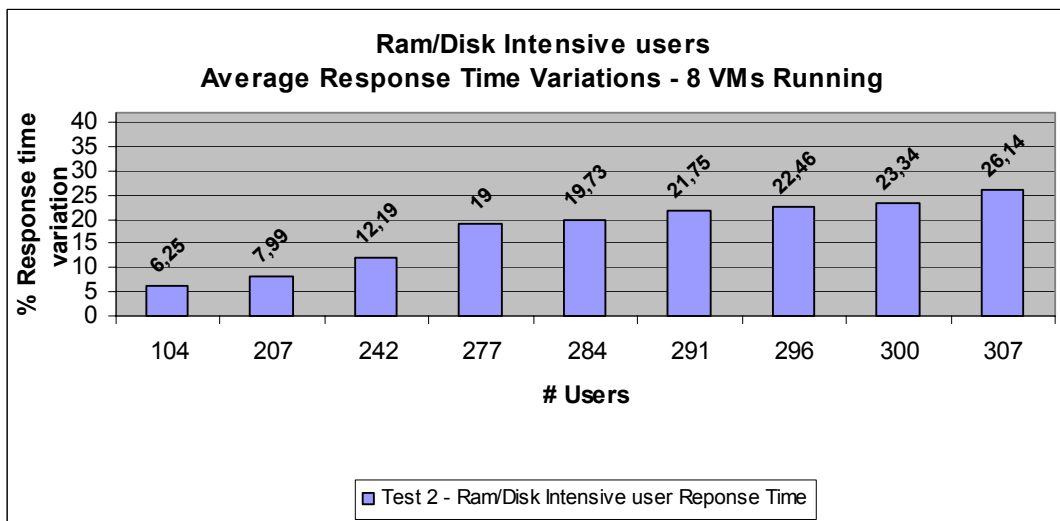
For complete results, refer to: "Test 2 - Ram/Disk Intensive users - Sequential user connections" and "Test 4 - CPU Intensive users - Sequential users connections" in the chapter "Detailed Results".

Processor Utilization

While the number of users increased and the "Reference User" response time was regularly measured on all the VMs, the percentage of Processor Time was recorded every minute. The resulting table was composed by more than 800 values per processor. In order to better understand the effect of active users o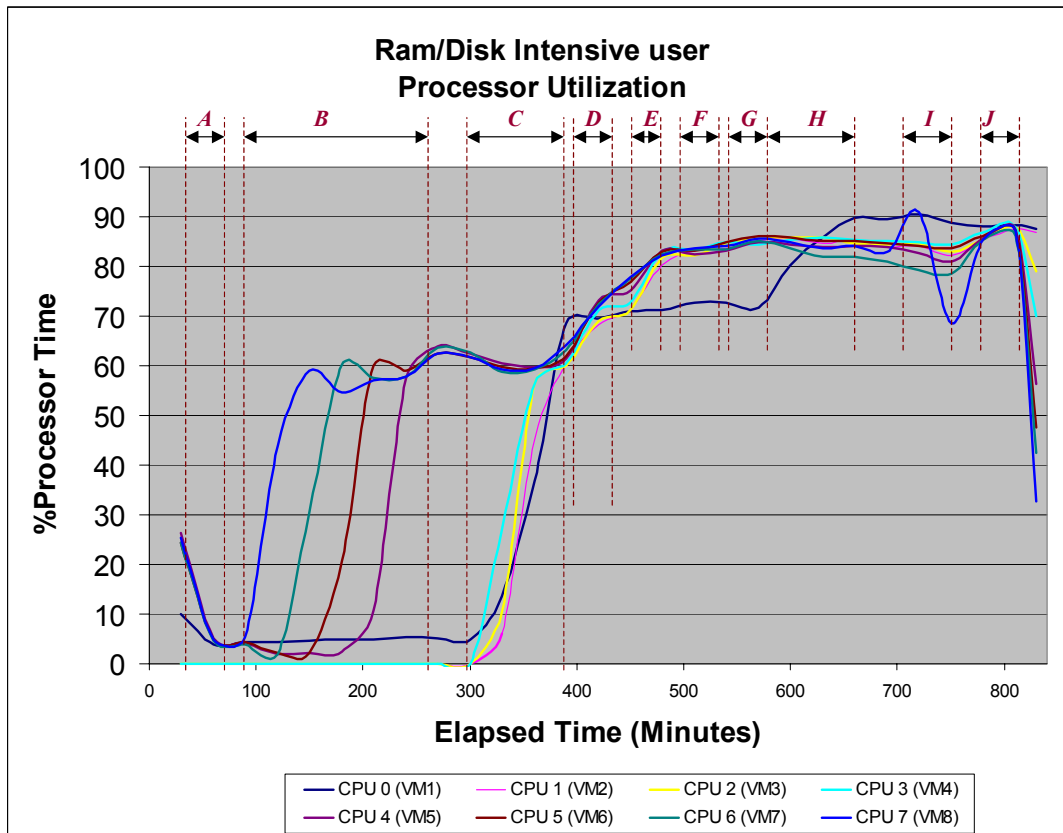n each processor, the recording values were aggregated by range of 30 minutes. The "Test 2" and "Test 4" charts are based on the aggregated values.

Test 2 - "Ram/Disk Intensive user" Server Processor Utilization

This chart has to be analyzed in association with the complete Test 2 table ("*Test 2 – RAM/DISK Intensive Users - Sequential users connections*"- chapter "*Detailed Results*").
The table includes letters used as an indicator in the graph above so that the benchmark activity done at that time on the server can easily be located.

Comments

Three plateaus were noted:

➤ **[B & C]:** The first one is at around **60% of Processor Time** for a total of **207 users** (26 users per Virtual Machine numbered 2 to 8 and 25 users on VM1).

➤ **[D]:** The second one is between **70-75% of Processor Time** and represents an average of **242 users**.

➤ **[F & G]:** The last one is located between **80 and 90 % of Processor Time** and represents an average of **284 to 291 users**. The processor resources utilization is well balanced and the whole instances of processors grow smoothly until 125 users. At this stage, there is 25 users in VM1 (using CPU 0) and is 36/37 on each of the other VMs.

During **[H & I]:** The number of users on VM1 (CPU 0) was increased. This has generated 90 % of Processor Time for CPU 0 which is the level at which the other Virtual Machines have a failing scripts.

It was noticed that an overload of CPU 0 impacts all the Virtual Machines behavior. An overload of another CPU impacts only the associated Virtual Machine.

Test 4 - "CPU Intensive user" - Server Processor Utilization
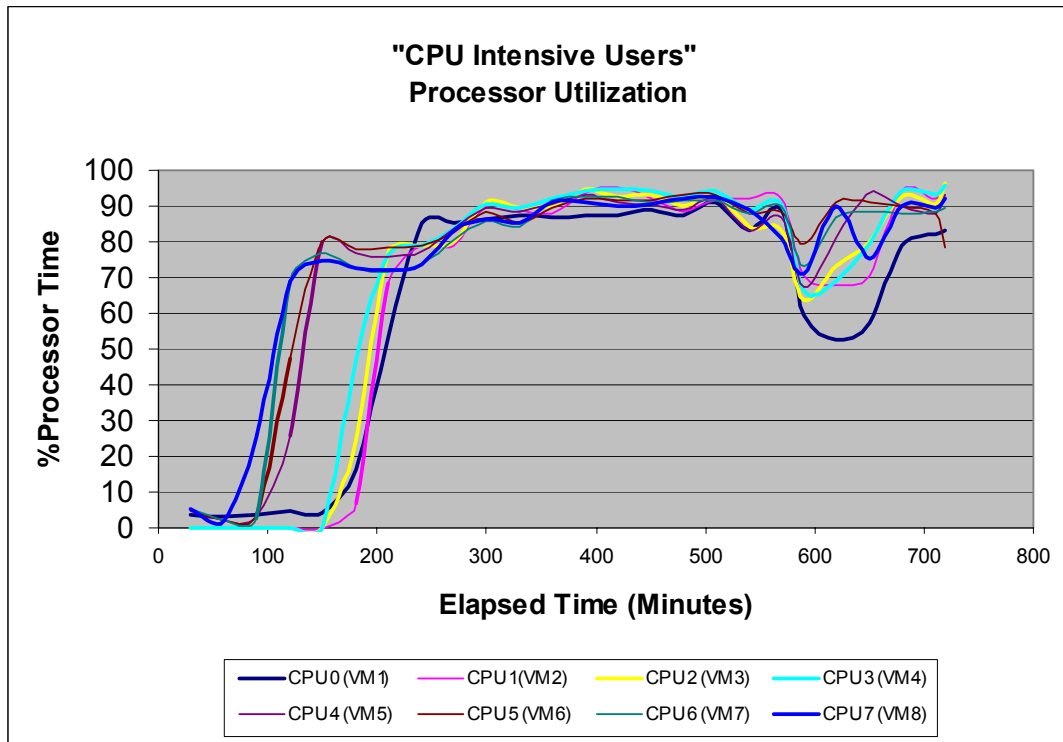
The table *"Detailed Results" / "Test 4 - CPU Intensive Users - Sequential users connections"* shows the benchmark activity done at that time.

<u>**Comments**</u>

This graph reflects a quite similar Processor Utilization to the previous one with only two plateaus. There is an earlier jump to a Percentage of Processor Time at around **90%.**

The first plateau is located between **78%-80 % of Processor Time** and represents a total of **207 users** (26 on VM 2 to VM 8 and 25 on VM1).
The average **% Response Time** of the "Reference Users" scripts processed in VM 2 to VM 8 is **11,42%.**

After this stage, the **% Processor Time** increases up to **88-92%.** The average response time of all the "Reference Users" increased up to **20,88%** for a total number of **242 users** (31 users on VMs 2 to 8 and 25 users on VM1).

Test 5 - "Connected Users" Server Processor Utilization

The following graph shows how ICA connections use the processor. No scripts were run. Using the Citrix Server Test Kit, ICA connections were started regularly from the injection servers (each ICA connection opens a Microsoft desktop windows on the server).

"Connected Users" - Processor Utilization
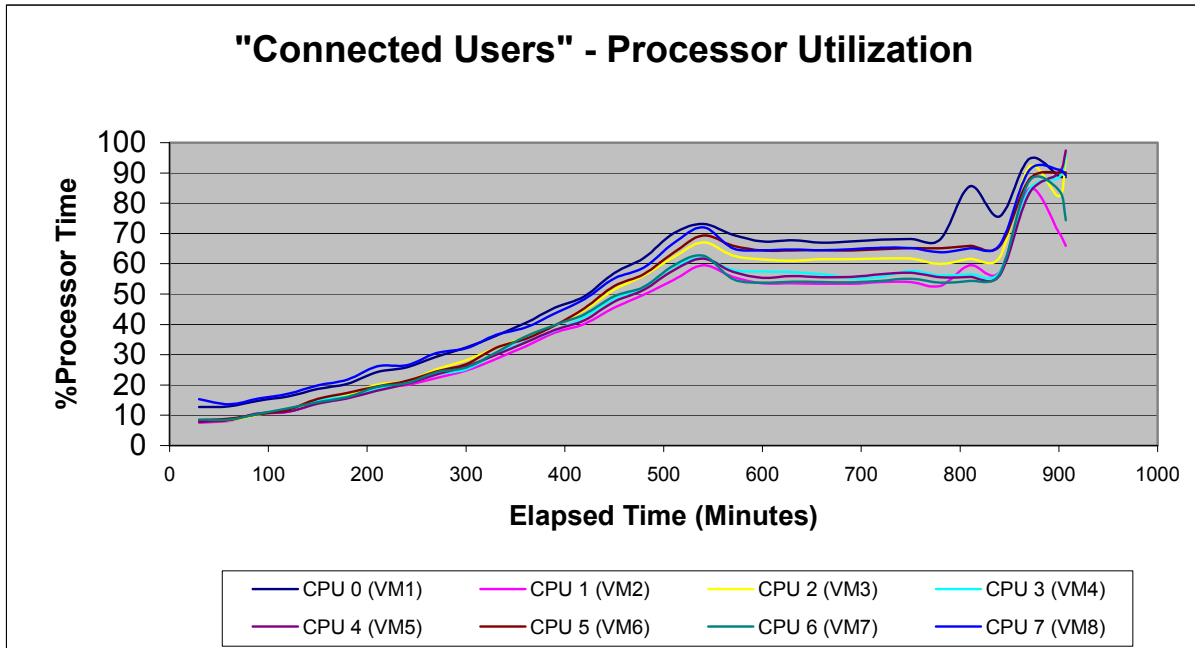
The test has been stopped when one of the conditions below occurred:
➢ The %Processor Time was near 90% for CPU0 (VM1).
➢ The Login Time was greater than one minute.

Important Note
No error was reported at the server, hardware, operating system and software level.

Detailed Results

Test 1 - Ram/Disk Intensive users - One VM running using CPU 7

	# Total of "Ram/Disk Intensive" users in VM8							
VM8 (CPU 7)	1	21	26	31	34	38	40	41
	Reference "Ram/Disk Intensive" user Response Time in seconds							
VM8 (CPU 7)	649	668	681	697	705	738	747	803
#Errors in scripts	0	0	0	0	0	0	2	5
% Response time variation	**0**	**2,93**	**4,93**	**7,40**	**8,63**	**13,71**	**15,10**	**23,73**

Test 2 - Ram/Disk Intensive users - Sequential user connections

	# of "Ram/Disk Intensive" users per VM									
VM1 (CPU 0)	Not Running	Not Running	25	25	25	25	25	30	34	34
VM2 (CPU 1)	Not Running	Not Running	25	30	35	36	37	37	37	38
VM3 (CPU 2)	Not Running	Not Running	25	30	35	36	37	37	37	38
VM4 (CPU 3)	Not Running	Not Running	25	30	35	36	37	37	37	38
VM5 (CPU 4)	0	25	25	30	35	36	37	37	37	38
VM6 (CPU 5)	0	25	25	30	35	36	37	37	37	38
VM7 (CPU 6)	0	25	25	30	35	36	37	37	37	38
VM8 (CPU 7)	0	25	25	30	35	36	37	37	37	38
	# Total of "Ram/Disk Intensive" users active on all the VMs **including Reference Users** (1 per running VM, except VM1)									
	4	104	207	242	277	284	291	296	300	307
	Reference to the corresponding Processor Utilization Graph									
	A	B	C	D	E	F	G	H	I	J
	Reference "Ram/Disk Intensive" user Response Time in seconds									
VM1 (CPU 0)	Not Running	Not Running	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured
VM2 (CPU 1)	Not Running	Not Running	699	721	768	773	775	780	785	792
VM3 (CPU 2)	Not Running	Not Running	697	723	764	779	787	793	785	801
VM4 (CPU 3)	Not Running	Not Running	697	721	766	769	789	790	792	808
VM5 (CPU 4)	650	690	705	734	778	764	792	803	809	820
VM6 (CPU 5)	648	693	703	729	779	797	798	807	819	838
VM7 (CPU 6)	648	686	698	729	772	774	793	778	792	834
VM8 (CPU 7)	648	687	703	736	775	779	793	808	817	833
#Errors in scripts	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked	**11**	**1**
Average Response Time in seconds	648,50	689,00	700,29	727,57	771,71	776,43	789,57	794,14	799,86	818,00
% Response time variation	**-**	**6,25**	**7,99**	**12,19**	**19,00**	**19,73**	**21,75**	**22,46**	**23,34**	**26,14**

Test 3 - CPU Intensive Users - One VM running using CPU 7

	# Total of "CPU Intensive" users in VM8						
VM8 (CPU 7)	1	21	26	31	34	38	40
	Reference "CPU Intensive" user Response Time						
VM8 (CPU 7)	1456	1501	1525	1577	1597	1694	1737
#Errors in scripts	0	0	1	0	4	0	1
% Response time variation	-	3,09	4,74	8,31	9,68	16,35	19,30

Test 4 - CPU Intensive Users - Sequential user connections

	# of "CPU Intensive" users per VM									
VM1 (CPU 0)	Not Running	Not Running	25	25	25	25	30	25	30	34
VM2 (CPU 1)	Not Running	Not Running	25	30	34	35	35	36	37	37
VM3 (CPU 2)	Not Running	Not Running	25	30	34	35	35	36	37	37
VM4 (CPU 3)	Not Running	Not Running	25	30	34	35	35	36	37	37
VM5 (CPU 4)	0	25	25	30	34	35	35	36	37	37
VM6 (CPU 5)	0	25	25	30	34	35	35	36	37	37
VM7 (CPU 6)	0	25	25	30	34	35	35	36	37	37
VM8 (CPU 7)	0	25	25	30	34	35	35	36	37	37
	# Total of "CPU Intensive" users on all the VMs **including Reference Users** (1 per running VM, except VM1)									
	4	104	207	242	270	277	282	284	296	300
	Reference "CPU Intensive" user Response Time in seconds									
VM1 (CPU 0)	Not Running	Not Running	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured	VM Running - Not measured
VM2 (CPU 1)	Not Running	Not Running	1624	1738	1722	1729	1920	1947	1960	Not measured
VM3 (CPU 2)	Not Running	Not Running	1610	1780	1650	1989	1943	2013	1759	Not measured
VM4 (CPU 3)	Not Running	Not Running	1641	1815	1834	1874	2015	1983	1883	Not measured
VM5 (CPU 4)	1454	1605	1635	1789	1919	1938	1738	2104	1960	Not measured
VM6 (CPU 5)	1457	1613	1654	1730	1784	2143	1799	2030	2074	Not measured
VM7 (CPU 6)	1453	1562	1584	1731	1729	2113	1707	2294	1922	Not measured
VM8 (CPU 7)	1455	1566	1598	1727	1720	1921	1759	1916	1841	Not measured
#Errors in scripts	Not checked	Not checked	Not checked	Not checked	25	19	34	9	37	47
Average Response Time in seconds	1454,75	1586,50	1620,86	1758,57	1765,43	1958,14	1840,14	2041,00	1914,14	Not measured
% Response time variation	-	9,06	11,42	20,88	21,36	34,60	26,49	40,30	31,58	Not measured

Test 5 - Connected Users

| VM1	VM2	VM3	VM4	VM5	VM6	VM7	VM8
161	159	160	159	169	169	167	168

Test environment

Two networks were used. The 10Mbps Network was used for management purpose and the Ethernet 100Mbps one for the injection.
The injectors used were two IBM Netfinity 8500R – 8-Way with 4 GB of Ram each.
To perform the "Connected Users" test (Test 5) and due to bottlenecks that appeared on the existing injectors, two additional injectors have been added to the injection network.

The Windows 2000 Domain Controller was used to manage VMware Virtual Machines through the *VMware Remote Console* and the *VMware Management User Interface.*
The CPU processor time has been monitored from this server through a telnet session.
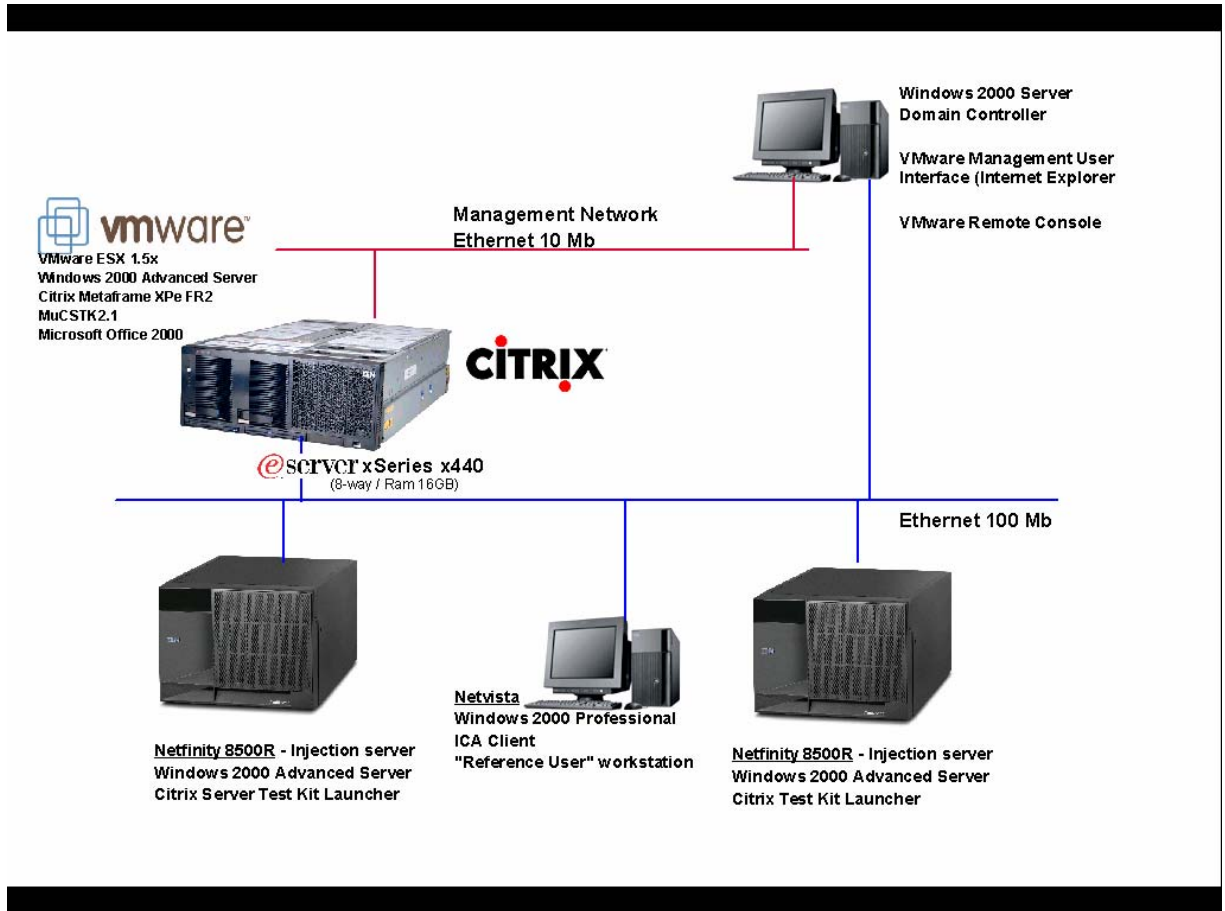
Test Procedures

Three types of tests were performed:
➢ "Reference User response time test procedure".
➢ "Connected Users" test procedure.
➢ "Server Performance test procedure" focusing on the CPU utilization.

During those tests, the number of users injected in each Virtual Machine was regularly increased. For each increment, **two values** were measured (excepting for the "Connected Users" tests described below):
1. The time spent by the "Reference User" to perform its script.
2. The number of ICA session with failed scripts (this value is used to determine the total number of active users).

Before each additional set of user injections, the sessions that failed were counted and the tables were filled in with the values. A script failure implies that no additional workload has been generated on the server (except the workload from the connection itself).

Before the injection of the next set of users, the failed scripts have been restarted in order to guarantee a server workload corresponding to the number of connected users. At this time, the processor utilization was monitored and summarized respectively in "Test 2 and Test 4 detailed results" graphs.

The complete results (but processors time) are included in the section "Detailed Results".

Reference User response time test procedure
This procedure consists in the measure of the time taken by a "Reference User" to execute a script while the number of users doing similar work (CPU Intensive - Ram/Disk Intensive) increased.

For this test **three different steps** have been defined:
1. No user was injected on the Metaframe servers excepting the "Reference User" scripts. The time spent to run the scripts was registered as the "Reference Time".
2. Start of the injection of a defined number of users running the same scripts.
3. Restart the "Reference User" scripts when all the users are active.

The results table is filled in with the time spent to run the script. The "% Response time variation" is computed.

Using this procedure, **four tests** were run:
1. Test 1 - Ram/Disk Intensive users - One VM running using CPU 7.
2. Test 2 - Ram/Disk Intensive users - Sequential user connections.
3. Test 3 - CPU Intensive Users - One VM running using CPU 7.
4. Test 4 - CPU Intensive Users - Sequential user connections.

Test 1 and Test 3 description
During these two tests, only one Virtual machine was running. The number of users was increased and the time spent by the "Reference User" to run the script was measured.

Test 2 and Test 4 description
During these two tests, the injection started with VM5, VM6, VM7 and VM8 running. 25 user connections were injected on VM8. The next 25 user connections were then started respectively on VM7, VM6, and VM5. The remaining four Virtual Machines were then started with the injection of the same number of users.
The "Maximum Number of Active Users" is an abstract of Test 2 and Test 4 table results.

Connected Users test procedure

Test 5 description

This test measured the maximum number of opened ICA sessions accepted by a VMware server. The ICA connections were started using the Citrix Server Test Kit. The "Startup" folder was empty so no scripts were launched.

The users were connected sequentially on each of the Citrix Metaframe server. This test was done with four injectors.

Two injectors were added because of an injection bottleneck during a previous run.

The first injector launched the connection of one hundred and forty users on VM8 and VM7. The second injector launched the connection of one hundred and forty users on VM6 and VM5. The third one on VM4 and VM3, the fourth one on VM2 and VM1.

Once all the sessions were opened, ten additional users connections were added on each Metaframe Server in each Virtual Machine, then five and finally one by one.

The test was stopped when one of the conditions below occurred:

➢ The %Processor Time was near 90% for CPU0 (VM1).
➢ The Login Time was greater than one minute.

Server Performance test procedure

While running the Test 2 and Test 4, the percentage of Processor Time was measured.

The tool used to measure the server performance on the VMware server is based on a Perl Script that checks CPU utilization each minute.

It was not possible to use the Microsoft Windows "System Monitor" (Perfmon.exe) to measure the system performance. It was noticed that running "Perfmon" in a Virtual Machine consumes up to 10 % of additional Processor Time.

Moreover, the impact of the "Virtualization" layer cannot be measured.

Appendices
Appendix A. IBM eServer x440 configuration

Software list

The following software products were installed on the server in this order:
➢ VMware ESX Server 1.5 with updates to 1.5.2.
➢ Windows 2000 Server SP3 with Terminal Services.
➢ VMware Tools installation: VMware Video Driver / VMware Network Driver
➢ Windows Installer Redistributable for Windows NT 4.0 and 2000 – V2.0 – 25 Sep 2002
➢ CITRIX MetaFrame XPe with Feature Release 2.
➢ Citrix Hot Fix installation: vdtw30.FR2.DLL
➢ MS Office 2000 SR-1, following the TSE installation procedure.
➢ CSTK v 2.1 + CSTK Client Modification (refer to: MuCSTK2.101.doc from: MuCSTK2101.zip – Modified for User Time recording).
➢ Registry modifications – See appendices.

Hardware configuration

Machine Type / Model: 8687-3RX (Bios Version: 1.04 07-31-2002)
➢ 4 processors 1.6 GHz Intel Xeon Processor MP 400 MHz FSB / L2 cache: 256 KB / L3 cache: 1024 KB.
➢ Hyperthreading deactivated.
➢ Memory: 16 GB.
➢ Two HDD – 15000 rpm – 36.4 GB.
➢ Carte ServeRaid 4Lx FRU 06P5741 – Bios Level: 4.84.01.
➢ IBM Ethernet PCI adapter 2 10-100 in PCI slot 1. P/N 34L1599. Connected to the management network. (10Mb).
➢ IBM Ethernet PCI adapter 2 10-100 in PCI slot 1. P/N 34L1599. Connected to the benchmark network. (100Mb).

Appendix B. VMware ESX Server and Virtual Machines Configuration

VMware Configuration
➢ Page Sharing disabled.
➢ Console OS assigned 192 MB RAM.
➢ *MemAllocHighThreshold* set to **4096 in** /proc/vmware/config
➢ Memory dedicated to the Console OS: 192 MB.
➢ VMFS Volumes created: vms and vms2
➢ Swap File size: 1024 MB
➢ The first network adapter was dedicated to Management Network. The other one was dedicated to the Virtual Machines using the Benchmark Network.

Virtual Machines configuration

VM Display Name	VMware Disk Name and Size	Disk	Memory	Processor Affinity
VM1	Vms0.dsk 7168 MB /Persistent	Disk 0	1608 MB	CPU 0
VM2	Vms1.dsk 7168 MB /Persistent	Disk 0	1608 MB	CPU 1
VM3	Vms2.dsk 7168 MB /Persistent	Disk 0	1608 MB	CPU 2
VM4	Vms3.dsk 7168 MB /Persistent	Disk 0	1608 MB	CPU 3
VM5	Vms4.dsk 7168 MB /Persistent	Disk 1	1988 MB	CPU 4
VM6	Vms5dsk 7168 MB /Persistent	Disk 1	1988 MB	CPU 5
VM7	Vms7dsk 7168 MB /Persistent	Disk 1	1988 MB	CPU 6
VM8	Vms8.dsk 7168 MB /Persistent	Disk 1	1988 MB	CPU 7

Common to all VMs:
Added in Vitual Machines configuration file: workload = "TerminalServices".

Appendix C. Windows 2000 Server tuning

Based on Microsoft and Citrix recommendations, some configuration parameters have been modified.
Here is the list.

❑ **Registry Size**
The "Maximum Registry Size" value is set to 120 MB.

❑ **Application Performance**
In "System Properties", "Advanced" tab, select: "Optimize Performance for": Background Services.

❑ **Terminal Services License**
The following registry key is modified as follow:
> **HKLM\SYSTEM\CurrentControlSet\Services\TermService\Parameter**
> **Value**: DefaultLicenseServer
> **Type**: REG_SZ
> **Data**: *enter the Netbios Name of the Terminal Server Licensing*

❑ **Disable "Paging Of Windows NT Executive"**
Disable paging of exec by setting the following registry key:
> **[HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\Session Manager\Memory Management] iaDisablePagingExecutiveIn=dword:00000001**

❑ **Increase Idle Connections To handle peak Logon Periods set to 5**
The default of 2 idle connections minimizes memory used, but may not be sufficient to handle peak logon traffic. Increasing the count helps ensure availability during peak logon periods.
> **[HKEY_LOCAL_MACHINE\SYSTEM\Current ControlSet\Control\Terminal Server]**
> **idleWinStationPoolCountll**=dword:00000005

❑ **Last Access Update**
The NTFS file system stores the last time a file is accessed, whether it is viewed in a directory listing, searched, or opened. In a multi-user environment, this updating can cause a small performance decrease. Modifying the following registry setting disables this feature:
> **HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\FileSystem**
> **NtfsDisableLastAccessUpdate** (REG_DWORD): 1

❑ **I/O Locks**
The registry setting *IoPageLockLimit* specifies the limit of the number of bytes that can be locked for I/O operations. Because RAM is being sacrificed for increased disk performance, determine the optimal setting for this value through pilot tests.
Changing this setting from the default can speed up file system activity. Use the table below as a guide for changing the registry setting.
The following registry key is modified as follow:
> **HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\SessionManager\Memory Management**
> **Value**: IoPageLockLimit (REG_DWORD): 10000 Hex

For additional information regarding this benchmark, please contact Isabelle Ferrand-Boutonnet (I_Ferrand@fr.ibm.com)