Principled Technologies®

TEST REPORT
MARCH 2009

Virtualized Exchange performance and power consumption on multiprocessor Intel- and AMD-based servers

Executive summary

Intel® Corporation (Intel) commissioned Principled Technologies (PT) to compare virtualized Exchange Server (e-mail) performance of three servers, all using Fibre Channel connected storage. To provide a baseline target score, we used a fourth system as a representative three-year-old server. We used the following hardware platforms:

- AMD* Opteron* 2384-based server
- Intel® Xeon® processor X5570-based server
- Intel Xeon processor E5450-based server
- 64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server (Intel Xeon processor 3.6 GHz)

KEY FINDINGS

- The Intel Xeon processor X5570-based server had an 80 percent performance advantage over both the Xeon processor E5450-based server and the AMD Opteron 2384-based server (see Figure 1).
- The Intel Xeon processor X5570-based server delivered 108 percent more virtual servers/watt than the Intel Xeon processor E5450-based server, 50 percent more virtual servers/watt than the AMD Opteron 2384-based server, and 761 percent more than the baseline Intel Xeon processor 3.6 GHz-based server (see Figure 2).

The AMD Opteron 2384- and Intel Xeon processor E5450-based server both contained 64 GB of RAM, while the Intel Xeon processor E5570-based server contained 72 GB of RAM. These three comparison servers used an EMC CX3-40f Fibre Channel storage area network (SAN) for all virtual machine (VM) and database storage. The baseline server, the Intel Xeon processor 3.6 GHz-based server, contained 4 GB of RAM and also used the EMC SAN.

For this comparison, we used Microsoft Exchange Load Simulator (LoadSim), a Microsoft-provided tool for benchmarking an Exchange Mail Server. We defined the peak number of virtual machines (VM) per server as the maximum number of concurrent VMs under load where each VM had acceptable performance.

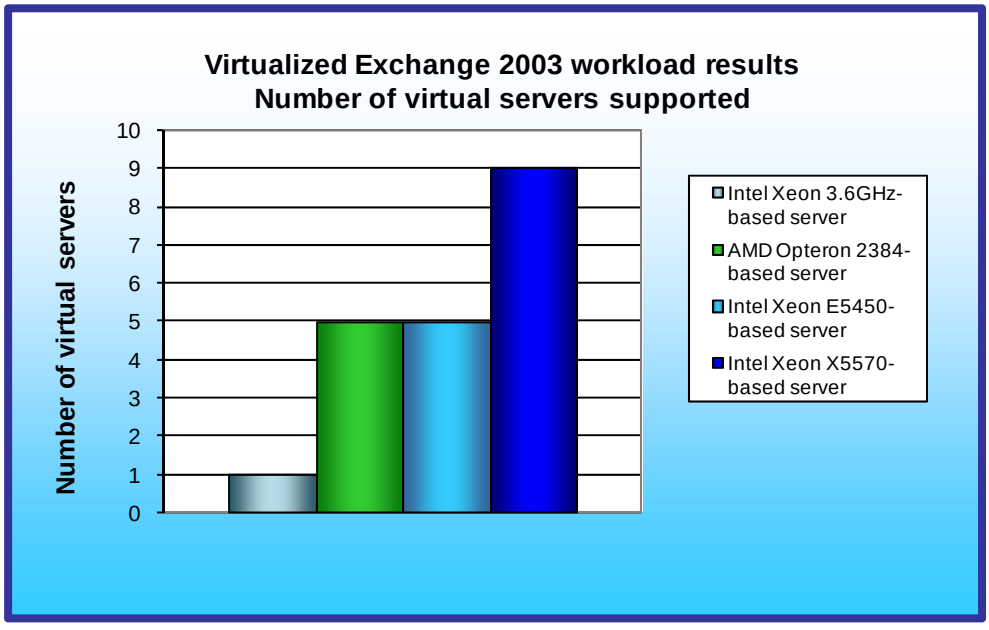

Figure 1: Virtualized Exchange 2003 workload performance results for the four servers. Higher numbers are better. (The Intel Xeon 3.6 GHz-based server ran a single, non-virtual version of the database test.)

Figure 1 compares the peak number of virtual machines running a Microsoft Exchange 2003 workload that each solution ran with acceptable performance. The Intel Xeon processor X5570-based server ran nine such simultaneous VMs, while both the Xeon processor E5450-based server and the AMD Opteron 2384-based server ran five such simultaneous VMs. Each VM contained 8,000 users, for a total of 72,000 users on the Intel Xeon processor X5570-based server and 40,000 users on both the Intel Xeon processor E5450-based server and the AMD Opteron 2384-based server. Thus, the Intel Xeon

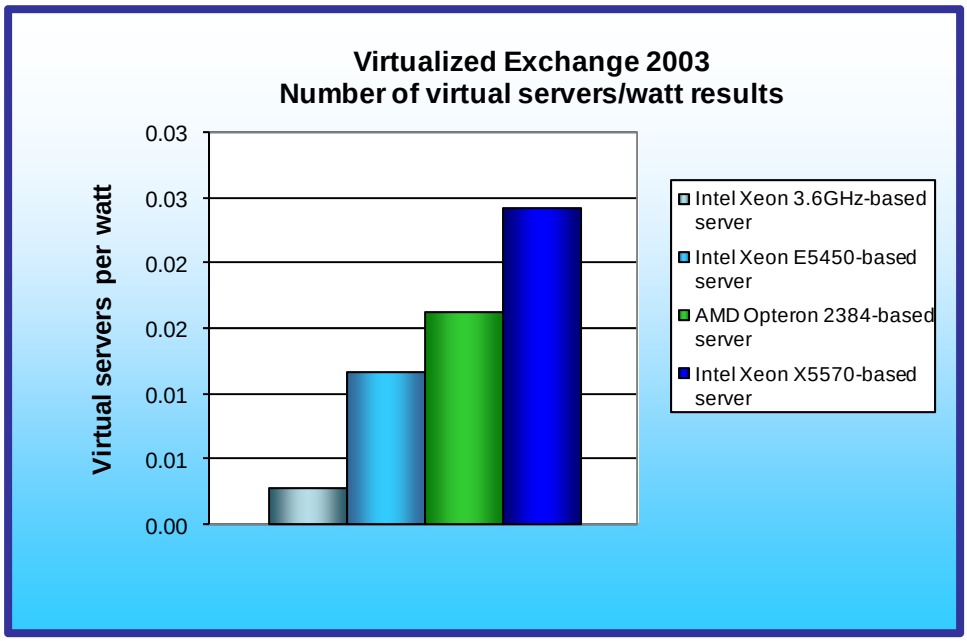

Figure 2: Virtual server/watt results for the four servers. Higher numbers are better.

processor X5570-based server had an 80 percent performance advantage over both the Xeon processor E5450-based server and the AMD Opteron 2384-based server.

Figure 2 illustrates the number of virtual servers each server supported per watt of power. We calculate this number by dividing the total number of virtual servers in the median run by the average power consumption, in watts, of the server during the period the benchmark ran.

As Figure 2 shows, the Intel Xeon processor X5570-based server delivered 108 percent more virtual servers/watt than the Intel Xeon processor E5450-based server, 50 percent more virtual servers/watt than the AMD Opteron 2384-based server, and 761 percent more than the baseline Intel Xeon processor 3.6 GHz-based server.

We installed and ran the LoadSim client on physical machines, using six machines per server VM.

Workload

Our goal was to see how many virtual machines running this workload on Microsoft Server 2003 with Exchange 2003 the server could handle with acceptable performance. We configured all virtual machines with two virtual processors and 4 GB of virtual memory. For complete configuration details, see the test methodology section. To reach that goal, we used Microsoft Exchange Load Simulator's MAPI Messaging Benchmark 3 (MMB3) workload to test the systems. We tuned the workload to in such a way as to stress CPU and memory. Our workload consisted of 8,000 users per VM. During the tests, LoadSim performs tasks to simulate a standard user generating mail activity. When the workload finishes, LoadSim reports the response time, which is the number of seconds necessary to complete the task. We ran this workload on all virtual machines simultaneously for 30 minutes. Figure 3 shows an example testbed set up for six Exchange Server VMs.

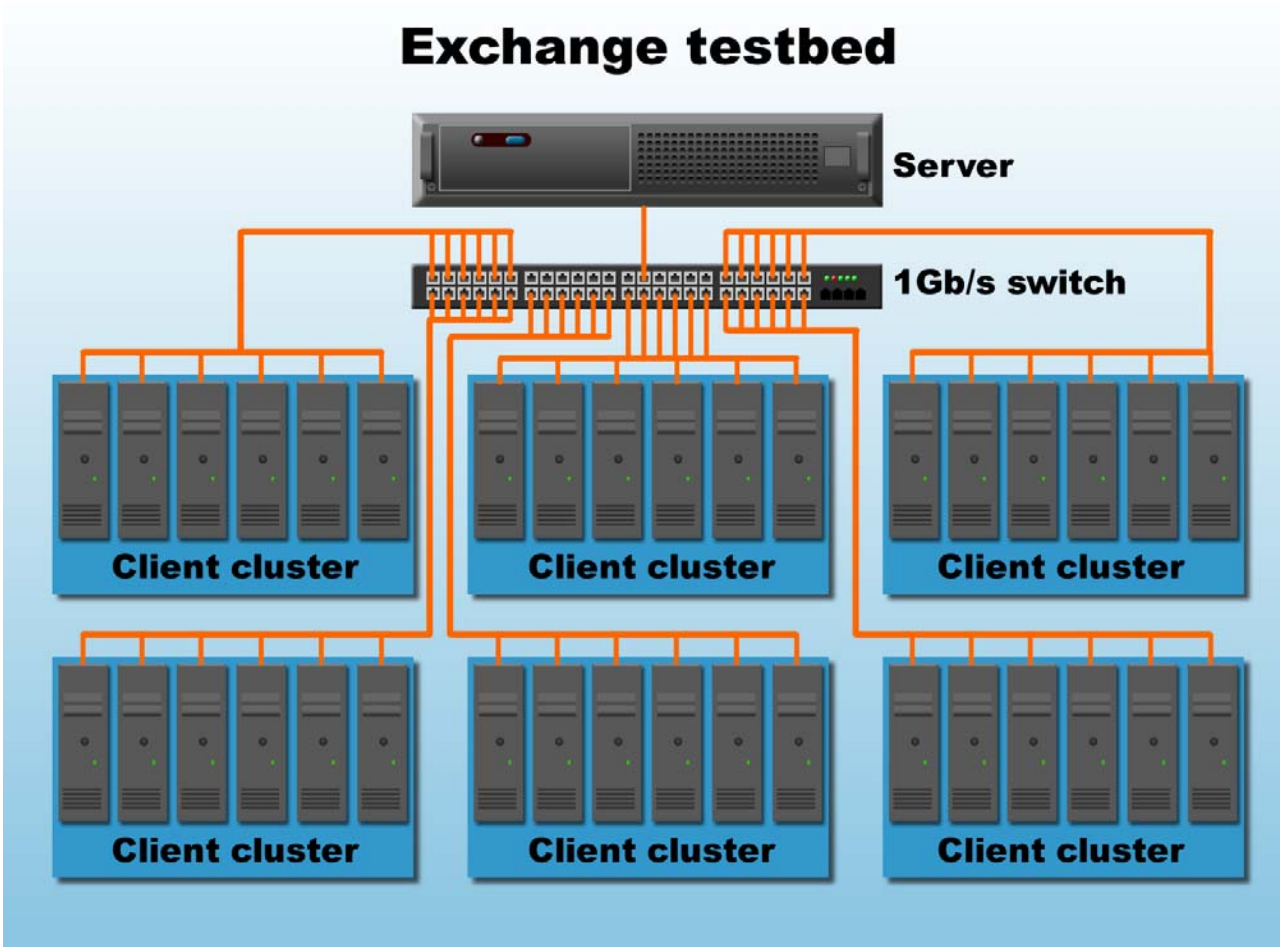

Figure 3: Example test bed for a virtualized Exchange Server workload with six VMs. Orange lines indicate network connections.

Test results

Figure 3 shows the total number of virtual machines each solution could handle during testing and the average total CPU utilization across all VMs. For a solution to earn an acceptable score, all VMs needed a transaction latency of less than one second. We define transaction latency here to be the 95th percentile latency for all MS Exchange requests (meaning 95 percent of all transactions have a latency equal to or less than the latency number provided). To determine the maximum number of simultaneous virtual machines each solution could handle, we added virtual machines until one or more had a transaction latency greater than one second. We then subtracted one VM to identify the total number of VMs the solution could handle. We performed three runs at the total number to verify the transaction response time always remained below one second.

Server	Peak number of VMs	Average total CPU utilization
AMD Opteron 2384-based server	5	90%
Intel Xeon processor E5450-based server	5	93%
Intel Xeon processor X5570-based server	5	34%
Intel Xeon processor X5570-based server	9	75%
Intel Xeon processor 3.6 GHz-based server (baseline)	N/A	73%

Figure 3: The total number of virtual machines and average CPU utilization for the four servers. Higher numbers of virtual machines are better. The Intel Xeon processor 3.6 GHz-based server was the baseline with the workload running natively and therefore ran as a standalone server with no virtual machines.

Figure 4 shows the 95th percentile transaction latency, in milliseconds, from the median run for each virtual machine.

Client	Intel Xeon processor X5570-based server (ms)	Intel Xeon processor E5450-based server (ms)	AMD Opteron 2384-based server (ms)	Intel Xeon processor 3.6 GHz-based server (ms)
Virtual machine 1	902	642	632	323
Virtual machine 2	548	652	575	
Virtual machine 3	728	713	571	
Virtual machine 4	527	663	533	
Virtual machine 5	668	679	642	
Virtual machine 6	581			
Virtual machine 7	631			
Virtual machine 8	457			
Virtual machine 9	898			

Figure 4: Transaction latency from median run for each virtual machine for the four servers. Lower numbers are better.

We tested the Intel Xeon processor X5570-based server with five VMs so we could compare its transaction latency with that of the Intel Xeon processor E5450-based and AMD Opteron 2384-based servers also with five VMs. As Figure 5 shows, the Intel Xeon processor X5570-based server at five VMs has much lower transaction latency (and lower CPU utilization; see Figure 3), than the other servers we tested, and as Figure 4 shows, it can go all the way to nine VMs with acceptable transaction latency.

Client	Intel Xeon processor X5570-based server (ms)	Intel Xeon processor E5450-based server (ms)	AMD Opteron 2384-based server (ms)
Virtual machine 1	374	642	632
Virtual machine 2	319	652	575
Virtual machine 3	370	713	571
Virtual machine 4	356	663	533
Virtual machine 5	373	679	642

Figure 5: Transaction latency from median run for each virtual machine for the three comparison servers when all of them ran with five VMs. Lower numbers are better.

Figure 6 details the power consumption, in watts, of the server while idle and during the median run of the virtualized Exchange 2003 workload.

Server	Idle power (watts)	Average power (watts)
AMD Opteron 2384-based server	213	308
Intel Xeon processor E5450-based server	347	426
Intel Xeon processor X5570-based server	255	369
Intel Xeon processor 3.6 GHz-based server	272	353

Figure 6: Average power usage (in watts) of the four servers while idle and during the median run of the Microsoft Exchange 2007 workload. Lower numbers are better.

Note: Microsoft Windows Server 2008 Hyper-V (v1.0) does not take advantage of the C6 power state feature in the Intel Xeon processor X5570-based server. If the next release of Windows Server 2008 Hyper-V takes advantage of this feature, as Microsoft predicts, Intel expects the idle power for this server to decrease by approximately 30 to 50 watts. (Intel bases idle power reduction estimates on power savings they have seen on other operating systems that support the X5570's C6 power state.)

Test methodology

Setting up and configuring EMC storage

We used an EMC CX3-40f Fibre Channel SAN in testing the AMD Opteron 2384, Intel Xeon processor X5570, and Intel Xeon processor E5450 servers. Figure 7 illustrates the configuration we used. The SAN had two storage processors, SP A and SP B. We used a dual port Fibre Channel host bus adapter (HBA) card in each server. We cabled one HBA port to each SP (A and B) on the SAN to balance the load between SPs. We used seven enclosures of disks on the SAN; with one exception, each enclosure had 15 disks. We designated RAID 0 for all RAID group configurations.

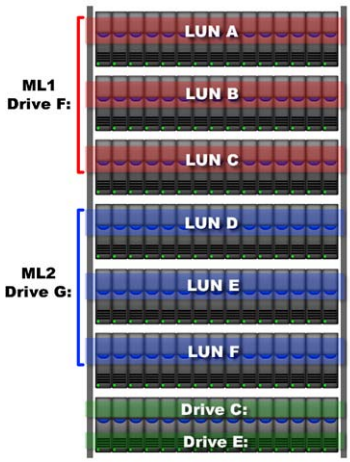

Figure 7: The EMC storage configuration we used.

We created 1 RAID group on the enclosure that had only 12 disks. We then created two logical unit numbers (LUNs) on this RAID group, one for the virtual hard drives (VHDs) that would hold the Exchange mail databases and one for the VHDs that would hold the virtual machine system drives and operating system data.

We created six RAID groups for Exchange data. Each of these six RAID groups was composed of 15 disks (an entire enclosure). We then created one 250GB LUN per RAID group, for a total of six LUNs dedicated to VHDs that would hold Exchange data. We used the EMC MetaLUN feature and assigned three LUNs to MetaLUN-A (which would handle our even mail server VM databases) and three LUNS to MetaLUN-B (which would handle our odd mail server VM databases). To balance processing load and disk transfers, we assigned MetaLUN-A to SP A and MetaLUN-B to SP B.

After installing EMC PowerPath software, we then accessed each LUN and MetaLUN through the Disk Management utility in Windows Server 2008. We then proceeded with test setup, creation of VHDs and virtual machines, and so on.

Adjusting BIOS settings

To maximize performance for each server, we adjusted the BIOS settings as follows:

- Intel Xeon processor X5570 system: We disabled Turbo Mode and enabled Virtualization Technology.
- Intel Xeon processor E5450 systems: We enabled Virtualization Technology.
- Intel Xeon processor 3.6 GHz-based system: We disabled HyperThreading Technology.

We made no adjustments to the AMD Opteron 2384-based system.

Installing and configuring Windows Server 2008, Enterprise x64 Edition

We installed a fresh copy of Windows Server 2008, Enterprise x64 Edition on the three comparison systems. (Note: For the baseline Intel Xeon processor 3.6 GHz system, we installed a fresh copy of Windows Server 2003 x86 R2 with SP2 using the steps outlined for the Master VM below.)

We followed this process for each installation:

1. Boot the server and insert the Windows Server 2008 x64 installation CD in the DVD-ROM drive.
2. At the Language Selection Screen, click Next.

3. Click Install Now.
4. Select Windows Server 2008 Enterprise (Full Installation) x64, and click Next.
5. Click the I accept the license terms check box, and click Next.
6. Click Custom.
7. Click Drive options (advanced).
8. Click New.
9. Click Apply.
10. Click Next.
11. At the warning that the user's password must be changed before logging on screen, click OK.
12. Type `Password1` as the new password in both fields, and click the arrow to continue.
13. At the Your password has been changed screen, click OK.

Setting up the Hyper-V server

Following the installing of Windows Server 2008, Enterprise x64 Edition, we proceeded to set up the host server, which included installing Hyper-V Manager and setting up the SAN.

Setting up network configuration on the host server

1. Click Start→Control Panel→Network and Internet→Network Connections, and double-click the Local Area Connection.
2. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
3. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
4. Enter a valid static IP address, subnet mask, and default gateway.
5. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server address.
6. Click OK, and then click Close to exit.

Installing system updates in Windows Server 2008 x64

We installed the following updates on the three comparison systems using the Microsoft Windows Update feature:

- Security Update for Windows Server 2008 x64 Edition (KB958687)
- Update for Windows Server 2008 x64 Edition (KB957388)
- Security Update for Windows Server 2008 x64-based Systems (KB938464)
- Update for Windows Server 2008 Server Manager x64 Edition (KB940518)
- Update for Windows Server 2008 x64 Edition (KB949189)
- Security Update for Windows Server 2008 x64 Edition (KB955069)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2008 x64 Edition (KB956391)
- Security Update for Windows Server 2008 x64 Edition (KB954459)
- Security Update for Windows Server 2008 x64 Edition (KB957097)
- Security Update for Windows Server 2008 x64 Edition (KB958623)
- Update for Windows Server 2008 x64 Edition (KB959130)
- Cumulative Security Update for Internet Explorer 7 in Windows Server 2008 x64 Edition (KB958215)
- Update for Windows Server 2008 x64 Edition (KB957200)
- Security Update for Windows Server 2008 x64 Edition (KB953733)
- Security Update for Windows Server 2008 x64 Edition (KB950762)
- Update for Windows Server 2008 x64 Edition (KB955839)
- Security Update for Windows Server 2008 x64 Edition (KB958624)
- Security Update for Windows Server 2008 x64 Edition (KB950974)
- Update for Windows Server 2008 x64 Edition (KB951978)
- Update for Windows Server 2008 for x64-based Systems (KB955020)
- Security Update for Windows Server 2008 x64 Edition (KB954211)
- Windows Malicious Software Removal Tool x64 – January 2009 (KB890830)
- Security Update for Windows Mail for Windows Server 2008 x64 Edition (KB951066)
- Security Update for Windows Server 2008 x64 Edition (KB956841)

- Security Update for Windows Server 2008 x64 Edition (KB956802)
- Update for Windows Server 2008 x64 Edition (KB957321)
- Update for Windows Server 2008 x64 Edition (KB952287)
- Security Update for Windows Server 2008 x64 Edition (KB958644)
- Security Update for Internet Explorer 7 in Windows Server 2008 x64 Edition (KB960714)
- Security Update for Windows Server 2008 x64 Edition (KB951698)
- Update for Windows Server 2008 x64 Edition (KB950050)
- Update for Windows Server 2008 x64 Edition (KB955302)
- Windows Update Agent 7.2.6001.788
- Windows Update software 7.2.6001.788

Installing Hyper-V in Windows Server 2008

Note: Be sure you have installed all the latest critical and recommended updates for Windows Server 2008 from Windows Update. Specifically, you must install the update that upgrades Hyper-V from beta to release software. (As of this writing, this update is KB950050 on Windows Server 2008 Enterprise Edition x64.)

1. Click Start→Administrative Tools→Server Manager.
2. Click Roles.
3. Click Add Roles.
4. Click Next.
5. Select the Hyper-V role by checking the box beside it, and click Next.
6. Check the box beside the Ethernet Card you wish to use, and click Next.
7. Click Install to begin the Hyper-V installation.
8. When the installation finishes, click Close.
9. When prompted to restart now, click Yes.
10. Follow the prompt to log on to the system.
11. Enter the password, and click the arrow to continue. The Resuming Configuration Wizard should start automatically.
12. Once the Resuming Configuration Wizard completes, the installation results should appear with a message that the installation succeeded.
13. Click Close.

Setting up the storage area network (SAN)

1. Install the dual-port QLogic FC card in the server.
2. Connect two fibre cables from the dual-port QLogic FC card in the server to the SAN, with each cable connecting to one storage processor (SP) on the EMC.
3. Install EMC Powerpath software x64 on the server with all defaults except for the following: select the CX SAN, not the AX.
4. When prompted to reboot at the end of the Powerpath installation, do so.
5. Click Start.
6. Right-click My Computer, and select Manage.
7. Select Disk Management.
8. When the wizard prompts you to initialize new disks, click OK. Note: If you must select a partition table, select MBR.
9. Right-click the first unallocated disk partition, and select New Simple Volume…
10. Click Next.
11. Use the entire LUN storage space, and click Next.
12. Select the drive letter to assign to the new partition, and click Next.
13. Label the volume appropriately (i.e., LUN0, LUN1, etc.).
14. Confirm that Perform a quick format is checked, and click Next.
15. Click Finish.
16. Repeat steps 8 through 15 for each volume.

Creating the master virtual machine

Note: We performed these following steps on only the first server. For subsequent servers, we used the same VHD files. We created three fixed-size virtual hard drives per VM, one on each volume in the appropriately named folders. Using Hyper-V manager, we assigned the VHD file containing the operating system to IDE Controller 0 and assigned the remaining two VHD files to the SCSI controller.

Create the virtual machines with the following VM parameters:

- Virtual processor: 2
- Virtual memory: 4,096 MB
- Virtual disk size: 8 GB

1. Create a folder for the Master VM on each LUN (i.e., MailServer1).
2. Click Start→Administrative Tools→Hyper-V Manager.
3. Click Connect to Server, and click OK.
4. Click Action→Virtual Network Manager…
5. Select New virtual network.
6. Select External, and click Add.
7. From the Actions menu, select New→Virtual Machine…
8. Click Next.
9. Enter a name for the virtual machine.
10. Click Next.
11. Specify the amount of memory to allocate to this virtual machine (4096 MB), and click Next.
12. Select Not Connected on the Configure Networking screen, and click Next.
13. Select the Attach a virtual hard disk later radio button, and click Next.
14. Click Finish.
15. Close Hyper-V Manager.

Setting up the Master VM

After creating the Master VM through the Hyper-V interface, we proceeded to set up the Master VM, which included installing and configuring Windows Server 2003 x86 R2 with SP2.

Configuring the Master VM

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the Master VM, and select Settings…
3. Select Processor.
4. Change the number of logical processors to 2, and click Apply.
5. Select Network Adapter.
6. Select the appropriate configuration from the drop-down menu, and click Apply.
7. Select Add Hardware.
8. Select SCSI Controller, and click Add.
9. Click Apply.
10. Select IDE Controller 0.
11. Select Disk Drive, and click Add.
12. Click New.
13. Click Next.
14. Click the Fixed size radio button, and click Next.
15. Enter a name for the VHD file.
16. Browse to MailServer1 folder on the OS LUN, and select Next.
17. Select the Create a new blank virtual hard disk radio button.
18. Enter 8 for the number of GB for the virtual hard disk, and click Next.
19. Click Finish.
20. Click Apply.
21. Select SCSI Controller.
22. Select Disk Drive, and click Add.
23. Click New.

24. Click Next.
25. Click the Fixed size radio button, and click Next.
26. Enter a name for the VHD file.
27. Browse to MailServer1 folder on the MailDB LUN, and select Next.
28. Select the Create a new blank virtual hard disk radio button.
29. Enter 45for the number of GB for the virtual hard disk, and click Next.
30. Click Finish.
31. Click Apply.
32. Select SCSI Controller.
33. Select Disk Drive, and click Add.
34. Click New.
35. Click Next.
36. Click the Fixed size radio button, and click Next.
37. Enter a name for the VHD file.
38. Browse to MailServer1 folder on the MailBackup LUN, and select Next.
39. Select the Create a new blank virtual hard disk radio button.
40. Enter 45 for the number of GB for the virtual hard disk, and click Next.
41. Click Finish.
42. Click Apply.
43. Click OK.

Installing Windows Server 2003 x86 R2 with SP2 on the Master VM

We installed a fresh copy of Windows Server 2003 x86 R2 with SP2 on the three comparison systems using the steps below. (Note: We also installed Windows Server 2003 x86 R2 with SP2 on the baseline Intel Xeon processor 3.6 GHz server, beginning with step 12.)

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the Master VM, and select Settings…
3. Select IDE Controller 1.
4. Select DVD Drive.
5. Select the Physical CD/DVD drive: radio button, and click Apply.
6. Select BIOS and confirm that CD is at the top of the Startup order list. If this is not the case, adjust the list appropriately, and click Apply.
7. Click OK.
8. Right-click the Master VM, and select Connect…
9. Click Menu→DVD Drive→Capture appropriate DVD-ROM drive (i.e., D:).
10. Insert the Windows Server 2003 R2 installation CD in the DVD-ROM drive.
11. Click Action→Start to start the Master VM.
12. At the Welcome to Set up screen, press Enter to begin the installation.
13. At the Windows Licensing Agreement screen, press F8 to agree to the terms.
14. Press Enter to install in the default location.
15. Select Format the partition using the NTFS file system (Quick), and press Enter to continue.
16. At the Regional and Language Options screen, click Next.
17. Enter Name and Organization, and click Next. Note: Organization is an optional field, while username is required.
18. At the Your Product Key screen, enter your product key, and click Next.
19. At the Licensing Modes screen, click Next.
20. At the Computer Name and Administrator Password screen, type `Password1` as the new password in both fields, and click Next.
21. At the Date and Time Settings screen, change the Date & Time and Time Zone if appropriate, and click Next.
22. After the system restarts automatically, follow the prompt to log in to the server.
23. At the Windows Setup screen, you will be prompted to insert the second installation CD. Insert the appropriate CD, and click OK.
24. At the Windows Server 2003 R2 Setup Wizard Welcome screen, click Next.

25. At the Windows Server 2003 R2 Setup Wizard Summary screen, click Next.
26. When prompted, click Finish to end the installation.
27. Once the installation completes, on the Hyper-V Manager menu, click Action→Insert Integration Services Setup Disk.
28. At the prompt to restart, click Yes.
29. Log back in to the Master VM at the prompt.
30. Click Start.
31. Right-click My Computer and select Manage.
32. Select Disk Management.
33. If the wizard prompts you to initialize new disks, click OK. Note: If you must select a partition table, select MBR.
34. Right-click the first unallocated disk partition, and select New Simple Volume…
35. Click Next.
36. Use the entire VHD storage space, and click Next.
37. Select the drive letter to assign to the new partition, and click Next.
38. Label the volume appropriately (i.e., MailDB, MailBackup, etc.).
39. Confirm that Perform a quick format is checked, and click Next.
40. Click Finish.
41. Repeat steps 34 through 40 for the remaining volumes.

Setting up network configuration on the Master VM

1. Click Start→Control Panel→Network Connections, and Local Area Connection.
2. At the Local Area Connection Status screen, click Properties.
3. At the Local Area Connection Properties screen, select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
4. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
5. Enter a valid static IP address, subnet mask, and default gateway.
6. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server address.
7. Click OK and then click Close twice. Close the Network Connections window.

Installing system updates in Windows Server 2003 R2 on the Master VM

We installed the following updates using the online Windows Update feature. Note: Reboot the VM as requested.

- Windows Server 2003 Security Update for Internet Explorer 7 for Windows Server 2003 (KB960714)
- Windows Server 2003 Security Update for Internet Explorer 7 for Windows Server 2003 (KB938127)
- Windows Server 2003 Windows Malicious Software Removal Tool - January 2009 (KB890830)
- Windows Server 2003 Security Update for Windows Server 2003 (KB958687)
- Windows Server 2003 Security Update for Windows Server 2003 (KB956803)
- Windows Server 2003 Security Update for Internet Explorer 6 for Windows Server 2003 (960714
- Windows Server 2003 Security Update for Windows Server 2003 (KB925902)
- Windows Server 2003 Update for Windows Server 2003 (KB955839)
- Windows Server 2003 Cumulative Security Update for Internet Explorer 6 for Windows Server 2003 (KB958215)
- Windows Server 2003 Security Update for Windows Server 2003 (KB956802)
- Windows Server 2003 Security Update for Windows Server 2003 (KB954600)
- Windows Server 2003 Security Update for Windows Server 2003 (KB952069)
- Windows Server 2003 Security Update for Windows Server 2003 (KB957097)
- Windows Server 2003 Security Update for Windows Server 2003 (KB955069)
- Windows Server 2003 Security Update for Windows Server 2003 (KB958644)
- Windows Server 2003 Security Update for Windows Server 2003 (KB956841)
- Windows Server 2003 Cumulative Security Update for ActiveX Killbits for Windows Server 2003 (KB956391)

- Windows Server 2003 Security Update for Windows Server 2003 (KB954211)
- Windows Server 2003 Security Update for Windows Server 2003 (KB938464)
- Windows Server 2003 Security Update for Windows Server 2003 (KB944338)
- Windows Server 2003 Security Update for Windows Server 2003 (KB950974)
- Windows Server 2003 Security Update for Windows Server 2003 (KB952954)
- Windows Server 2003 Security Update for Outlook Express for Windows Server 2003 (KB951066)
- Windows Server 2003 Security Update for Windows Server 2003 (KB951748)
- Windows Server 2003 Security Update for Windows Server 2003 (KB951698)
- Windows Server 2003 Security Update for Windows Server 2003 (KB950762)
- Windows Server 2003 Security Update for Windows Server 2003 (KB945553)
- Windows Server 2003 Update for Windows Server 2003 (KB948496)
- Windows Server 2003 Security Update for Windows Server 2003 (KB943055)
- Windows Server 2003 Security Update for Windows Server 2003 (KB946026)
- Windows Server 2003 Security Update for Windows Server 2003 (KB943485)
- Windows Server 2003 Security Update for Windows Server 2003 (KB941569)
- Windows Server 2003 Security Update for Windows Server 2003 (KB944653)
- Windows Server 2003 Security Update for Windows Server 2003 (KB943460)
- Windows Server 2003 Windows Internet Explorer 7 for Windows Server 2003
- Windows Server 2003 Update for Windows Server 2003 (KB936357)
- Windows Server 2003 Security Update for Windows Server 2003 (KB933729)
- Windows Server 2003 Security Update for Microsoft .NET Framework, Version 1.1 Service Pack 1 (KB933854)
- Windows Server 2003 Security Update for Windows Server 2003 (KB938127)
- Windows Server 2003 Security Update for Windows Server 2003 (KB936782)
- Windows Server 2003 Security Update for Windows Server 2003 (KB926122)
- Windows Server 2003 Security Update for Windows Media Player 6.4 (KB925398)
- Windows Server 2003 Security Update for Windows Server 2003 (KB935839)
- Windows Server 2003 Security Update for Windows Server 2003 (KB935840)
- Windows Server 2003 Cumulative Security Update for Outlook Express for Windows Server 2003 (KB929123)
- Windows Server 2003 Security Update for Windows Server 2003 (KB924667)
- Windows Server 2003 Update for Windows Server 2003 (KB927891)
- Windows Server 2003 Security Update for Windows Server 2003 (KB932168)
- Windows Server 2003 Security Update for Windows Server 2003 (KB930178)

The following subsections detail how we created and configured each of these VMs.

Copying the VMs

Use the following steps to create VMs with the same base OS:

1. Navigate to the Virtual Hard Disk folder on the server where the Virtual Hard Disks are stored.
2. Highlight your base VM, and use the copy/paste method to create the appropriate number of copies for your VMs.
3. Right click each Hard Disk and rename them according to the VM for which they are to be used.
4. Select Start→Administrative Tools→Hyper-V Manager…
5. Choose New→Virtual Machine.
6. Click Next.
7. Enter a name for the virtual machine, and select the location to store the VM files The New Virtual Machine Wizard will automatically create a subfolder with the name of the VM.
8. Click Next.
9. Specify the amount of memory to allocate to the virtual machine, and click Next.
10. Select the network connection for the virtual machine to use, and click Next.
11. Select Attach a virtual hard disk later, and click Next.
12. Click Finish.
13. Select the newly created VM and choose Settings→IDE Controller 0.

14. Choose Add to add a Hard Disk to the VM.
15. Choose Browse.
16. Select the appropriate Hard Disk and click Okay.
17. Click OK.

Installing and configuring the mail server VM

1. Follow the steps in the earlier Copying the VMs section using the following VM specifications:
   Base VM: Base32
   Name: MailServer1
   Virtual processors: 2
   Virtual memory: 4 GB
   Virtual disk size: 8 GB
   Virtual network: Internal Network (set the IP address to 192.168.1.1 in Windows within the VM)

To finish setting up this VM, we had to install several additional software components. The following subsections detail the necessary installation processes.

Installing the domain controller

1. Select Start→Administrative Tools→Manage Your Server.
2. Click Add or remove a role.
3. At the Configure Your Server window, click Next.
4. At the Configuration and Options screen, select Custom Configuration, and click Next.
5. At the Server Role screen, select Domain Controller, and click Next.
6. At the Summary of Selections screen, click Next.
7. At the Welcome pop-up window, click Next.
8. At the Operating System Compatibility screen, click Next.
9. For the Domain Controller Type, leave the default option (Domain controller for a new domain), and click Next.
10. At the Create New Domain screen, leave the default (Domain in a new forest), and click Next.
11. At the Install or Configure DNS window, select No, and click Next.
12. At the New Domain Name screen, type a domain name (`loadsim.com`), and click Next.
13. At the NetBIOS Domain Name screen, enter a NETBIOS domain name (loadsim), and click Next.
14. Click Next through the following screens: Database and Log Folders, Shared System Volume, and Permissions. Doing so accepts the default options for each of those screens.
15. At the Directory Services Restore Mode Administrative Password screen, enter a `Password1`, and click Next.
16. When the installation software prompts you to do so, insert the OS CD, and click OK.
17. At the Completing the Active Directory Installation Wizard screen, click Finish.
18. When the system prompts you to reboot the VM, click Restart Now.
19. After the VM reboots, log in to the system.
20. At the This Server is Now a Domain Controller window, click Finish.

Installing Internet Information Services 6.0

1. Select Start→Control Panel→Add or Remove Programs.
2. Click Add/Remove Windows Components.
3. Select Application Servers, and click Details.
4. Click ASP.NET, and make sure a check appears in the check box.
5. Select Internet Information Services (IIS), and click Details.
6. Click NNTP Services and SMTP Services, make sure a check appears in both check boxes, and click OK.
7. Click OK to close the Application Server window.
8. At the Windows Components Wizard, click Next to begin the installation.
9. When the system prompts you to do so, insert the OS CD, and click OK.
10. At the Completing the Windows Components Wizard window, click Finish.
11. Close the Add or Remove Programs window.

Installing Exchange Server 2003

1. Insert the Microsoft Exchange Server 2003 CD. The CD should automatically launch the installation software.
2. Choose Exchange Server Enterprise Edition.
3. Run the Setup application.
4. Click the Exchange Deployment Tools link.
5. Click the Deploy the first Exchange 2003 Server link.
6. Click the New Exchange 2003 Installation link.
7. Click the Run ForestPrep now link.
   a. When the compatibility issue notice appears, click Continue, and check the Don't display this message again box.
   b. At the Welcome screen, click Next.
   c. Accept the End User License Agreement, and click Next.
   d. At Component Selection Screen, keep the defaults, and click Next.
   e. Leave the default account information, and click Next.
   f. Installation should start. (This process may take a while to complete.)
   g. When the installation completes, click Finish.
8. Return to the Exchange Server Deployment Tools screen, and click the Run DomainPrep now link.
   a. At the Welcome screen, click Next.
   b. Accept the End User License Agreement, and click Next.
   c. At Component Selection Screen, keep the defaults, and click Next.
   d. At the insecure domain notice, click OK.
   e. When the installation completes, click Finish.
9. Return to the Exchange Server Deployment Tools screen, and click Run Setup Now.
   a. At the Welcome screen, click Next.
   b. Accept the End User License Agreement, and click Next.
   c. At the Component Selection screen, the action for Microsoft Exchange should by default be Typical. (If it is not, use the drop-down box to set it to Typical.)
   d. Click Next.
   e. For the Installation Type, select Create new Exchange Organization, and click Next.
   f. Leave the default Organization Name, and click Next.
   g. Accept the Microsoft Exchange Server Licensing Agreement, and click Next.
   h. Review the installation summary, and click Next.
   i. The installation should start. (This process may take a while to complete.)
   j. When the installation completes, click Finish.
10. Close the Exchange Server Deployment Tools window.
11. Install Microsoft Exchange Server 2003 Service Pack 2.
    a. Insert the SP2 CD, and double-click update exe.
    b. Accept the default location to extract the file, and click OK.
    c. After the extraction finishes, open Windows Explorer, and browse to the update.exe executable.
    d. At the Welcome screen, click Next.
    e. Select I agree to accept the License Agreement, and click Next.
    f. At the Component Selection window, leave the default option (Update), and click Next.
    g. Verify the installation Summary, and click Next.
    h. When the installation completes, click Finish.
12. In the Virtual Infrastructure Client console, add a new 40GB virtual hard disk to this VM by doing the following:
    a. Right-click the MailServer1 VM, and select Settings from the menu.
    b. On the Hardware Tab, click Add Hardware.
    c. Choose the "SCSI Controller" device and click Add.
    d. Click "Add" to add a new hard drive to the virtual SCSI Controller.
    e. Click New to create a new virtual hard disk file.
    f. Click Next.
    g. Select "Fixed size" and click Next.
    h. Specify the name and location of the virtual hard disk file.

i. Specify the size of the new blank virtual hard disk (in GB).
j. Click Finish. The server will then begin creating the new virtual hard disk.
k. Once it finishes creating the new virtual hard disk, click OK.

13. Restart the VM by selecting Start→Shut down→Restart inside the MailServer VM.
14. In the MailServer VM, right-click My Computer, and select Manage.
15. In the Computer Management Console, select Disk Management.
16. When a Welcome to Initialize and Convert Disk Wizard window appears, click Next.
17. Select Disk 1 to initialize.
18. At the Select Disk to Convert screen, leave the disk unchecked.
19. At the Completing the Initialize and Convert Disk Wizard screen, click Finish.
20. Right-click the Disk 1 unallocated box, and select New Partition.
21. At the Welcome screen, click Next.
22. Leave the partition type as Primary, and click Next.
23. Accept the default Partition Size, which should be the same as the Maximum disk space, and click Next.
24. Assign the drive letter E, and click Next.
25. Format the partition with the NTFS File system, enter `Mail Store` for the volume label, and click Next.
26. At the Completing the New Partition Wizard screen, click Finish.
    The partition should begin formatting.
27. When the formatting completes, close the Computer Management console.
28. Select Start→All Programs→Microsoft Exchange→System Manager.
29. In the left window pane, expand Servers and MailServer so the First Storage Group is visible.
30. Right-click First Storage Group, and select Properties.
31. Click Browse, and change the Transaction log and System path location to E:\.
32. Check the Enable circular logging box, and click Apply.
33. When the pop-up message appears asking if you want to perform this task, click Yes.
34. When the message appears saying that all mounted stores are back online, click OK.
35. Right-click Mailbox Store under First Storage Group, and select Properties.
36. Select the Database tab.
37. Click Browse, and move the Exchange database and Exchange streaming database to E:\.
38. Check the This database can be overwritten by a restore box.
39. Click Customize next to Maintenance interval.
40. Remove all blue from the boxes so the system will not perform maintenance, and click OK.
41. At the Mailbox Store Properties window, click Apply.
42. When a warning message appears, click Yes.
43. When the message that the database files have been moved appears, click OK.
44. Click OK to close the Mailbox Store Properties window.
45. Right-click Public Store under First Storage Group, and select Properties.
46. Select the Database tab.
47. Click Browse, and move the Exchange database and Exchange streaming database to E:\.
48. Check the This database can be overwritten by a restore box.
49. Click Customize next to Maintenance interval.
50. Remove all blue from the boxes so the system will not perform maintenance, and click OK.
51. At the Public Store Properties window, click Apply.
52. When a warning message appears, click Yes.
53. When the message that the database files have been moved appears, click OK.
54. Click OK to close the Public Store Properties window.
55. Reboot the virtual machine.

Installing the mail test client

We performed the following steps to set up the systems:

1. Install Microsoft Windows XP Professional with Service Pack 3 using all defaults.
2. Install relevant drivers on the machine.
3. Right-click My Computer, and select Properties.
4. Click the Computer Name tab.
5. Click Change.

6. Select Domain in the member of section, and type the domain `loadsim.com` into the text box.
7. In the pop-up window, enter Administrator for user name, Password1 for password, and click OK.
8. At the Welcome to the domain screen, click OK.
9. When the warning that you must restart dialog appears, click OK.
10. Click OK to close the System Properties window.
11. Click Yes to the pop-up message to restart the computer.
12. Login to the domain by using Administrator and Password1.
13. Install Microsoft Outlook 2003 with the default settings. (Outlook 2003 doesn't require any configuration.)
14. Install LoadSim 2003 by double-clicking the loadsim.msi installation file. Accept all defaults.
15. Open LoadSim 2003, and make sure no error messages appear.
16. Repeat steps 1-15 five times on new machines to form the client cluster.

Configuring LoadSim 2003

1. Start LoadSim by clicking Start Menu→All Programs→Exchange LoadSim→LoadSim 2003 with Remote.
2. From the LoadSim menu bar, select Configuration→Topology Properties.
3. Click the Servers tab.
4. In the left pane, click the + next to the name of this server.
5. In the left pane, select the First Storage Group.
6. In the right pane, you will see four databases. Set the number of users to 2000 for each database.
7. Select the Security and Credentials tab.
8. Leave the Credentials choice set to Login to users using the account LoadSim is running on.
9. In the password portion of the tab, enter the password `Password1`, and click OK.
10. From the LoadSim menu bar, select Configuration→Test Properties, and click Add.
11. In the number of users box, select 1333 users, click OK.
12. Click Customize Tasks.
13. Select the Initialization tab.
14. Enter the following settings:
    - Number of messages in Inbox: 10
    - Number of messages in Deleted items: 1
    - Number of new folders: 3
    - Messages per new folder: 10
    - Number of Smart Folders: 3
    - Number of Rules in Inbox: 5
    - Initialize Free/Busy Information: Leave it unselected
    - Number of appointments: 10
    - Number of contacts: 32
15. Click OK.
16. In Test Properties, select that first mailserver and click Copy five times.
17. Arrange the other machines in this manner:
    - Client 2: First user: 1333, Number of users: 1333
    - Client 3: First user: 2666. Number of users: 1334
    - Client 4: First user: 4000. Number of users: 1333
    - Client 5: First user: 5333. Number of users: 1333
    - Client 6: First user: 6666. Number of users: 1334
18. In the Test Properties window, change the run time to 30 minutes, and click OK.
19. From the LoadSim menu bar, choose File→Save As.
20. Save a backup copy of the simulation file as C:\loadsim.sim.
21. From the LoadSim menu bar, select Run→Create Topology, and wait until the Creating Users and Creating DLs tasks complete.
22. From the LoadSim menu bar, select Remote Control→Control.
23. From the LoadSim menu bar, select Remote Control→Share SIM file.
24. From the LoadSim menu bar, select Remote Control→Initialize→All.

25. The run is complete when the bottom LoadSim window shows Status: Idle. This task typically takes about 2 to 3 hours to complete.
26. From the LoadSim menu bar, select Run→Run Simulation.
27. The run is complete when the bottom LoadSim window shows Status: Idle. This task typically takes a little over 2 hours to complete.

Changing servers between tests

We performed the following steps between tests on subsequent servers to minimize the amount of time required for setting up each subsequent server. Note: This eliminates the need to create and configure the master VM and clone the VM on each server.

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Confirm that all VMs are in the Off State. If all VMs are in the Off State, skip to Step 5.
3. To shut down a VM that is not in the Off State, right-click the VM.
4. Select Shut down…
5. Right-click the VM, and select Settings…
6. Select Network Adapter.
7. Click Remove, and click Apply.
8. Select Disk Drive under IDE Controller 0.
9. Click Remove, and click Apply.
10. Select Disk Drive under SCSI Controller.
11. Click Remove, and click Apply.
12. Select next Disk Drive under SCSI Controller.
13. Click Remove, and click Apply.
14. Select last Disk Drive under SCSI Controller.
15. Click Remove, and click Apply.
16. Repeat Steps 5 through 15 for the remaining VMs.
17. Click OK to finish.
18. Close Hyper-V Manager.
19. Click Start→Administrative Tools→Computer Management.
20. Click Disk Management.
21. With the exception of the C: drive, right-click each volume and select offline. This cleanly unmounts the SAN drives.
22. Shut down the server.
23. Switch the QLogic FC HBA to the next server, using the steps outlined above in the section Setting up the Storage Area Network (SAN). Note: You will not need to initialize the disks, as they have already been initialized.
24. Click Start→Administrative Tools→Computer Management.
25. Click Disk Management.
26. With the exception of the C: drive, right-click each volume, and select Online.
27. Click Start→Administrative Tools→Hyper-V Manager.
28. Right-click each VM, and select Settings…
29. Select Add Hardware.
30. Select Network Adapter, and click Add.
31. Select the appropriate configuration from the drop-down menu and click Apply.
32. Select Add Hardware.
33. Select SCSI Controller, and click Add.
34. Click Apply.
35. Select IDE Controller 0.
36. Select Disk Drive, and click Add.
37. Browse to the appropriate location for the appropriate VHD file (i.e., OS LUN, MailServer1 folder), and click Apply.
38. Select SCSI Controller.
39. Select Disk Drive, and click Add.
40. Browse to the appropriate location for the appropriate VHD file (i.e., MailDB LUN, MailServer1 folder),

41. Click Apply.
42. Select SCSI Controller.
43. Select Disk Drive, and click Add.
44. Browse to the appropriate location for the appropriate VHD file (i.e., MailBackup LUN, MailServer1 folder),
45. Repeat steps 28 through 44 for the remaining VMs.
46. Click OK to finish.

Power measurement procedure

To record each server's power consumption during each test, we used an Extech Instruments (www.extech.com) 380803 Power Analyzer/Datalogger. We connected the power cord from the server under test to the Power Analyzer's output load power outlet. We then plugged the power cord from the Power Analyzer's input voltage connection into a power outlet.

We used the Power Analyzer's Data Acquisition Software (version 2.11) to capture all recordings. We installed the software on a separate Intel processor-based PC, which we connected to the Power Analyzer via an RS-232 cable. We captured power consumption at one-second intervals.

To gauge the idle power usage, we recorded the power usage for two minutes while each system was running Hyper-V and the appropriate number of VMs, but otherwise idle, meaning they were not running any test workload.

We then recorded the power usage (in watts) for each system during the testing at one-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results. We call this time the power measurement interval. See Figure 7 (idle and average peak power) for the results of these measurements.

Appendix A – Server configuration information

This appendix provides detailed configuration information about the servers, which we present in alphabetical order in Figure 8.

Servers	AMD Opteron 2384-based server	Intel Xeon processor X5570-based server	Intel Xeon processor E5450-based server	64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server
General processor setup				
Number of processor packages	2	2	2	2
Number of cores per processor package	4	4	4	1
Number of hardware threads per core	1	2	1	2
CPU				
Vendor	AMD	Intel	Intel	Intel
Name	Opteron 2384 (Shanghai)	Xeon X5570 (Nehalem)	Xeon E5450 (Harpertown)	3.6 GHz Xeon with 2MB L2 cache (Irwindale)
Stepping	2	5	C0	R0
Socket type	Socket F	LGA 1366	LGA 771	Socket 604
Core frequency (GHz)	2.7GHz	2.93 GHz	3.0 GHz	3.60GHz
Front-side bus frequency (MHz)	2.0 GT/s HyperTransport	6.4 GT/s (QPI)	1,333 MHz	800
L1 cache	64KB + 64KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	12KB + 16KB
L2 cache	2MB (4 x 512 MB)	1 MB (4 x 256 KB)	12 MB (2 x 6,144 MB)	2 MB (1 x 2,048 MB)
L3 cache	1 x 6MB	1 x 8 MB	N/A	N/A
Platform				
Vendor and model number	Supermicro A+ Server 2021M-T2R+V	Supermicro SuperServer	Supermicro SuperServer 6025B-TR+	Supermicro 6024H-T
Motherboard model number	H8DME-2	X8DTN+	X7DBE+	X6DHT-G
Motherboard chipset	NVIDIA MCP55	Intel 5520	Intel 5000P	Intel E7520
Motherboard revision number	01	1.02	B1	01
BIOS name and version	AMIBIOS 08.00.14 (10/13/08)	American Megatrends v4.6.3.2 (01/13/2009)	PhoenixBios v2.1 (06/23/08)	Phoenix Technologies LTD 6.00 (08/16/2007)
BIOS settings	Default	Turbo Mode Disabled Intel Virtualization Technology Enabled	Intel Virtualization Technology Enabled	HyperThreading Technology Disabled

Servers	AMD Opteron 2384-based server	Intel Xeon processor X5570-based server	Intel Xeon processor E5450-based server	64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server
Memory module				
Vendor and model number	Kingston KVR667D2S4P5/4G	Micron MT36JSZF51272PY-1G1D1	Kingston KVR667D2D4F5/4GI	Samsung M312L5720DZ3-CB3
Type	DDR2 PC2-5300	DDR3 PC3-8500	DDR2 PC2-5300 FB-DIMM	DDR PC2700R
Speed (MHz)	667	1,066	666	333
Speed in the system currently running @ (MHz)	533	800	666	333
Timing/Latency (tCL-tRCD-iRP-tRASmin)	4-4-4-12	6-6-6-16	5-5-5-15	2.5-3-3-10
Size	64 GB (16 x 4 GB)	72 GB (18 x 4 GB)	64 GB (16 x 4 GB)	4GB (2 x 2 GB)
Number of RAM modules	16	16	16	2
Chip organization	Double-sided	Double-sided	Double-sided	Double-sided
Hard disk				
Vendor and model number	Western Digital WD1601ABYS	Western Digital WD1600AAJS-00B4A0	Western Digital WD1600AAJS	Western Digital WD1600YD
Number of disks in system	1	1	1	6
Size (GB)	160	160	160	160
Buffer size (MB)	16	8	8	8
RPM	7,200	7,200	7,200	7,200
Type	SATA	SATA	SATA	SATA
Controller	NVIDIA nForce SATA controller	Intel Corporation ICH10 SATA AHCI Controller	Intel ESB2 RAID Controller	Adaptec Serial ATA HostRAID
Driver version	NVIDIA 5.10.2600.830 (04/23/2007)	Microsoft 6.0.6001.18000 (06/21/2006)	Microsoft 6.0.6001.18000 (06/21/2006)	Adaptec 1.1.5735.0 (01/13/2006)
Operating system				
Name	Microsoft Windows Server 2008 Enterprise Edition	Microsoft Windows Server 2008 Enterprise Edition	Microsoft Windows Server 2008 Enterprise Edition	Microsoft Windows Server 2003 R2 Enterprise Edition
Build number	6001	6001	6001	3790
Service pack	SP1	SP1	SP1	SP2
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI Multiprocessor PC
Language	English	English	English	English
Graphics				
Vendor and model number	ATI ES1000	ATI ES1000	ATI ES1000	ATI Rage XL SVGA PCI Video
Chipset	ES1000	ES1000	ES1000	ATI Rage XL
Type	Integrated	Integrated	Integrated	Integrated

Servers	AMD Opteron 2384-based server	Intel Xeon processor X5570-based server	Intel Xeon processor E5450-based server	64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server
Memory size (MB)	16	32	16	8
Resolution	1,024 x 768	1,024 x 768	1,024 x 768	1,024 x 768
Network card/subsystem				
Vendor and model number	Intel Pro/1000	Intel 82576 Gigabit Ethernet	Intel Pro/1000 EB	Intel PRO/1000 MT
Type	Integrated	Integrated	Integrated	Integrated
Driver version	Microsoft 6.2.0.126 (6/21/2008)	Intel 10.3.49.400 (12/11/2008)	Intel 9.12.36.0 (12/04/2008)	Intel 8.10.3.0 (8/20/2008)
Optical drive				
Vendor and model number	Matshita DVD-ROM UJDA780	Slimtype DVD A DS8A1P	Matshita DVD-ROM SR-8178	TEAC CD-224E-N
USB ports				
Number	4	4	4	2
Type	USB 2.0	USB 2.0	USB 2.0	USB 2.0
Power supplies				
Total number	2	2	2	1
Wattage of each	700W	805W	700W	550W
Cooling fans				
Total number	3	3	3	4
Dimensions	3” x 3”	3” x 3”	3” x 3”	3.25” x 3.25”
Voltage	12V	12V	12V	12V
Amps	1.1A	1.1A	1.1A	1.1A

Figure 8: Detailed system configuration information for the four test servers.

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When the assessment is complete, we know how to present the results to a broad range of target audiences. We provide our clients with the materials they need, from market-focused data to use in their own collateral to custom sales aids, such as test reports, performance assessments, and white papers. Every document reflects the results of our trusted independent analysis.

We provide customized services that focus on our clients' individual requirements. Whether the technology involves hardware, software, Web sites, or services, we offer the experience, expertise, and tools to help you assess how it will fare against its competition, its performance, whether it's ready to go to market, and its quality and reliability.

Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.

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