



vConsolidate performance and power on quad- and dual-processor Intel- and AMD-based servers

Executive summary

Intel® Corporation (Intel) commissioned Principled Technologies® (PT) to measure power and performance with Intel's vConsolidate version 2.0 workload using Windows Server 2008 Hyper-V on quad- and dual-processor servers using the following processors:

- Intel Xeon® processor X7460
- Intel Xeon processor X7350
- AMD® Opteron® processor 8360 SE
- Intel Xeon processor X5470

The quad-processor servers were similarly configured with four processors, 16 4GB DIMMs, and identical PCI-e NICs and HBAs. The dual-processor server had similar NIC's and HBAs, but had 16 2GB DIMMs. Figure 1 shows the vConsolidate results for all four servers. It provides a comparison for the test servers with the optimal number of vConsolidate work units, consolidation stack units (CSUs). For the quad-processor servers, the Intel Xeon processor X7460-based server achieved optimal performance with six CSUs. The Intel Xeon processor X7350-based server achieved optimal performance with five CSUs, while the AMD Opteron processor 8360 SE-based server achieved optimal performance with seven CSUs. The dual-processor Intel Xeon processor X5470-based server achieved optimal performance with three CSUs. (See the Workload section and later sections for more on CSUs.)

KEY FINDINGS

- The Intel Xeon processor X7460-based server delivered 44.3 percent more performance running vConsolidate with the optimum number of CSUs than the AMD Opteron processor 8360 SE-based server, 105.1 percent more performance than the Intel Xeon processor X5470-based server, and 39.8 percent more performance than the Intel Xeon processor X7350-based server (see Figure 1).
- The Intel Xeon processor X7460-based server produced 37.7 percent better performance per watt with the optimal number of CSUs than the AMD Opteron processor 8360 SE-based server, 31.4 percent more performance per watt than the Intel Xeon processor X5470-based server, and 52.5 percent more performance per watt than the Intel Xeon processor X7350-based server. (see Figure 2).

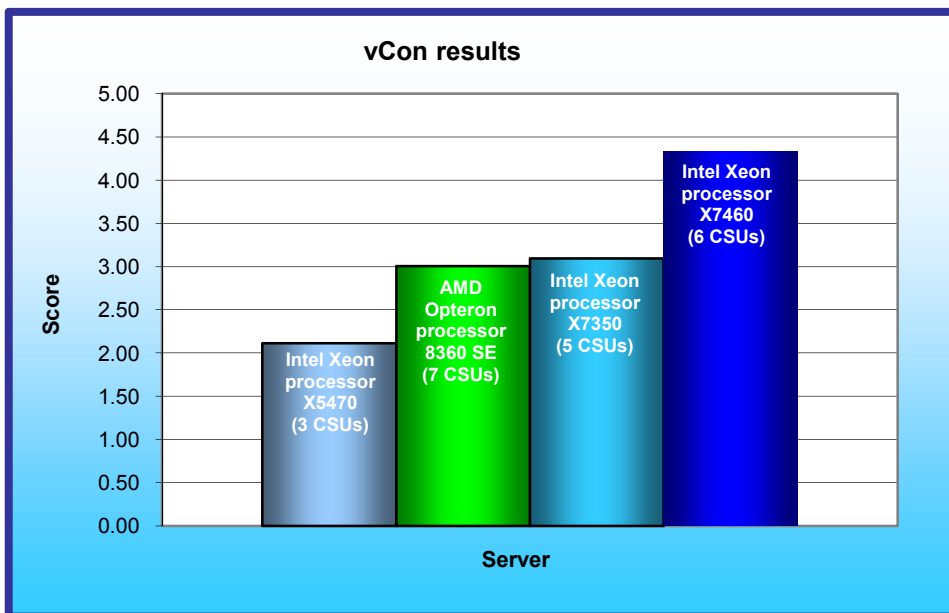


Figure 1: vConsolidate results at the optimal number of CSUs for the four servers we tested.

In this section, we discuss the best results for all servers. For complete details of the performance of each server at its optimum number of CSUs, see the Test results section.

As Figure 1 illustrates, the Intel Xeon processor X7460-based server delivered 44.3 percent more performance running vConsolidate with the optimum number of CSUs than the AMD Opteron processor 8360 SE-based server, 105.1 percent more performance than the Intel Xeon processor X5470-based server, and 39.8 percent more performance than the Intel Xeon processor X7350-based server.

As Figure 2 shows, the Intel Xeon processor X7460-based server produced 37.7 percent better performance per watt at the optimal number of CSUs than the AMD Opteron processor 8360 SE-based server, 31.4 percent more performance per watt than the Intel Xeon processor X5470-based server, and 52.5 percent more performance per watt than the Intel Xeon processor X7350-based server.

This chart normalizes the results to the lower-performing server, the Intel Xeon processor X7350-based server. That system's score is thus 1.00. Normalizing makes each data point in the chart a comparative number, with higher numbers indicating better performance per watt.

We calculated performance per watt by dividing the vConsolidate score for each server at the optimal number of CSUs by the measured power when running the optimal number of CSUs for a minimum 30-minute interval. We measured power at 208 V on all servers.

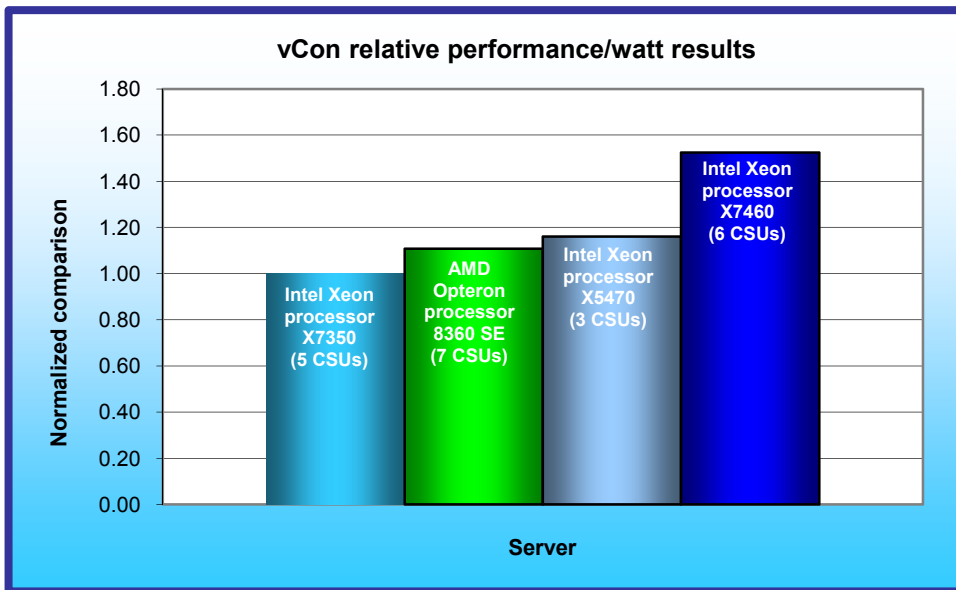


Figure 2: Relative vConsolidate performance/watt results at the optimal number of CSUs for the four servers we tested.

Workload

Intel defined, implemented, and supplied the vConsolidate version 2.0 workload. vConsolidate includes four different performance tests—database, Java, mail, and Web—that run simultaneously in different virtual machines (VMs) on a server. A fifth, idle VM is also present during the test. vConsolidate refers to a single collection of these five virtual machines as a consolidate stack unit (CSU). Depending on the type of server and its available resources, testers can choose to run one or more CSUs. The typical goal is to

run enough CSUs to push the server under test to its maximum capacity by consuming close to 100 percent of the CPU capacity.

vConsolidate sums the throughput results of each type of work across all CSUs in a test. Then it amalgamates the combined throughputs of all CSUs to create an overall score for the server under test. See the Test results section for more information on this process.

vConsolidate uses the following four performance tests:

LoadSim

Microsoft Exchange Server 2003 Load Simulator (LoadSim) is a benchmark that measures a server's performance handling email. LoadSim uses the MAPI Messaging Benchmark 3 (MMB-3) to simulate MAPI email clients. The simulated clients issue requests to an Exchange server to generate an email load. LoadSim measures both the server's response time and the number of messages it delivers. LoadSim is available for free download from www.microsoft.com/downloads/details.aspx?FamilyId=92EB2EDC-3433-47CA-A5F8-0483C7DDEA85&displaylang=en.

SPECjbb2005

SPECjbb2005 is an industry-standard benchmark from the Standard Performance Evaluation Corp. (SPEC) that measures a server's Java performance. (Note: SPEC and SPECjbb2005 are trademarks of the Standard Performance Evaluation Corporation.) SPEC modeled SPECjbb2005 on the three-tier client/server architecture, with the middle layer as the primary focus. According to SPEC, "Random input selection represents the first (user) tier. SPECjbb2005 fully implements the middle tier business logic. The third tier is represented by tables of objects, implemented by Java Collections, rather than a separate database." For more information about SPECjbb2005, see www.spec.org/jbb2005/docs/UserGuide.html.

The results we quote here for this workload are not official SPECjbb2005 results because the vConsolidate workload uses a slightly modified version of the benchmark. These results are not comparable to SPECjbb2005 results on SPEC's Web site.

SysBench

The developers at SourceForge.net (www.sourceforge.net) created SysBench to test various aspects of the performance of servers running database systems. The benchmark's original target was the MySQL database system (see www.mysql.com). Intel created a version of SysBench 0.4.0 that would work with Microsoft SQL Server 2005 Enterprise Edition (www.microsoft.com/sql/editions/enterprise/default.msp). We ran that version in our test. In the vConsolidate workload, SysBench created a 100,000-row SQL database and executed a batch of online transaction processing (OLTP) transactions against that data.

WebBench

WebBench 5.0 (128-bit US version) is an industry-standard benchmark for Web server software and hardware. It uses PC clients to send Web requests to the server under test. It generates performance results by incrementally increasing the number of clients making HTTP 1.0 GET requests to the Web server; the result is a curve showing the server's performance under increasing load. The peak of that curve represents the peak throughput of the server. WebBench reports both the total number of requests per second the server handled and the server's total throughput in bytes per second. To be certain that we found the true peak performance in our testing, we verified that the server's processor utilization reached or was extremely close to 100 percent during the test.

vConsolidate profiles

The vConsolidate workload comes with four sets of VM specifications, which it calls profiles. These profiles define five key factors for each workload VM:

- number of virtual CPUs (vCPUs) the workload should receive
- amount of virtual RAM (vMemory) the workload should receive
- the operating system (OS) the workload should run
- the key application the workload should run
- the workload itself

As we noted earlier, vConsolidate refers to a single collection of these five virtual machines as a consolidate stack unit (CSU). Depending on the type of server and its available resources, you may choose to run one or more CSUs. The typical goal is to run enough CSUs to push the server under test to its maximum capacity by consuming close to 100 percent of the CPU capacity. vConsolidate offers four profiles; we tested with Profile 2, which we detail in Figure 3.

	Profile 2			
	vCPUs	vMemory	OS	Application
WebBench (Web)	2	1.5 GB	Windows 32-bit	IIS
LoadSim (mail)	1	1.5 GB	Windows 32-bit	Exchange
SysBench (database)	2	1.5 GB	Windows 64-bit	SQL Server
SPECjbb2005 (Java)	2	2.0 GB	Windows 64-bit	BEA JVM
Idle	1	0.4 GB	Windows 32-bit	NA

Figure 3: The vConsolidate profile we used in our testing.

For further information on vConsolidate, please contact Intel.

Test results

The result for an execution of the vConsolidate workload amalgamates the results of all four of the workloads it includes. To calculate a final score for a vConsolidate run, we used the following four steps, as vConsolidate specifies:

1. Benchmark throughput = benchmark's raw results/benchmark duration (for each of the four benchmarks)
2. Total benchmark throughput = add benchmark throughput for all CSUs in test
3. Normalized throughput = total benchmark throughput/reference system's benchmark throughput
4. vConsolidate score = geomean (normalized throughput of all four benchmarks)

The first step in this process uses whatever raw results a benchmark produces, such as number of transactions or operations, and the benchmark's duration in seconds. We calculate a benchmark's duration by subtracting the start time of the vConsolidate test from its stop time and converting that time to seconds. WebBench is an exception to this process because it automatically produces a score in requests per second. For this benchmark, we calculate the average requests per second for the three WebBench mixes that run while the other benchmarks are running and record this result as its throughput.

The second step is to sum the throughput for a given benchmark across all CSUs. In the one-CSU case, there is no need for this step. For the two-, three-, four-, five-, and six- CSU tests, we summed the throughput of each individual benchmark across all CSUs to obtain that benchmark's final score.

The third step is to normalize the throughput. We use the one-CSU score of one of the systems under test as the reference system and assign it a normalized score of 1.00. We then divide the summed throughput for a given type of work by the reference score for that benchmark. This produces the normalized score for that type of work in this test. In this test, we used as the reference score the one-CSU score on the Intel Xeon processor X7350-based server. The last step is to take the geometric mean of the normalized throughput for all four benchmarks.

Figure 4 shows the final score (the median of three runs) and CPU utilization of the test servers by number of CSUs. The CPU utilization percentage is the average over the period the vConsolidate workload ran.

The optimum CSU for all systems is the number of CSUs that produce the peak score. For example, the Intel Xeon processor X7460-based server produced a peak score of 4.34 at six, seven, and eight CSUs. This means its optimum is six CSUs. The score stays the same for the higher numbers of CSUs, which means it can still handle the load of more virtual machines; however, its optimum score remains six CSUs. For the AMD Opteron processor 8360 SE-based server we performed one run at eight CSUs to ensure it did not get a better score; that run produced worse results, so we present results through only seven CSUs for that system.

Server	AMD Opteron processor 8360 SE		Intel Xeon processor X5470		Intel Xeon processor X7350		Intel Xeon processor X7460	
	Score	CPU	Score	CPU	Score	CPU	Score	CPU
1	1.13	33%	1.38	59%	1.17	33%	1.22	22%
2	2.08	64%	2.03	92%	2.23	65%	2.33	43%
3	2.56	91%	2.12	98%	2.85	89%	3.26	65%
4	2.70	96%			3.03	96%	3.92	86%
5	2.78	98%			3.10	98%	4.23	94%
6	2.94	99%			3.10	99%	4.34	97%
7	3.01	100%			3.03	100%	4.34	98%
8							4.34	99%

Figure 4: vConsolidate results for the four test systems with varying numbers of CSUs with corresponding CPU utilizations. Higher scores are better.

Figure 5 details the power consumption, in watts, of the test servers while idle and during the median peak number of CSUs.

Server	Idle power (watts)	Average power (watts)
AMD Opteron processor 8360 SE	519.91	723.09
Intel Xeon processor X5470	385.88	485.44
Intel Xeon processor X7350	539.38	824.60
Intel Xeon processor X7460	534.77	757.91

Figure 5: Average power usage (in watts) of the test servers while idle and during the median peak CSU runs. Lower numbers are better.

Figure 6 shows the seven-CSU test results, by benchmark and CSU, for the AMD Opteron processor 8360 SE-based server.

AMD Opteron processor 8360 SE-based server	Database	Java	Mail	Web	Final score
CSU 1	40.31	7,628.59	14.77	253.95	
CSU 2	40.89	9,327.90	14.34	258.47	
CSU 3	39.18	7,860.90	14.34	259.81	
CSU 4	40.52	8,152.39	14.68	250.38	
CSU 5	48.66	8,202.46	15.12	261.44	
CSU 6	48.89	8,206.49	13.91	253.08	
CSU 7	39.08	8,185.22	10.58	257.39	

Figure 6: vConsolidate seven-CSU median results, by benchmark and CSU, for the AMD Opteron processor 8360 SE-based server. Higher scores are better.

Figure 7 shows the three-CSU test results, by benchmark and CSU, for the Intel Xeon processor X5470-based server.

Intel Xeon processor X5470-based server	Database	Java	Mail	Web	Final score
CSU 1	76.65	17,307.78	15.37	460.31	
CSU 2	74.35	17,411.25	14.91	456.11	
CSU 3	77.03	17,516.81	15.06	447.16	

Figure 7: vConsolidate three-CSU median results, by benchmark and CSU, for Intel Xeon processor X5470-based server. Higher scores are better.

Figure 8 shows the five-CSU test results, by benchmark and CSU, for the Intel Xeon processor X7350-based server.

Intel Xeon processor X7350-based server	Database	Java	Mail	Web	Final score
CSU 1	60.61	15,208.48	15.29	383.43	
CSU 2	60.02	15,270.64	15.18	380.69	
CSU 3	59.99	15,209.45	15.14	388.93	
CSU 4	60.63	15,307.38	15.67	380.86	
CSU 5	61.38	15,346.50	15.56	389.91	

Figure 8: vConsolidate five-CSU median results, by benchmark and CSU, for the Intel Xeon processor X7350-based server. Higher scores are better.

Figure 9 shows the six-CSU test results, by benchmark and CSU, for the 6-Core Intel Xeon processor X7460-based server.

Intel Xeon processor X7460-based server	Database	Java	Mail	Web	Final score
CSU 1	80.80	18,247.28	14.67	445.98	
CSU 2	80.99	18,186.89	14.86	444.86	
CSU 3	81.10	18,319.26	16.18	454.22	
CSU 4	82.69	18,249.15	15.51	448.64	
CSU 5	80.70	18,305.59	14.01	445.79	
CSU 6	81.58	18,343.71	15.35	451.73	

Figure 9: vConsolidate six-CSU median results, by benchmark and CSU, for the 6-Core Intel Xeon processor X7460-based server. Higher scores are better.

We include complete results for all three runs on the four test systems in Appendix B.

Note: Due to the complexity and number of components the vConsolidate benchmark uses (e.g., network interfaces, client computers, storage sub-system, configuration of VMs and benchmark components), Intel does not recommend directly comparing test results from this report with results from other vConsolidate reports. Unless the benchmark and its components have identical configurations, results may vary, providing an inadequate basis for direct comparison.

Test methodology

Intel configured and provided all servers.

With the following exception, we used the default BIOS settings on each server: we enabled Intel Virtualization Technology on all Intel based servers. On the AMD Opteron processor 8360 SE-based server we enabled AMD Virtualization and No-Execute Page-Protection, and set Power Regulator for ProLiant to Static Performance mode.

To be sure we could push the processors of each of the four system configurations to their maximum capacities, we tested each server with as many vConsolidate CSUs as the server could handle, starting with one CSU, up to or extremely close to 100 percent processor utilization. The rest of this section details how we set up the servers and the vConsolidate workload.

Hardware and software the test involved

Software

We used the following software to configure and run the vConsolidate workload:

- Windows Server 2008 Hyper-V
- Microsoft Windows Server 2003 R2, Enterprise Edition
- Microsoft Windows Server 2003 R2, Enterprise x64 Edition
- Microsoft Exchange Server 2003
- Microsoft SQL Server 2005
- BEA JRockit 1.6.0_02-b05
- WebBench 5.0
- Microsoft Exchange Server Load Simulator (LoadSim) 06.05.7775
- SPECjbb2005 v1.07
- SysBench v0.4.0
- Intel vConsolidate OEM framework package version 1

Hardware

Our test bed consisted of the following hardware:

- The server under test

- Eleven custom-built Intel Desktop Board D915GMH with Intel Pentium 4 3.0GHz w/HT systems, which we used for all WebBench clients, LoadSim clients, and WebBench controllers (CSU 2 and CSU 3).
- One custom-built Intel Server Board D945GTP system, which we used as both the main vConsolidate controller and the CSU 1 WebBench controller
- NETGEAR GS724T, which we set up into two VLANs (one for external network and one for internal network)
- EMC CLARiion CX3 storage
- Three EMC CX-4PDAE-FD disk enclosures, with 15 x Hitachi HUS151473VLF4E0 73.4 GB disk drives each
- QLogic SANblade QLE2462 Dual Port 4-Gbps Fibre Channel Host Bus Adapter (HBA) installed in the server under test

Figure 10 illustrates the test bed.

vConsolidate test bed

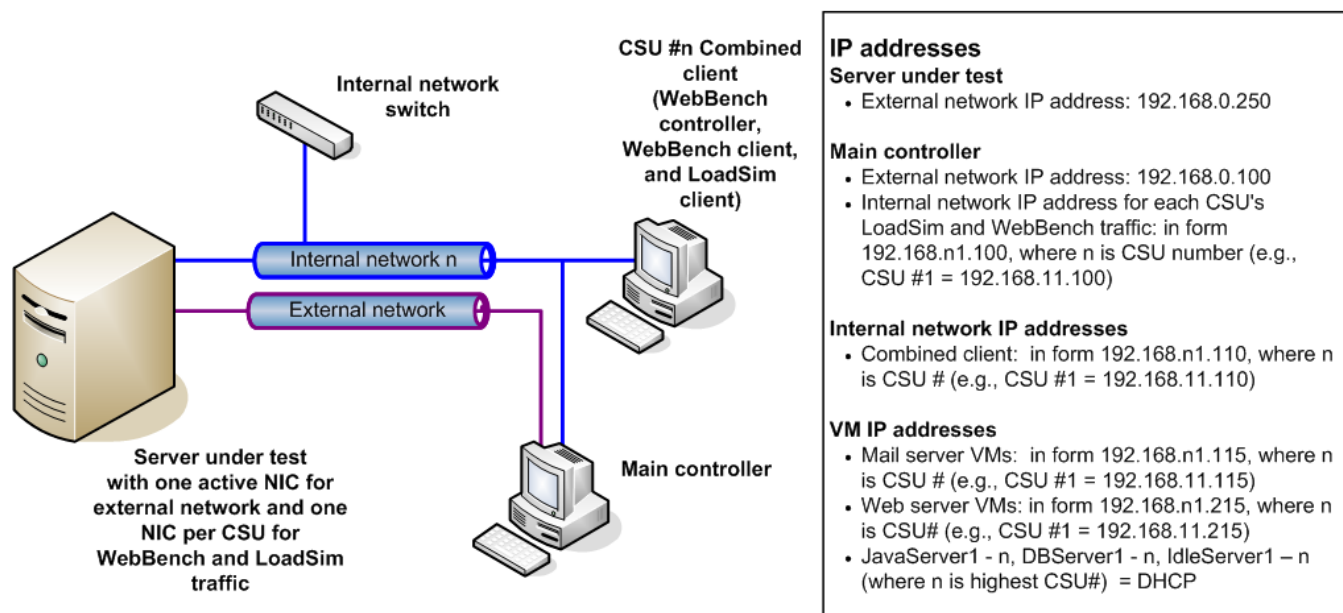


Figure 10: Our vConsolidate test bed.

Server installation

We configured all servers with the same disk setup using the EMC CLARiion CX3. We split the storage into four volumes, one with 10 GB and five with 130 GB. For each server, we installed Windows Server 2008 Hyper-V on the 10GB volume and installed a CSU on each of the five 130GB volumes. We installed the boot loader on the hard drive installed in the server's drive chassis on the server under test.

Adding the Hyper-V role to Windows Server 2008

Note: Make 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 07/21/2008, this update is KB950050 on 64-bit Windows.)

1. Click Server Manager→Roles→Add Roles.
2. Check the box beside the Hyper-V role, and click Next.
3. Click Next.

4. Check the box beside the Ethernet card you wish to use, and click Next.
5. Click Install. Installation begins.
6. When installation finishes, click Close.
7. When the system prompts you to restart, click Yes.
8. Once the system finishes rebooting (this might happen twice), log in. The Resume Configuration Wizard should start automatically.
9. Once the Resume Configuration Wizard completes, the installation results should appear with a message that the installation succeeded.
10. Click Close.
11. Restart the server.

Adding logical unit numbers (LUNs)

Note: Make sure the Fibre Channel/iSCSI LUN is mapped to the card in your system.

1. Click Server Manager→Storage→Disk Management.
2. When the wizard prompts you to initialize new disks, click OK. Note: If you must select a partition table, select MBR.
3. Right-click the first unallocated disk partition, and select New Simple Volume...
4. Click Next.
5. Use the entire LUN storage space (this should be the default), and click Next.
6. Select the drive letter to assign to the new partition, and click Next.
7. Label the volume appropriately (i.e., LUN0, LUN1, etc.), make sure Perform a quick format is checked, and click Next.
8. Click Finish.

Configure Hyper-V default options

1. Click Start→Administrative Tools→Hyper-V Manager.
2. From the Actions menu, select Hyper-V Settings...
3. From the left menu of the Settings screen, select Virtual Hard Disks, and enter the default folder to store virtual hard disk files (e.g., E:\Hyper-V\Virtual Hard Disks).
4. From the left menu of the Settings screen, select Virtual Machines, and enter the default folder to store virtual hard disk files (e.g., E:\Hyper-V).
5. Click OK.
6. You may also want to configure any VM network switch settings at this time.

Creating a virtual machine

1. Click Start→Administrative Tools→Hyper-V Manager.
2. From the Actions menu, select New→Virtual Machine...
3. Click Next.
4. Enter a name for the virtual machine, and browse to the location where you want to store the VM files. The New Virtual Machine Wizard will automatically create a subfolder with the name of the VM).
5. Click Next.
6. Specify the amount of memory to allocate to the virtual machine, and click Next.
7. Select the network connection for the virtual machine to use, and click Next.
8. Select Attach a virtual hard disk later, and click Next.
9. Click Finish.

Modifying the Virtual Machine (Creating the virtual HDD)

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the Virtual Machine on which you want to install Windows, and click "Settings..."
3. From the menu on the left, select IDE Controller 0, and click Add to add a new hard drive to the IDE Controller.
4. Click New to create a new virtual hard disk file.
5. Click Next.
6. Select Fixed size, and click Next.
7. Specify the name and location of the virtual hard disk file.

8. Specify the size of the new blank virtual hard disk (in GB).
9. Click Finish. The server begins creating the new virtual hard disk.
10. Once it finishes creating the new virtual hard disk, click OK.

Modifying the Virtual Machine (adding an additional hard disk)

Note: Do not use this method to configure the VM primary hard disk; for that you must use a virtual IDE hard disk. However, we recommend that you perform high-usage I/O tasks (i.e., database server, file server, mail server, etc.) on a secondary disk whenever feasible.

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the Virtual Machine on which you want to install Windows, and click Settings...
3. From the menu on the left, select Add Hardware.
4. Choose the "SCSI Controller" device and click Add.
5. Click "Add" to add a new hard drive to the virtual SCSI Controller.
6. Click New to create a new virtual hard disk file.
7. Click Next.
8. Select "Fixed size" and click Next.
9. Specify the name and location of the virtual hard disk file.
10. Specify the size of the new blank virtual hard disk (in GB).
11. Click Finish. The server will then begin creating the new virtual hard disk.
12. Once it finishes creating the new virtual hard disk, click OK.

Installing Windows on the VM

Note: We have tested this using Windows Server 2003 R2 Enterprise x64 Edition with SP2.

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the Virtual Machine on which you want to install Windows, and click Connect...
3. From the menu, select Media→DVD Drive→Insert Disk...
4. Select the ISO image file for the version of Windows you are installing, and click Open.
5. To start the virtual machine, select Start from the Action menu.
6. Click the screen, and begin installing Windows as you normally would.
7. Once installation is complete, select action →Ctrl-Alt-Delete.
8. Enter your password and hit Enter.
9. Select Media→Eject CD.
10. Select Media→Insert CD and choose the second installation disk.
11. When the Windows installation completes select Action→Insert Integration Services Setup Disk from the menu. Installation should begin automatically.
12. At the prompt to restart, click Yes.
13. Once the system has restarted, log in, and verify that all configured devices (mouse, keyboard, video, network, etc.) are working.
14. Once you are sure all your devices are working, from the menu select Media→DVD Drive→Eject vmquest.iso.

Installing vmbus.sys patch

Note: We installed an updated version of vmbus.sys on both systems to provide optimum performance. The version we installed was 6.0.6001.18018. We did not use this patch on the AMD Opteron processor 8360 SE-based server for testing. Note: We tried the runs both with and without the patch to ensure best results and found that on that system we achieved the best results without installing the patch.

1. On both 64-bit and 32-bit virtual machines, copy the vmbus.sys file to C:\WINDOWS\system32\drivers.
2. On all virtual machines, copy the vmbus.sys file to c:\WINDOWS\Virtualization\6.0.6001.18016.
3. On the Hyper-V server, open a command prompt and type `bcdedit /set testsigning on`.
4. Copy the 64-bit vmbus.sys file to c:\WINDOWS\system32\drivers.

To create one vConsolidate CSU, we had to create the five virtual machines that CSU describes:

- mail server
- Web server
- Java application server

- database server
- idle server

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: 1
 - Virtual memory: 1.5 GB
 - Virtual disk size: 10 GB
 - Virtual network: Internal Network (set the IP address to 192.168.11.115 in Windows within the VM)

To finish setting up this VM for vConsolidate, 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 (vcon.com), and click Next.
13. At the NetBIOS Domain Name screen, enter a NETBIOS domain name (vcon), 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 password (password), 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. Enter vcon as the 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 and configuring the Web server VM

1. Follow the steps in the earlier Cloning the base VMs section using the following VM specifications:
 - Source VM: Base32
 - Name: WebServer1 (use WebServer for the Host Name in the VM)
 - Virtual processors: 2
 - Virtual memory: 1.5 GB
 - Virtual Disk Size: 10GB
 - Virtual Network: Internal Network (set the IP address to 192.168.11.215 in Windows within the VM)

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

Installing Microsoft Internet Information Server

1. Select Start→Administrative Tools→Manage Your Server.
2. Select Add or remove a role.
3. At the Configure Your Server window, click Next.
4. At the Configuration Options screen, select Custom configuration, and click Next.
5. At the Server Role screen, select Application Server, and click Next.
6. At the Application Server Options screen, select Enable ASP.NET, and click Next.
7. At the Summary of Selections screen, click Next.
8. When the installation software prompts you to do so, insert the Operating System CD, and click OK.
9. When the installation completes, click Finish.
10. Close the Manage Your Server window.

Installing WebBench 5.0

1. Insert the WebBench 5.0 CD into the Virtual Client, and connect with the Virtual CDROM.
2. Copy wbtrees.exe from the \wb50\workload directory on the CD to C:\inetpub\wwwroot.
3. Double-click wbtrees.exe to expand the workload. (This step will create a wbtrees folder with all the test data WebBench required.)
4. Create a cgi-bin folder in c:\inetpub\wwwroot.
5. After installing the WebBench controller, copy simcgi.exe from the controller machine in C:\WebBench\Controller\Suites\WebBench\Examples directory to the Web server VM's C:\inetpub\wwwroot\cgi-bin\ directory.
6. Right-click My Computer, and select Manage.
7. Expand Services and Applications, Internet Information Services, and Web Sites in the left window pane.
8. Click Default Web Sites.
9. Right-click the cgi-bin directory in the right pane, and select Properties from the drop-down menu.
10. In the Execute permissions field, select Scripts and Executables, and click OK.

11. Using Windows Explorer, browse to C:\inetpub\wwwroot\cgi-bin, right-click simcgi.exe, and select Properties from the drop-down menu.
12. Select the Security tab, and grant Read/Read & Execute permissions to the user, Internet Guest Account.
13. Click OK to close simcgi.exe properties.
14. Close Windows Explorer.
15. In the Computer Management window, right-click the Default Web Server, and select properties from the drop-down menu.
16. Select the HTTP Headers tab, and click MIME Types.
17. In the MIME Types window, click New.
18. In the Extension text box, enter .ex.
19. In the MIME type text box, enter application/octet-stream, and click OK.
20. Click OK again to close the MIME Types window and the Default Web Site Properties window.
21. If a notification window about a child node pops up, click OK.
22. In the Computer Management console, select Web Service Extension.
23. Select All unknown CGI Extensions in the right pane, and click Allow.
24. Click Yes, you do want to allow All Unknown CGI Extensions in the pop-up window.
25. Open a Web browser, and type the URL http://localhost/cgi-bin/simcgi.exe to verify you correctly installed the WebBench files. Text about the system should appear in the browser window.
26. Close the Web browser.

Installing Certificate Server

1. Select Start→Control Panel→Add or Remove Programs.
2. Click Add/Remove Windows Components.
3. Select Certificate Servers, and accept the CA Service warning.
4. Click Next.
5. Select Standalone root CA in the CA Type Windows, and click Next.
6. Enter WEBBENCH in the common name field, and click Next.
7. At the Certificate Database Settings screen, leave the default options, and click Next.
8. When the warning about stopping IIS appears, click Yes.
9. When the installation software prompts you to do so, insert the OS CD, and click OK.
10. Click Yes to enable Active Server Pages.
11. When the installation completes, click Finish.

Creating a certificate request

1. In the Computer Management Console, right-click the Default Web site, and select Properties.
2. Select the Directory Security tab, and then click Server Certificate under Secure Communications to start the Web Server Certificate Wizard.
3. At the Welcome screen, click Next.
4. Select Create a new certificate, and click Next.
5. Select Prepare the request now, but send it later, and click Next.
6. Type Default Web Site for the certificate name.
7. Use the default bit length (1024), and click Next.
8. Type MyWeb for the organization name and Development Dept for the organizational unit, and click Next.
9. Type the server name as the common name, and click Next.
10. Enter your location information, and click Next.
11. Save the certificate information to the default path and file name, and click Next.
12. Verify the information that you have typed, and then click Next to complete the process and create the certificate request.
13. Click Finish to close the IIS Certificate Wizard.
14. Click OK to close the Default Web Site Properties window.

Submitting a certificate request

1. Open a Web browser, navigate to <http://localhost/CertSrv/>, and press Enter.
2. Click Request a certificate.

3. Click Advanced certificate request.
4. Click Submit a certificate request by using a base-64-encoded CMC or PKCS #10 file, or submit a renewal request by using a base-64-encoded PKCS #7 file.
5. Open the request document that you created in the Create a certificate request section.
6. Copy the contents of the document to a text box with the following format.
 - -----BEGIN NEW CERTIFICATE REQUEST-----
 -
 - -----END NEW CERTIFICATE REQUEST-----

Note: If you saved the document with the default name and location, it is located at C:\Certreq.txt. Be sure to copy all of the content as we illustrated above.
7. Paste the contents of the document into the Web form's Base64 Encoded Certificate Request text box.
8. Click Submit.
9. You should receive a Certificate Pending message in the Web browser.
10. Close the Web browser window.

Issuing and downloading a certificate

1. Select Start→All Programs→Administrative Tools→Certificate Authority.
2. In the Certificate Authority window, expand the server name.
3. Click the Pending Requests folder.
4. In the pending request folder, right-click the pending certificate request that you just submitted, select All Tasks, and then click Issue. (Note: After you select Issue, the certificate no longer appears in this window and folder. It now resides in the Issued Certificate folder.)
5. Close the Certificate Authority window.
6. Open a Web browser, and type `http://localhost/CertSrv/`.
7. Click View the status of a pending certificate request.
8. Click the certificate request that you can see.
9. Click Download Certificate.
10. Click Save in the File Download window.
11. Save the certificate to C:\.
12. Close the download complete pop-up window.
13. Close the Web browser window.

Installing the certificate and setting up an SSL Web site

1. Open the Computer Management console by right-clicking My Computer, and selecting Manage.
2. Right-click the Default Web site, and select Properties.
3. Select the Directory Security tab.
4. Under Secure Communications, click Server Certificate. This step will start the Certificate Installation Wizard.
5. At the Welcome screen, click Next.
6. Select Process the pending request and install the certificate, and click Next.
7. Browse to the location of the certificate that you downloaded in the Issue and download a certificate section, and click Next.
8. Keep the default SSL Port, and click Next.
9. Verify the information is correct on the Certificate Summary page, and click Next.
10. Click Finish to complete the installation.
11. Click OK to close the Default Web Site Properties window.
12. Close the Computer Management window.

Configuring and testing the certificate

1. Open a Web browser, and type `https://webserver/cgi-bin/simcgi.exe`.
2. You may receive a security alert that states that the certificate is not from a trusted root CA. Click Yes to continue to the Web page.
3. If the page appears, you have successfully installed the certificate.
4. Close the Web browser.

Installing and configuring the Java application server VM

1. Follow the steps in the earlier Cloning the base VMs section using the following VM specifications:
 - Base VM: Base64
 - Name: JavaServer1
 - Virtual processors: 2
 - Virtual memory: 2 GB
 - Virtual Disk Size: 10 GB
 - Virtual Network: External Network (keep the default Windows Network DHCP settings)

To finish setting up this VM for vConsolidate, we had to install and modify an additional software component. The following subsections detail the necessary installation processes.

Installing SPECjbb2005

1. Copy the BEA JRockit JVM 1.6.0_02 folder to the root of C: in the VM.
2. Install SpecJBB2005 in the VM directory: c:\vSpecJBB2005.
3. Add the BEA JRockit JVM to the Windows system path by doing the following:
 - a. Right-click My Computer, and select Properties.
 - b. Select the Advanced tab, and click Environment Variables.
 - c. In the System variables section, select Path, and click Edit.
 - d. Add the following to the end of the Variable value string: C:\jrockit-jdk1.6.0_02 \bin (jrockit-jdk1.6.0_02 is the folder name of the JVM installation).
 - e. Click OK to close the Edit System Variable, Environment Variables, and System Properties windows.
4. Open a command prompt by selecting Start→Run.
5. Type `cmd`, and click OK.
6. Change to the vSpecJBB2005 directory by typing `cd C:\vSpecJBB2005`, and then press Enter.
7. Type `runit.bat`, and press Enter to verify SPECjbb2005 starts.
8. Press Ctrl-C to stop the benchmark.
9. Confirm that you do want to stop the run by typing `Y` and pressing Enter.
10. Copy the following files from the vConsolidate package to the VM directory C:\:
 - `Daemon.exe`
 - `killapp.exe`

Modifying SPECjbb2005

To run the vConsolidate benchmark, you must modify SPECjbb2005 as follows:

1. Modify the following three original source files in the SPECjbb directory (C:\SPECjbb2005\src\spec\jbb\)
by opening each file with WordPad and making the changes below. Save each file after you have made the changes.
 - `Company.java`
Change `private long measurement_time;` to `public long measurement_time;`
Change `JBBUtil.SecondsToSleep((int) measurement_time);` to
`JBBUtil.SecondsToSleep(Long.MAX_VALUE/1000);`
 - `DeliveryTransaction.java`
After the line `customerPtr.adjustBalance(matchingOrder.getTotalAmount());`, add the following lines:
`int timerCount = 0;`
`timerCount = (short)JBBUtil.random(1,100);`
`if (timerCount == 1)`
`JBBUtil.millisecondsToSleep(company.measurement_time);`
 - `TransactionManager.java`
Change `myTimerData.updateTimerData(txntype, txntime);` to the following lines:
{
`myTimerData.updateTimerData(txntype, txntime);`
`if (txntype==0 && myTimerData.getTransactionCount(0)%1000 == 0) {`
`int sum = 0;`
`for (int k=0; k<=5; k++)`

```

        sum += myTimerData.getTransactionCount(k);
        System.out.println("====+this+":"+"+"===="+sum);
    }
}

```

2. Open the command prompt by clicking Start→Run, type cmd, and press Enter.
3. At the command prompt, type `cd C:\SPECjbb2005\src\spec\jbb\`.
4. At the command prompt, type the following commands. Press Enter after each command:
 - `mkdir class`
 - `"C:\Program Files\Java\jrookit-jdk1.5.0\bin\javac" -cp "C:\Program Files\Java\jrookit-jdk1.5.0\jre\lib\rt.jar" -d class\ *.java infra\Util*.java validity*.java ..\reporter*.java`
 - `cd class\`
 - `"C:\Program Files\Java\jrookit-jdk1.5.0\bin\jar" -cf jbb.jar spec\jbb*.class spec\jbb\infra\Util*.class spec\reporter*.class`
 - `"C:\Program Files\Java\jrookit-jdk1.5.0\bin\jar" -cf check.jar spec\jbb\validity*.class`
5. Type `exit` to close the command prompt.
6. Open Windows Explorer from the start menu.
7. Copy the `jbb.jar` and `check.jar` files from `C:\SPECjbb2005\src\spec\jbb\class` to `C:\vSpecJBB2005\`.
8. When the system asks if you want to overwrite files, click Yes to overwrite the original `jbb.jar` and `check.jar` files.
9. Using Windows Explorer, navigate to `C:\vSpecJBB2005`, and open the `SPECjbb.props` file.
10. Make the following changes to the `SPECjbb.props` file:
 - Change `input.starting_number_warehouses=1` to `#input.starting_number_warehouses=1`
 - Change `input.increment_number_warehouses=1` to `#input.increment_number_warehouses=1`
 - Change `#input.sequence_of_number_of_warehouses=1 2 3 4 5 6 7 8` to `input.sequence_of_number_of_warehouses=2`
 Note: Set the above parameter to be equal to the number of vCPUs you configured for Java server VM.
 - Change `input.measurement_seconds=240` to `input.measurement_seconds=10`
11. In the `C:\vSpecJBB2005` directory, right-click `runit.bat`, and change `set JAVAOPTIONS=-Xms256m -Xmx256m` to `set JAVAOPTIONS=-Xms1000m -Xmx1000m -Xxthroughputcompaction -XXallocprefetch -XXallocRedoPrefetch -XXcompressedRefs -XlazyUnlocking -XXtlasize128k`

Installing and configuring the database server VM

1. Follow the steps in the earlier Cloning the base VMs section using the following VM specifications.
 - Base VM: Base64
 - Name: DBServer1
 - Virtual processors: 2
 - Virtual memory: 1.5 GB
 - Virtual disk size: 10 GB
 - Virtual network: External Network (keep the default Windows Network DHCP settings)

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

Installing Microsoft Internet Information Server

1. Select Start→Administrative Tools→Manage Your Server.
2. Select Add or remove a role.
3. At the preliminary steps screen, click Next.
4. At the Server Role screen, select Application Server, and click Next.
5. At the Summary of Selections screen, click Next.
6. When the installation software prompts you to do so, insert the OS CD, and click OK.

7. When the installation completes, click Finish.
8. Close the Manage Your Server window.

Installing Microsoft SQL Server 2005

1. Insert the SQL Server 2005 CD into the controller, and connect with the Virtual CD ROM.
2. Click the Server Components link under the Install section to begin the installation.
3. Accept the license agreement, and click Next.
4. Click Next to install the prerequisites.
5. After the prerequisites complete installing screen, click Next.
6. At the Welcome screen, click Next.
7. At the System Configuration Check, assuming everything has a status of success click Next.
8. Enter the registration information, and click Next.
9. At the Components to Install screen, select SQL Server Database Services, then click Advanced.
10. Instruct the software to install both the Database Services and Client Components by clicking the drop-down arrow on both and selecting Entire feature will be installed on local hard drive.
11. Click Next to start the installation.
12. For Instance Name, leave the default option, and click Next.
13. At the Service Account screen, select Use the built-in system account (Local system), and click Next.
14. Keep the default option for Authentication Mode, and click Next.
15. For Collation Settings, leave the defaults, and click Next.
16. Accept the default Error and Usage Report Settings, and click Next.
17. At the Ready to Install screen, click Install to begin the installation.
18. When the installation software prompts you to do so, insert Microsoft SQL Server 2005 disk 2. Use the Virtual CDROM to connect it to the VM, and click OK.
19. When the setup process completes, click Next.
20. Click Finish to complete the initial installation.
21. Install Service pack 2 by copying SQLServer2005SP2-KB921896-x64-ENU.exe to the virtual machine
22. Double-click the executable to launch the installer.
23. At the Welcome screen, click Next.
24. At the License Terms screen, accept the license agreement.
25. At the Feature Selection screen, click Next to accept all defaults.
26. At the Authentication screen, click Next to accept all defaults.
27. At the Error and Usage Reporting Settings screen, click Next to accept all defaults.
28. At the Running Processes screen, click Next.
29. Click install on the Ready To Install screen.
30. Click OK, on the Computer Reboot Requires message box.
31. Click Next at the Installation Complete Screen.
32. At the Additional Information screen, deselect Launch the User Provisioning Tool for Windows Vista after SP2 installation completes.
33. Click Finish.

Creating the test database and generating data

1. Select Start→Microsoft SQL Server 2005→SQL Server Management Studio.
2. In the Connect to Server window, use the drop-down menu next to Server name to select <Browse for more>.
3. In the Browse for Server window, select the Network Servers tab, and wait for it to retrieve data.
4. When Database Engine appears, expand the menu, select DBSERVER1, and click OK.
5. At the Connect to Server window, the server name should be present.
6. Click Connect to connect to the server.
7. Right-click the Database folder in the left window, and select New Database from the pop-up menu.
8. In the Database name field, type `sbttest`, and click OK.
9. Copy the following files from the vConsolidate package to the VM C:\ directory:
 - vSysbench.exe
 - Daemon.exe
 - killapp.exe

10. Open a command prompt by selecting Start→Run, type `cmd`, and click OK.
11. In the command prompt, type `cd \` to change to C:\.
12. To prepare the database, type `vsysbench.exe --test=oltp --oltp-table-size=100000 prepare`, and press Enter.
13. When the command finishes, the C:\ prompt appears.
14. Type `exit`, and press Enter to close the command prompt.
15. In SQL Server 2005 Management Studio, stop the database service by right-clicking DBSERVER1 in the left window pane, and then select Stop from the drop-down menu.
16. Using Windows Explorer, create the folder C:\backup.
17. With Windows Explorer, copy all sbtest files from C:\Program File\Microsoft SQL Server\MSSQL.1\MSSQL\Data\ to c:\backup. (You should see two files: sbtest.mdf and sbtest_log.ldf.)
18. Close Windows Explorer once the copy completes.
19. Restart the database service using SQL Server 2005 Management Studio by right-clicking DBSERVER1 and selecting start.

Installing and configuring the idle server VM

1. Follow the steps in the earlier Cloning the base VMs section using the following VM specifications.
2. Use the VM Specifications below:
 - Base VM: Base32
 - Name: IdleServer1
 - Virtual processors: 1
 - Virtual memory: 0.4 GB
 - Virtual disk size: 5 GB
 - Virtual network: External Network (keep the default Windows Network DHCP settings)

Installing and configuring the second CSU

To create the VMs the second CSU requires, we copied the existing virtual Hard Disks from the first CSU and directed the new VMs to point to the copied hard disks. We then started each VM and entered a new IP address or name depending on the need of each VM.

1. Navigate to the Virtual Hard Disk folder on the server where the Virtual Hard Disks are stored.
2. Highlight the first VM hard disk, and use the copy/paste method to create the appropriate number of copies for your CSUs.
3. Right click each Hard Disk and rename them according to the CSU 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.
18. Repeat the steps for each VM for the appropriate number of CSUs.

Client installation

In addition to setting up the server under test, we also had to set up the client systems we show in Figure 10. Both the WebBench and LoadSim workloads require test clients. Each CSU requires one consolidated test client.

Installing the WebBench 5.0 test client system

To run WebBench, you need two types of test systems. WebBench clients use WebBench software engines to send HTTP requests to stress the server under test. A WebBench controller system manages the clients during as the benchmark runs. Both systems run on the same physical client.

Installing a WebBench 5.0 client

1. Install Windows 2003 Enterprise Edition 32-bit. Use mailclient as the system name.
2. Install Windows Server 2003 Service Pack 2 with the default settings.
3. Open the Network Connections window by right-clicking My Network Places and selecting Properties from the menu.
4. Right-click the network connection, and click Properties.
5. Highlight TCP/IP, and select Properties.
6. Select Use the following IP address, and enter the following information: IP address 192.168.11.211, Subnet 255.255.255.0.
7. Click OK to close the two Properties windows.
8. Insert the WebBench CD, and open it with Windows Explorer.
9. Run setup.exe from the location /wb50/client/setup.exe.
10. Click Next through all screens, a process that accepts the defaults.
11. When the installation completes, copy the WebBench shortcut icon from the open window to the system's desktop.
12. With WordPad, open the file c:\Windows\system32\drivers\etc\hosts.
13. After the last text in that file, enter the following additional lines, and click Save.
 - 192.168.11.211 controller
 - 192.168.11.215 server
14. Close the hosts file and Windows Explorer.
15. Run /wb50/controlr/setup.exe.
16. Click Next through the installation, which accepts all default options.
17. With Windows Explorer, open C:\WebBench\Controller\Clientids\client.cdb.
18. Add the client's IP address to the top of the file. Enter Tab twice, and type the number 1.
19. Click File→Save, and close the client.cdb file.
20. Copy vConsolidate.tst file from the vCON\WebBench directory to C:\WebBench\controller\suites\WebBench.
21. Copy ecommerce_cgi_template_w2k3.tst and ecommerce_cgi_template_w2k3.wl files from vCON\WebBench directory to C:\WebBench\controller\suites\WebBench.
22. Copy all files from \vCON_framework\WebBench_daemon in the vConsolidate package to C:\.
23. Select Start→All Programs→PC Magazine Benchmarks→WebBench 5.0 Controller.
24. Click Create/Edit from the Suites drop-down menu.
25. Browse to the vConsolidate.tst file, and click Open.
26. Highlight the first Mix, and click Edit.
27. On the General tab, change Engines per client to 8.
28. Select the Workload tab.
29. Change the number of threads to 1.
30. Click Copy across.
31. Select the Engines per client and Number of threads check boxes, and click OK.
32. Click OK to close the suites windows.
33. Close the WebBench Controller window.

Installing the mail test client

Install the mail client on the same consolidated client at WebBench client and controller. We performed the following steps to set up the system:

1. Right-click My Computer, and select Properties.
2. Click the Computer Name tab.
3. Click Change.
4. Select Domain in the member of section, and type the domain vcon.com into the text box.
5. In the pop-up window, enter administrator for user name, password for password, and click OK.

6. At the Welcome to the domain screen, click OK.
7. When the warning that you must restart dialog appears, click OK.
8. Click OK to close the System Properties window.
9. Click Yes to the pop-up message to restart the computer.
10. Login to the domain by using administrator and password.
11. Install Microsoft Outlook 2003 with the default settings. (Outlook 2003 doesn't require any configuration.)
12. Install LoadSim 2003 by double-clicking the loadsim.msi installation file. Accept all defaults.
13. Open LoadSim 2003, and make sure no error messages appear.
14. Copy c:\Program Files\LoadSim\lslog.exe file to a floppy disk or USB thumb drive. You will need this file during the vConsolidate controller installation.

Configuring LoadSim 2003

1. Start LoadSim by clicking Start Menu→All Programs→Exchange LoadSim→LoadSim 2003.
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, set the number of users to 500.
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. Click Customize Tasks.
12. Select the Initialization tab.
13. Enter the following settings:
 - Number of messages in Inbox: 150
 - Number of messages in Deleted items: 1
 - Number of new folders: 2
 - Messages per new folder: 100
 - Number of Smart Folders: 3
 - Number of Rules in Inbox: 5
 - Initialize Free/Busy Information: Leave it unselected
 - Number of appointments: 25
 - Number of contacts: 64
14. Click OK.
15. In the Test Properties window, change the run time to 2 hours, and click OK.
16. From the LoadSim menu bar, choose File→Save As.
17. Save a backup copy of the simulation file as C:\loadsim.sim.
18. From the LoadSim menu bar, select Run→Create Topology, and wait until the Creating Users and Creating DLs tasks complete.
19. From the LoadSim menu bar, select Run→Initialize Test.
20. When a dialog box appears with the question Do you want to initialize Public Folders from this client machine?, click Yes.
21. The run is complete when the bottom left corner of the LoadSim window shows Status: Idle. This task typically takes about 2 to 3 hours to complete.
22. From the LoadSim menu bar, select Run→Run Simulation.
23. The run is complete when the bottom left corner of the LoadSim window shows Status: Idle. This task typically takes a little over 2 hours to complete.

Back up the mail and database server files

For test consistency we made backup copies of the Mail and Database Server's database files. Once you've set up LoadSim and created its initial mail database, you need to back up that database so you can have clean copies for each test. Do the same on the database server. We created a folder called backup on the C: drive of

each VM for the backup files. For testing we used scripts to perform a restore before each run so we started at the same point for each run. An example of the scripts we used for an 8-CSU restore follows:

Restore 8 CSU script

```
Set CSU_COUNT=8

Set SHUTDOWN_CMD=-r
Set PREPEXCHANGE=restore_reboot_exchange.bat
Set PREPSYSBENCH=restore_sysbench.bat
Set DBSERVER_WAIT=90

Set /A I=1

pause
:_CSU_LOOP
copy %PREPSYSBENCH% \\DBServer%I%\C$\servicecontent.bat /y
copy %PREPEXCHANGE% \\192.168.%I%1.115\C$\servicecontent.bat /y

shutdown %SHUTDOWN_CMD% -f -t %DBSERVER_WAIT% -m \\DBServer%I%
shutdown %SHUTDOWN_CMD% -f -t 5 -m \\JavaServer%I%
shutdown %SHUTDOWN_CMD% -f -t 5 -m \\IdleServer%I%
shutdown %SHUTDOWN_CMD% -f -t 5 -m \\192.168.%I%1.110

shutdown %SHUTDOWN_CMD% -f -t 5 -m \\192.168.%I%1.215

Set /A I+=1
if %I% LEQ %CSU_COUNT% GOTO _CSU_LOOP

pause
```

Restore SysBench script

```
net stop mssqlserver
sleep 1
del /F /Q "C:\Program Files\Microsoft SQL Server\MSSQL.1\MSSQL\Data\sbtest*"
sleep 1
copy /Y /V C:\sysbench_backup\sbtest* "C:\Program Files\Microsoft SQL
Server\MSSQL.1\MSSQL\Data\"
sleep 1
net start mssqlserver
```

Restore Exchange script

```
dismount.vbs
sleep 5

del /F /Q E:\pub1.*
del /F /Q E:\priv1.*

copy /Y "E:\backup\pub1.*" E:\
copy /Y "E:\backup\priv1.*" E:\

mount.vbs

REM - While we are waiting for the main Exchange services to stop,
REM - Some peripheral services will be closed in the background.
start /min net stop MExchangeMGMT /yes
start /min net stop RESvc /yes
```

```
start /min net stop POP3Svc /yes
start /min net stop IMAP4Svc /yes
start /min net stop NntpSvc /yes
start /min net stop SMTPSVC /yes
```

REM - Stop Exchange main services before shutdown to avoid timing conflicts.

```
net stop MExchangeES /yes
net stop MExchangeIS /yes
net stop MExchangeMTA /yes
net stop MExchangeSA /yes
```

REM - Well, why not stop other services in the background just for fun?
REM - Stopping IISADMIN will stop other dependant services like W3SVC, and HTTPFilter (SSL).

```
start /min net stop IISADMIN /yes
start /min net stop MSSEARCH /yes
start /min net stop Spooler /yes
```

```
shutdown -r -f -t 15
```

vConsolidate controller

You use a separate physical system, the controller, to manage the vConsolidate workload. We used a single section both for this function and as the controller system for the first CSU's WebBench benchmark. This controller offers a graphical user interface (GUI) to start and stop the vConsolidate workload. After the workload finishes, the controller copies the independent benchmark result files from all the VMs and combines their results into a single file, results.txt. We performed the following steps to set up this vConsolidate controller:

1. With Windows explore, create a C:\vCON directory.
2. Copy all files from the \vCON_framework\controller directory of the vConsolidate package to c:\vCON.
3. Copy the Islog.exe file the mail client installation created to c:\vCON.

The vCON directory contains a Profiles sub-directory. The Profiles directory contains four sample profiles, 1CSU.profile, 2CSU.profile, 3CSU.profile, 4CSU.profile and a blank template, Profile.template. vConsolidate uses these files to identify the number and name of the VMs a test should include. An example 1CSU.profile contains the following:

```
<Profile>
<Name>1 CSU</Name>
<CSUNum>1</CSUNum>
<Servers>
<DB>
<OS>Win</OS>
<Host>DBServer1</Host>
</DB>
<Loadsim>
<Host>192.168.202.110</Host>
</Loadsim>
<Java>
<OS>Win</OS>
<Host>JavaServer1</Host>
</Java>
<WebBench>
<Host>192.168.202.210</Host>
</WebBench>
</Servers>
</Profile>
```


Running vConsolidate

To run vConsolidate and get consistent results, you must first prepare the VMs with clean copies of the test data. We outline below the process for getting ready to run the workload. We then explain how to start and stop the workload. Finally, we detail how to find its results.

Preparing the vConsolidate run

Prior to running vConsolidate we restore the backup Mail and Database Server backup files, so we can ensure consistent results.

Verify connectivity and setting profiles

1. Open a command prompt by selecting Start→Run, type `cmd`, and click OK.
2. Type the following commands at command prompt:
 - `net use \\loadsim client IP Address\c$`
 - `net use \\JavaServer1\c$`
 - `net use \\DBServer1\c$`
 - `net use \\WebBench Controller IP Address\c$`
3. Verify that the vConsolidate controller can read and write remote files to all VMs with the following commands:
 - With Windows Explorer, create an empty file, `dummy.txt`.
 - `copy dummy.txt \\loadsim client IP Address\c$`
 - `copy dummy.txt \\JavaServer1\c$`
 - `copy dummy.txt \\DBServer1\c$`
 - `copy dummy.txt \\WebBench Controller IP Address\c$`
4. Modify the profile file by entering the VM name or IP address appropriate to each VM in the test. For the one-CSU test, enter four server names or IP addresses; for the two-CSU test, enter eight.

Starting and stopping vConsolidate

1. Shut down all VMs by selecting Start→Shutdown and then selecting Shutdown from the window.
2. In the left pane of the Virtual Infrastructure Client window, highlight `localhost.localdomain`.
3. Select the Summary tab in the right pane.
4. Click Reboot under the Commands section.
5. While the server is rebooting, reboot all clients in the test bed.
6. After the Hyper-V Server has rebooted, login using the Virtual Infrastructure Client, and start all VMs in the test.
7. Once the VMs are up, log the LoadSim client(s) into the appropriate domain(s).
8. Double-click `Daemon.exe` manually on the following VMs and systems:
 - a. `DataServer1`
 - b. `JavaServer1`
 - c. `LoadSim client`
 - d. `WebBench controller`
9. Start the WebBench Controller application on the WebBench controller system by selecting Start→All Programs→PC Magazine Benchmarks.
10. In the WebBench Controller application, choose the Clients menu, and click Start Log In.
11. Double-click the WebBench 5.0 client shortcut on all the WebBench test client desktops.
12. Once all the client machines are logged into WebBench, click OK.
13. At the Would you like to add a test suite? dialog, click Yes.
14. In the Select a test suite window, choose `vConsolidate.tst`, and click OK.
15. When the Would you like to start executing the test suites? window appears, do NOT click Yes or No. The vConsolidate controller application will handle that task that at the start of the test.
16. Double-click `c:\vCON\vconsolidate.exe`.
17. Select the profile name you want to run.
18. Wait 10 minutes to allow all virtual machines and Hyper-V Server to load all processes and become completely idle.
19. Click start.

20. The vConsolidate controller software will immediately start the LoadSim application. LoadSim will take about 60 to 80 seconds to log 500 users onto the Exchange Server. The remaining benchmarks will start once all the LoadSim users have logged in.
21. After about 30 minutes, vConsolidate controller application will stop the benchmark and collect their results.

Locating and interpreting the results file

vConsolidate places all result data in the following location:

c:\vCON\vCONMM-dd-hh-mm

where MM is the month, dd is the day, hh is the hour, and mm is the minute of the test. The file result.txt in that directory summarizes all the results. It contains the following information:

- Java transaction score
- Database transaction score
- Mail transaction score
- Web server throughput
- Start and stop times

Figure 11 shows an example results.txt file for a test with one CSU. We have labeled each score with a brief description. See the Test results section for more information on how we used these individual results to calculate each server's overall score on the workload.

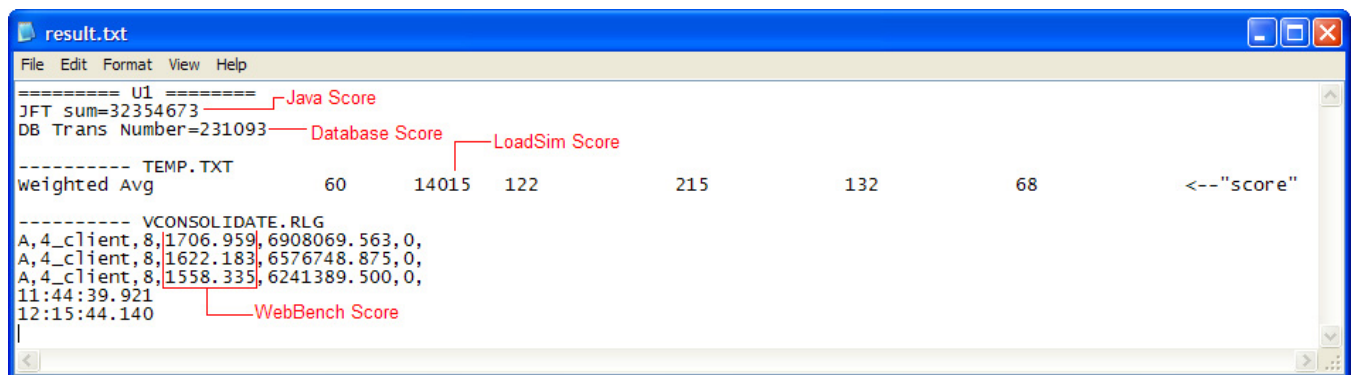


Figure 11: Example of vConsolidate results file.

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 while each server was running the operating system but otherwise idle. To ensure the server was idle, we allowed the server to boot and power on all virtual machines. Once the virtual machines had booted, we waited for 15 minutes to allow everything to stabilize. Then we recorded two minutes of idle power (in watts) at one-second intervals.

To compute the average power usage, we averaged the power usage during the time the server was producing its peak performance results. We call this time the power measurement interval. See Figure 5 (idle and average peak power) for the results of these measurements.

Appendix A – Test system configuration information

Figure 12 provides detailed configuration information about each of the test server systems, which we list in alphabetical order by processor name.

Servers	AMD Opteron processor 8360 SE-based server	Intel Xeon processor X5470-based server	Intel Xeon processor X7350-based server	Intel Xeon processor X7460-based server
General processor setup				
Number of processor packages	4	2	4	4
Number of cores per processor package	4	4	4	6
Number of hardware threads per core	1	1	1	1
System Power Management Policy	Always On	Always On	Always on	Always on
CPU				
Vendor	AMD	Intel	Intel	Intel
Name	Opteron 8360 SE	Intel Xeon processor X5470	Intel Xeon processor X7350	Intel Xeon processor X7460
Stepping	3	A	B	1
Socket type	Socket F (1207)	Socket 771 LGA	Socket P (478)	Socket P (478)
Core frequency (GHz)	2.50	3.33	2.93	2.66
Front-side bus frequency (MHz)	2,000 with HyperTransport	1,333	1,066	1,066
L1 cache	64 KB x 64 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	4 x 512 KB (512 KB per core)	2 x 6 MB (each 6 MBs shared by 2 cores)	2 x 4 MB (each 4 MBs shared by 2 cores)	3 x 3 MB (each 3 MB shared by 2 cores)
L3 cache	2MB	N/A	N/A	16 MB
Platform				
Vendor and model number	HP DL585 G5	Intel	Intel Fox Cove	Intel Fox Cove
Motherboard model number	PAAXH0H9SW 30B1	Supermicro X7DB8	S7000FC4UR	S7000FC4UR
Motherboard chipset	NVIDIA nForce Pro 2050	Intel 6321ESB	Intel ID3600	Intel ID3600
Motherboard revision number	0H	92	01	01
BIOS name and version	HP A07 (06/27/2008)	Phoenix Technologies LTD 2.1 (06/23/2008)	Intel SFC4UR.868.0 1.00.0024.0613 20082253	Intel SFC4UR.868.0 1.00.0024.0613 20082253

Servers	AMD Opteron processor 8360 SE-based server	Intel Xeon processor X5470-based server	Intel Xeon processor X7350-based server	Intel Xeon processor X7460-based server
BIOS settings	Power Regulator for ProLiant set to Static Performance Mode, enable AMD Virtualization and No-Execute Page-Protection	Enabled Intel Virtualization Technology	Enabled Intel Virtualization Technology	Enabled Intel Virtualization Technology
Memory module(s)				
Vendor and model number	ELPIDA EBE41AE4ACF A-6E-E	Kingston KVR667D2D4F 5/2G	Kingston KVR667D2D4F 5/4GI	Kingston KVR667D2D4F 5/4GI
Type	PC2-5300 DDR2	PC2-5300 FB-DDR2	PC2-5300 FB-DDR2	PC2-5300 FB-DDR2
Speed	667	667 MHz	667 MHz	667 MHz
Speed in the system currently running @	667	667 MHz	667 MHz	667 MHz
Timing/Latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15	5-5-5-11	5-5-5-15	5-5-5-15
RAM Module Size	4 GB	2 GB	4 GB	4 GB
Number of RAM modules	16	16	16	16
Chip organization	Double-sided	Double-Sided	Double-sided	Double-sided
Total System Memory	64 GB	32 GB	64 GB	64 GB
Hard drive				
Vendor and model number	HP DG072BABCE	WD740ADFD	Seagate ST973401SS	Seagate ST973401SS
Number of disks in system	2	2	2	2
Size	72 GB	74 GB	73.4 GB	73.4 GB
Buffer size	16 MB	16 MB	8 MB	8 MB
RPM	10,000	10,000	10,000	10,000
Type	SAS	SAS	SAS	SAS
Controller	Smart Array P400 Controller	Intel ESB2 SATA RAID Controller	Integrated Intel RAID Controller SROMBSASFC	Integrated Intel RAID Controller SROMBSASFC
Driver	HP 6.12.4.64	Intel 8.2.0.1001	LSI 2.13.0.64	LSI 2.13.0.64
Operating system				
Name	Microsoft Windows Server 2008 Enterprise x64 Edition	Microsoft Windows Server 2008 Enterprise x64 Edition	Microsoft Windows Server 2008 Enterprise x64 Edition	Microsoft Windows Server 2008 Enterprise x64 Edition
Build number	6001	6001	6001	6001
Service Pack	Service Pack 1	Service Pack 1	Service Pack 1	Service Pack 1
File system	NTFS	NTFS	NTFS	NTFS

Servers	AMD Opteron processor 8360 SE-based server	Intel Xeon processor X5470-based server	Intel Xeon processor X7350-based server	Intel Xeon processor X7460-based server
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX version	10	10	10	10
Graphics				
Vendor and model number	ATI ES1000	ATI ES 1000	ATI ES1000	ATI ES1000
Chipset	ATI ES1000	ATI ES1000	ES1000	ES1000
BIOS version	BK-ATI VER008.005.0 13.000	BK-ATI VER008.005.0 07.001	BK-ATI VER008.005.0 31.000	BK-ATI VER008.005.03 1.000
Type	Integrated	Integrated	Integrated	Integrated
Memory size	32 MB	16 MB	32 MB	32 MB
Resolution	1,280 x 1,024	1,280 x 1,024	1,024 x 768	1,024 x 768
Network card/subsystem				
Vendor and model number	Broadcom BCM5706C NetXtreme II GigE	Intel PRO/1000 EB	Intel PRO/1000 EB	Intel PRO/1000 EB
Type	Integrated	Integrated	Integrated	Integrated
Driver version	Microsoft 3.7.19.0	Intel 9.12.17.0	Intel 1.2.79.9	Intel 1.2.79.9
Vendor and model number	Intel PRO/1000 PT	Intel PRO/1000 PT	Intel PRO/1000 PT	Intel PRO/1000 PT
Type	PCIe	PCIe	PCIe	PCIe
Driver version	Intel 10.2.28.0	Intel 10.2.28.0	Intel 10.2.28.0	Intel 10.2.28.0
Optical drive				
Vendor and model number	HL-DT-ST RW/DVD GCC-C10N	MATSHITA SR-8178 DVD/CD-ROM	Optiarc DVD-ROM DDU810A	Optiarc DVD-ROM DDU810A
USB ports				
Number	4	4	5	5
Type	USB 2.0	USB 2.0	USB 2.0	USB 2.0
Power supplies				
Total number	2	2	2	2
Wattage of each	1,300W	700W	1,570W	1,570W
Cooling fans				
Total number	6	3	8	8
Dimensions	5"x5"	1-1/2" x 3-1/8"	4 x 80 mm + 4 x 120 mm	4 x 80 mm + 4 x 120 mm
Voltage	12V	12V	12 V	12 V
Amps	3.3A	1.1A	4 x 1.76 A + 4 x 3.3 A	4 x 1.76 A + 4 x 3.3 A

Figure 12: Detailed system configuration information for the test servers.

Appendix B – Complete test and power results

Figures 13 through 16 show the complete results for all three runs on the two test systems.

AMD Opteron processor 8360 SE				
	Score	CPU utilization	Idle power	Average power
1 CSU				
Run 1	1.12	33	518.08	642.97
Run 2	1.13	33	511.21	643.73
Run 3	1.12	33	507.07	643.86
2 CSUs				
Run 1	2.08	63	509.68	683.13
Run 2	2.09	64	511.12	682.00
Run 3	2.08	64	515.18	681.64
3 CSUs				
Run 1	2.58	90	517.62	706.68
Run 2	2.56	91	517.25	705.99
Run 3	2.56	91	517.81	705.04
4 CSUs				
Run 1	2.67	96	518.92	714.90
Run 2	2.70	96	520.69	718.09
Run 3	2.70	96	524.30	711.91
5 CSUs				
Run 1	2.80	98	513.91	709.72
Run 2	2.78	98	520.24	711.31
Run 3	2.78	98	529.90	714.38
6 CSUs				
Run 1	2.94	99	526.51	712.93
Run 2	2.94	99	523.54	712.15
Run 3	2.95	99	517.43	711.63
7 CSUs				
Run 1	3.01	100	519.91	723.09
Run 2	3.04	100	521.62	720.03
Run 3	2.70	100	528.07	720.12

Figure 13: Complete results for all three runs on the HP DL585 G5 server.

Intel Xeon processor X5470				
	Score	CPU utilization	Idle power	Average power
1 CSU				
Run 1	1.40	59	384.89	465.93
Run 2	1.38	59	384.99	467.44
Run 3	1.38	59	385.26	467.29
2 CSUs				
Run 1	2.05	92	384.66	483.84
Run 2	2.03	92	384.82	484.66
Run 3	2.03	92	385.63	485.01
3 CSUs				
Run 1	2.13	98	386.07	485.87
Run 2	2.12	98	385.88	485.44
Run 3	2.09	98	386.20	485.65

Figure 14: Complete results for all three runs on the Intel Xeon processor X5470-based server.

Intel Xeon processor X7350				
	Score	CPU utilization	Idle power	Average power
1 CSU				
Run 1	1.19	33	547.72	683.32
Run 2	1.16	33	546.21	679.45
Run 3	1.17	33	544.13	676.94
2 CSUs				
Run 1	2.22	65	543.13	784.24
Run 2	2.23	65	542.63	785.49
Run 3	2.23	65	547.43	793.12
3 CSUs				
Run 1	2.86	89	538.52	820.38
Run 2	2.82	89	538.78	822.12
Run 3	2.85	89	546.18	833.54
4 CSUs				
Run 1	3.03	96	543.11	830.11
Run 2	3.02	96	542.03	827.24
Run 3	3.05	96	539.63	826.62
5 CSUs				
Run 1	3.12	97	547.32	840.38
Run 2	3.10	98	539.38	824.60
Run 3	3.07	98	539.97	823.53
6 CSUs				
Run 1	3.12	99	524.50	802.92
Run 2	3.10	99	524.48	801.04
Run 3	3.09	99	525.82	805.72
7 CSUs				
Run 1	3.04	100	525.05	799.08
Run 2	3.03	100	525.97	799.59
Run 3	2.73	100	528.53	798.60

Figure 15: Complete results for all three runs on the Intel Xeon processor X7350 server.

Intel Xeon processor X7460				
	Score	CPU utilization	Idle power	Average power
1 CSU				
Run 1	1.19	22	534.13	606.41
Run 2	1.23	22	532.80	603.64
Run 3	1.22	22	536.38	606.73
2 CSUs				
Run 1	2.33	42	532.27	662.59
Run 2	2.33	43	531.68	663.83
Run 3	2.32	42	532.02	664.06
3 CSUs				
Run 1	3.26	65	536.93	719.03
Run 2	3.26	65	533.15	715.86
Run 3	3.30	65	531.45	715.54
4 CSUs				
Run 1	3.92	86	537.52	770.09
Run 2	3.92	85	568.33	794.08
Run 3	3.95	86	535.99	754.53
5 CSUs				
Run 1	4.20	93	533.06	756.23
Run 2	4.23	94	534.18	754.68
Run 3	4.26	93	532.89	752.03
6 CSUs				
Run 1	4.33	97	534.18	757.49
Run 2	4.34	97	534.77	757.91
Run 3	4.37	97	533.18	755.18
7 CSUs				
Run 1	4.35	98	536.42	757.85
Run 2	4.34	98	537.30	758.29
Run 3	3.91	98	537.25	758.17
8 CSUs				
Run 1	4.34	99	536.89	757.01
Run 2	4.31	99	537.47	757.03
Run 3	4.34	99	537.45	756.79

Figure 16: Complete results for all three runs on the Intel Xeon processor X7460 server.



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