



## Performance of four Intel-based SMB servers running Web, email, and database applications

### Executive summary

Intel Corporation commissioned Principled Technologies (PT) to compare the Web, email, and database service performance of four small- and medium-sized business (SMB) focused servers:

- Intel® Core 2™ Quad Desktop Processor Q8400-based server (2.66 GHz, 4MB L2 cache, 1,333MHz bus)
- Intel® Xeon® Processor X3220-based server (2.40 GHz, 8MB L2 cache, 1,066MHz bus)
- Intel® Xeon® Processor X3380-based server (3.16 GHz, 12MB L2 cache, 1,333MHz bus)
- Intel® Xeon® Processor X3450-based server (2.66 GHz, 8MB L3 cache, 1,333MHz bus)

All servers ran Microsoft Windows Server\* 2008 Standard Edition x64. We measured performance with simultaneous workloads that exercised three of the functions a typical small business server may have to handle: Web, email, and database services. We used WebBench to simulate Web traffic, Microsoft Exchange\* Load Generator (LoadGen) to simulate email activity, and DVD Store Version Two (DS2) to simulate database activity. The Workload section provides more information on the benchmarks.

### KEY FINDINGS

- Across the three workloads on Microsoft Windows Server\* 2008 Standard Edition x64, the Intel Xeon Processor X3450-based server delivered the following performance increase: 48 percent more than the Intel Xeon Processor X3380-based server, 110 percent more than the Intel Xeon Processor X3220-based server, and 119 percent more than the Intel Core 2 Quad Desktop Processor Q8400-based server. (See Figure 1.)
- The Intel Xeon Processor X3450-based server delivered the following performance-per-watt increase: 49 percent more than the Intel Xeon Processor X3380-based server, 136 percent more than the Intel Xeon Processor X3220-based server, and 87 percent more than the Intel Core 2 Quad Desktop Processor Q8400-based server. (See Figure 2.)
- The Intel Xeon Processor X3450-based server used under 60 percent of its processor while delivering better performance on these tests, leaving performance headroom for the future. (See Figure 4.)

Figure 1 presents averaged results for the four Intel processor-based servers running the three workloads relative to the lowest-performing server, the Intel Core 2 Quad Desktop Processor Q8400-based server. For each benchmark, we assigned a value of 100 percent to that server's results and then calculated the percentage performance improvement.

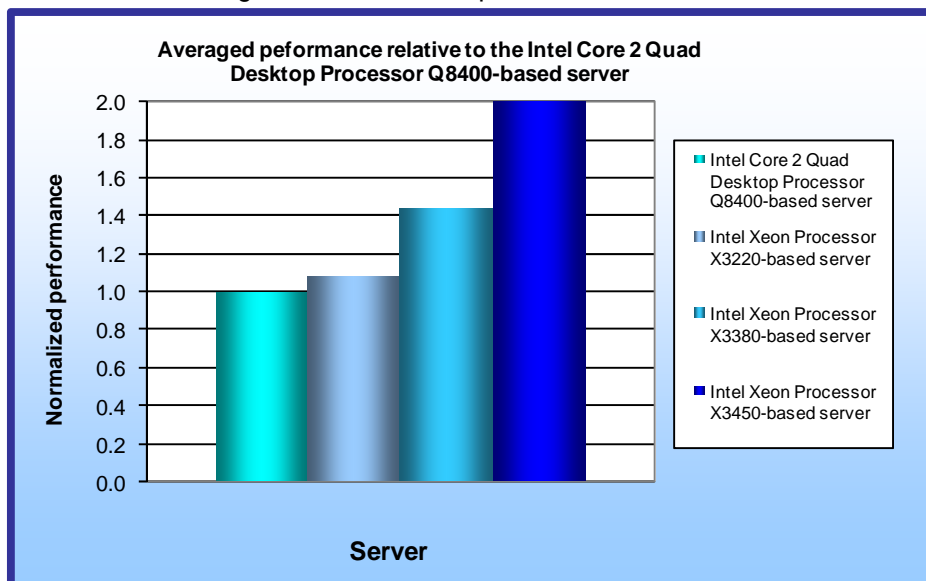
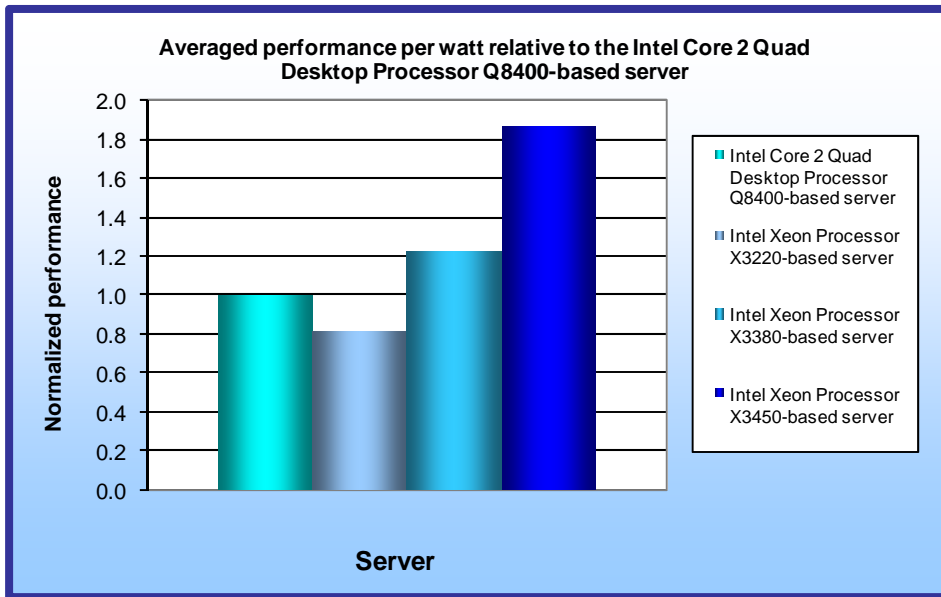


Figure 1: Performance of the Intel processor-based servers across the three benchmarks relative to the Intel Core 2 Quad Desktop Processor Q8400-based server. Higher numbers are better.

This approach makes each data point a comparative number, with higher numbers indicating better performance. Finally, we took the percentage performance improvement over the Intel Core 2 Quad Desktop Processor Q8400-based server for the three benchmarks and averaged them.

While running the three benchmarks, the Intel Xeon Processor X3450-based server delivered the following performance increase: 48 percent more than the Intel Xeon Processor X3380-based server, 110 percent more than

the Intel Processor X3220-based server, and 119 percent more than the Intel Core 2 Quad Desktop Processor Q8400-based server.



**Figure 2: Normalized performance-per-watt results of the Intel processor-based servers across the three benchmarks relative to the Intel Core 2 Quad Desktop Processor Q8400-based server. Higher numbers are better.**

The Intel Xeon Processor X3450-based server provided better performance than the other systems, across all workloads, while only using around 60 percent processor utilization. This shows it can provide better performance and still have headroom to handle additional tasks. See figure 4 for all results.

We also measured power consumption during the workload run. We took the averaged relative performance results and divided them by the active power consumption. We normalized those results to those of the Intel Core 2 Quad Desktop Processor Q8400-based server.

As Figure 2 illustrates, the Intel Xeon Processor X3450-based server produced the following performance-per-watt increase: 49 percent more than the Intel Xeon Processor X3380-based server, 136 percent more than the Intel Processor X3220-based server, and 87 percent more than the Intel Core 2 Quad Desktop Processor Q8400-based server.

## Workload

We ran the following three workloads simultaneously, as a typical small business server might.

### 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 a 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.

We ran WebBench's default ecommerce CGI test suite, which generates both secure and non-secure static and dynamic HTTP 1.0 GET requests. While running the ecommerce suite, the clients must negotiate to a secure Web server port using the Secure Socket Layer (SSL) protocol. A default WebBench test suite incrementally increases the number of clients making the HTTP 1.0 GET requests to the Web server. As the workload increases the number of clients, the Web server's processor utilization also increases, until the clients saturate the processor in the Web server with work. Each workload point with a fixed number of clients is a WebBench "mix." The ecommerce CGI test suite begins with a mix that involves one client; the next mix involves four clients; and each subsequent mix increases the number of clients by four. We modified the test suite so it would run 20 clients, with 10 engines per client for the entire test. This allowed us to keep a constant Web load on the server. We performed only nine mixes for testing to limit the amount of time WebBench ran.

We ran this workload on the four servers for 45 minutes each.

## DVD Store

DVD Store Version 2 is an open-source application with a back-end database component, a front-end Web application layer, and a driver layer that operates as the middle tier and actually executes the workload. Because our goal was to isolate and test database server and storage, we did not use the Web application layer. Instead, we ran the driver application on client machines directly via its command-line interface.

DS2 models an online DVD store. Simulated customers log in; browse movies by actor, title, or category; and purchase movies. The workload also creates new customers. Browsing movies involves select operations, some of which use SQL Server 2008 full-text search and some of which do not. The purchase, login, and new customer stored procedures involve update and insert statements, as well as select statements. The workload's main reporting metric is orders per minute (OPM).

For the client machine, we used a desktop class system running Windows Server® 2003 Enterprise Edition x64. The client machine ran a single instance of DS2, which spawned 32 threads, with 0.3 seconds of think time, and 10 searches per order. This simulated a realistic business environment. We used the default DS2 parameters and setup configuration, with the exceptions we note above and in the DVD Store setup section in the Test methodology section of this report.

The DS2 driver application creates an orders-per-minute performance counter on the client machine. While the DVD Store client application visually outputs OPM at 10-second intervals, we chose to collect this OPM metric via a performance monitor counter on each client machine at 1-second intervals.

We ran this workload on the four servers for 40 minutes each.

For more details about the DS2 tool, see <http://www.delltechcenter.com/page/DVD+Store>.

## LoadGen

LoadGen is an industry-standard tool for benchmarking an Exchange 2007 Mail Server. LoadGen performs tasks to simulate a standard user generating mail activity. When the workload finishes, LoadGen reports the response time, which is the number of seconds necessary to complete the task.

Our goal was to compare the Microsoft Exchange Server 2007 response time of the servers.

Microsoft Exchange Load Generator is a simulation tool that measures the impact that various clients (MAPI, OWA, IMAP, POP, and SMTP) have on Exchange servers. This allows users to test how effectively a server running Exchange responds to e-mail loads. The simulator sends multiple message requests to the server running Exchange, resulting in a mail load.

We created a custom workload of 75 users that LoadGen distributed across a single storage group with one Mailbox database. We ran the Microsoft Exchange Load Generator benchmark for 30 minutes on the servers.

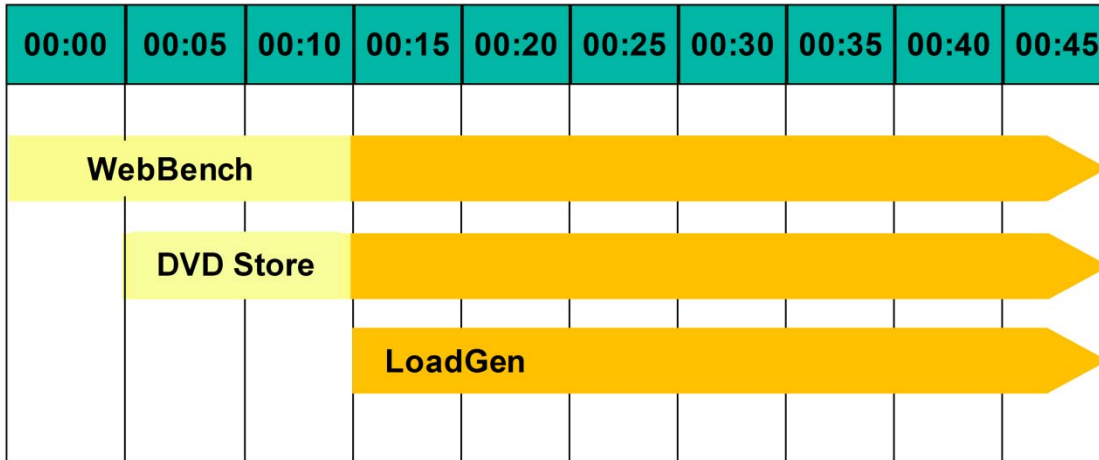
For more details about LoadGen, see <http://www.microsoft.com/downloads/details.aspx?FamilyId=DDEC1642-F6E3-4D66-A82F-8D3062C6FA98&displaylang=en>.

## Test results

For testing, we staggered the starting times of the benchmarks to allow each server to ramp up slowly. We began the benchmarks in the following order: WebBench, DVD Store, and LoadGen. Figure 3 shows a timeline for the benchmark runs. To obtain the final results, we removed the first parts of the WebBench and DVD Store runs, and computed the results based on the 30 minutes of peak performance during the LoadGen run.

To make sure each server achieved its optimum results, we allowed each to sit idle for 10 minutes before starting the workload.

**Multiple benchmark timeline  
45 minutes total time**



**Figure 3: The timeline we followed when starting the benchmarks for the multiple-benchmark runs on all Intel processor-based servers. The shaded areas from 00:15 to 00:45 represent the period during which we measured performance.**

Figure 4 presents results for the servers on the three benchmarks relative to the lowest-performing server, the Intel Core 2 Quad Desktop Processor Q8400-based server. For each benchmark, we assigned a value of 100 percent to that server’s results and then calculated the percentage performance improvement. This approach makes each data point a comparative number, with higher numbers indicating better performance. Finally, we took the percentage performance improvement over the Intel Core 2 Quad Desktop Processor Q8400-based server for the three benchmarks and averaged them.

As figure 4 shows, the Intel Xeon Processor X3450-based server provided better performance than the other servers, across all workloads, while only using around 60 percent processor utilization. This shows it can provide better performance and still have headroom to handle additional tasks.

Server	Web requests per second	Email response time	OPM	Average Web, email, and database scores	Percentage CPU utilization
Intel Core 2 Quad Desktop Processor Q8400-based server	1.00	1.00	1.00	1.00	92.94
Intel Xeon Processor X3220-based server	1.01	1.16	1.04	1.07	92.82
Intel Xeon Processor X3380-based server	1.34	1.22	1.77	1.44	92.72
Intel Xeon Processor X3450-based server	1.57	1.42	3.58	2.19	59.39

**Figure 4: Performance for the Intel processor-based servers on the three benchmarks, relative to the Intel Core 2 Quad Desktop Processor Q8400-based server. With the exception of CPU utilization, higher numbers are better.**

**WebBench results**

A WebBench run reports the total requests per second a server can perform and the total throughput, in bytes per second, that the server delivered. WebBench reports these results for each mix. To obtain the results, we averaged the requests per second and throughput from the mixes that ran during the peak performance of the benchmark run, as Figure 3 illustrates.

Figure 5 shows the WebBench peak results in requests per second and in throughput (bytes per second) for the servers. Each result is the median of three runs.

Server	Throughput (bytes per second)	Requests per second (raw)	Requests per second*
Intel Core 2 Quad Desktop Processor Q8400-based server	136,940,400.84	14,036.73	1.00
Intel Xeon Processor X3220-based server	138,741,935.43	14,198.56	1.01
Intel Xeon Processor X3380-based server	183,178,393.82	18,776.55	1.34
Intel Xeon Processor X3450-based server	214,984,053.91	22,033.50	1.57

**Figure 5: Median WebBench results for the four Intel processor-based servers. Higher numbers are better.**

\* Relative to the Intel Core 2 Quad Desktop Processor Q8400-based server

### DVD Store results

Figure 6 shows the number of OPM each solution achieved during our measurement period of the DVD Store test on the median run. We calculated the scores by averaging the OPM during the 30-minute period.

Server	Orders per minute (raw)	Orders per minute*
Intel Core 2 Quad Desktop Processor Q8400-based server	1,652.91	1.00
Intel Xeon Processor X3220-based server	1,722.78	1.04
Intel Xeon Processor X3380-based server	2,920.29	1.77
Intel Xeon Processor X3450-based server	5,924.57	3.58

**Figure 6: Median DVD Store results for the two servers. Lower response time is better.**

\* Relative to the Intel Core 2 Quad Desktop Processor Q8400-based server

### LoadGen results

LoadGen results show the response time each for each server, which is the time in milliseconds it took to complete a request. Because the object of the server is to handle as many requests as possible, lower scores, which show a server able to handle more requests in a given time, are better.

For testing, we used 75 Microsoft Exchange mailboxes; all four servers could handle the load while performing other tasks. Figure 7 shows the average Exchange 2007 Mail Server 95<sup>th</sup> percentile response time that LoadGen reported for the four servers. Each result is the median of three runs.

Server	95 <sup>th</sup> percentile response time (in seconds)	95th percentile*
Intel Core 2 Quad Desktop Processor Q8400-based server	316.37	1.00
Intel Xeon Processor X3220-based server	264.37	1.16
Intel Xeon Processor X3380-based server	245.33	1.22
Intel Xeon Processor X3450-based server	184.05	1.42

**Figure 7: Median LoadGen results for the four Intel processor-based servers. Lower response time is better.**

\* Relative to the Intel Core 2 Quad Desktop Processor Q8400-based server

Because the results are in response time for each task, we created a weighted average to calculate a final score. To create a weighted average, we used a similar procedure as the one that Microsoft Exchange Server 2003 Load Simulator (LoadSim) uses. (Note: LoadSim is an older tool for testing Exchange Mail Servers; Microsoft has replaced it with LoadGen.) Figure 8 shows the weighted average we used for testing.

Task name	Weight	Task name	Weight
BrowseCalendar	1	BrowseContacts	0
Logon	0	CreateContact	0
Logoff	0	BrowseTasks	0
SendMail	1	CreateTask	0
ReadAndProcessMessages	51	EditRules	2
MoveMail	0	DownloadOab	0
DeleteMail	0	EditSmartFolders	2
ExportMail	0	SynchronizeFolders	0
CreateFolder	0	Search	0
PublicFolderPost	0	InitializeMailbox	0
BrowsePublicFolder	0	UserInit	0
PostFreeBusy	2	UserTerm	0
RequestMeeting	1	ModuleInit	0
MakeAppointment	0	ModuleTerm	0
<b>Total 60</b>			

Figure 8: Weighted average for LoadGen tasks.

Figure 9 shows the power results during the median run of the four servers. Lower numbers are better.

Server	Workload power
Intel Core 2 Quad Desktop Processor Q8400-based server	138.40
Intel Xeon Processor X3220-based server	182.40
Intel Xeon Processor X3380-based server	162.69
Intel Xeon Processor X3450-based server	162.51

Figure 9: Average workload power results, in watts, for the servers during the median run. Lower numbers are better.

To calculate the power, we average the power we recorded during our workload measurement period. We allowed the system to sit for 10 minutes after booting to the desktop and then started the test.

## Test methodology

We configured each server in the following areas: processor details, RAM, hard drive, and operating system. The baseline configuration specifications for each system are as follows:

Intel Core 2 Quad Desktop Processor Q8400-based server: Intel Core 2 Quad Processor Q8400 (2.66 GHz, 4MB L2 cache, 1,333MHz system bus), 4GB memory (4 x 1,024GB PC2-5300), 4 x 500GB SATA 7,200 RPM, Microsoft Server 2008 Standard x64 SP1 OS.

Intel Xeon Processor X3220-based server: Intel Xeon Processor X3220 (2.40 GHz, 8MB L2 cache, 1,066MHz system bus), 4GB memory (4 x 1,024GB PC2-5300), 4 x 500GB SATA 7,200 RPM, Microsoft Windows Server 2008 Standard x64 SP1 OS.

Intel Xeon Processor X3380-based server: Intel Xeon Processor X3380 (3.16 GHz, 12MB L2 cache, 1,333MHz system bus), 4GB memory (4 x 1,024 PC2-5300), 4 x 500GB SATA 7,200 RPM, Microsoft Windows Server 2008 Standard x64 SP1 OS.

Intel Xeon Processor X3450-based server: Intel Xeon Processor X3450 (2.66 GHz, 8MB L3 cache, 1,333MHz system bus), 6GB memory (6 x 1,024 PC3-8500R), 4 x 500GB SATA 7,200 RPM, Microsoft Windows Server 2008 Standard x64 SP1 OS.

Intel provided and configured all servers. Appendix B provides detailed configuration information.

## Installing and configuring the OS

We began our testing by installing a fresh copy of Windows Server 2008, Standard x64 Edition on each server. We followed this process for each installation:

1. At the Language Selection Screen, click Next.
2. Click Install Now.
3. Select Windows Server 2008 Standard (Full Installation) x64, and click Next.
4. Click the I accept the license agreement check box, and click Next.
5. Click Custom.
6. Click Next.
7. At the warning that the user's password must be changed before entering the OS, click OK.
8. Type Password1 as the new password.
9. At the Your password has been changed screen, click OK.

## Installing system updates

We installed the following updates using Microsoft Windows update feature:

- Security Update for Windows Server 2008 x64 Edition (KB961063)
- Security Update for Windows Server 2008 x64 Edition (KB949014)
- Hotfix for Windows (KB942288)
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update (KB951847)
- 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 x64 Edition (KB949189)
- Security Update for Windows Server 2008 x64 Edition (KB955069)
- 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 (KB958690)
- Cumulative Security Update for Internet Explorer 7 for Windows Server 2008 x64 Edition (KB963027)
- Security Update for Windows Server 2008 x64 Edition (KB960803)
- Internet Explorer 8 for Windows Server 2008 x64 Edition
- Security Update for Windows Server 2008 x64 Edition (KB958623)
- Update for Windows Server 2008 x64 Edition (KB959130)
- Windows Malicious Software Removal Tool x64 – May 2009 (KB890830)
- 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 (KB956572)
- Security Update for Windows Mail for Windows Server 2008 x64 Edition (KB951066)
- Update Rollup for ActiveX Killbits for Windows Server 2008 x64 Edition (KB960715)
- Security Update for Windows Server 2008 x64 Edition (KB960225)
- 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 Windows Server 2008 x64 Edition (KB959426)
- Security Update for Windows Server 2008 x64 Edition (KB952004)

- Security Update for Windows Server 2008 x64 Edition (KB951698)
- Update for Windows Server 2008 x64 Edition (KB950050)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2008 x64 Edition (KB950760)
- Update for Windows Server 2008 x64 Edition (KB955302)
- Windows Update Agent 7.2.6001.788

## General OS settings

1. Open the control panel.
2. Double-click User Accounts.
3. Click Turn User Account Control on or off.
4. Beside Use User Account Control (UAC), uncheck the check box.
5. Reboot the system.

## Installing and configuring the mail server

### Setting up the Active Directory

1. Click Start→Administrative Tools→Server Manager.
2. Click Roles on the left side.
3. Click Add Roles.
4. Click the Skip this page by default check box, and click Next.
5. Click the Active Directory Domain Services check box, and click Next.
6. Click Next.
7. Click Install.
8. Click Close.

### Assigning static IPs to the NICs

1. Click Start→Network.
2. Click Network and Sharing Center.
3. Click Manage Network Connections.
4. Right-click Local Area Connection.
5. Click Properties.
6. Click Internet Protocol Version 4 (TCP/IPv4), and click Properties.
7. Select Use the following IP Address, and input the following numbers:  
 IP Address: 192.168.1.1  
 Subnet mask: 255.255.255.0
8. In the Internet Protocol (TCP/IP) Properties, click Advanced.
9. In IP addresses, click Add.
10. Input the following numbers:  
 IP Address: 10.1.5.250  
 Subnet mask: 255.255.255.0
11. Repeat steps 4 through 7 for Local Area Connection 2 and Local Area Connection 3 using the following IP information for each:  
 Local Area Connection 2:  
 IP Address: 10.1.1.250  
 Subnet mask: 255.255.255.0  
 Local Area Connection 3:  
 IP Address: 10.1.2.250  
 Subnet mask: 255.255.255.0

### Setting up the domain

1. Click Start, type `cmd` in the prompt, and press Enter.
2. Type `dcpromo`, and press Enter.
3. Click Next.
4. Click Next.

5. Click Next.
6. Select Create a new domain in a new forest, and click Next.
7. Type `gaston.lan` as the FQDN (Fully Qualified Domain Name), and click Next.
8. Set the forest functional level to Windows Server 2003, and click Next.
9. Set the domain functional level to Windows Server 2003, and click Next.
10. Leave defaults on the Additional Domain Controller Options screen, and click Next.
11. If a warning window appears asking about dynamically assigned IP addresses, click Yes.
12. Click Yes to continue.
13. Leave defaults at the Location for Database, Log Files, and SYSVOL screen. Click Next.
14. At the Directory Services Restore Mode Administrator Password screen, type `Password1`.
15. At the summary screen, click Next.
16. Click Finish.
17. Click Restart now.

### Setting up the Application Server

1. Click Start→Administrative Tools→Server Manager.
2. Click Roles on the left side.
3. Click Add Roles.
4. Click the Application Server check box.
5. When the Add features required for Application Server? screen appears, click Add Required Features.
6. Click Next.
7. Click Next.
8. At the Select Role Services page for Application Server, click the Web Server (IIS) Support check box.
9. When the Add features required for Web Server (IIS) Support? screen appears, click Add Required Features.
10. Click Next.
11. Click Next.
12. At the Select Role Services page for Web Server (IIS), click IIS 6 Management Compatibility, ASP, and CGI check boxes. Click Next.
13. Click Install.
14. Click Close.

### Installing Microsoft Exchange

1. Click Start→Administrative Tools→Server Manager.
2. Click Features.
3. Click Add Features.
4. Select check box Windows PowerShell, and select Next.
5. Click Install.
6. Click Close.
7. Run Exchange 2007 SP1 `install.exe`.
8. Type `C:\exc` in the choose directory for extracted files text prompt.
9. Click OK.
10. Click OK.
11. In the `C:\exc` folder, double-click `setup.exe`.
12. Click Step 4 Install Microsoft Exchange Server 2007 SP1.
13. Click Next.
14. Accept the License agreement, and click Next.
15. Click Next.
16. Select Typical Exchange Server installation, and click Next.
17. At the Exchange organization screen, click Next.
18. At the Client settings screen, click Next.
19. After the system finishes the readiness check, click Install.
20. Click Finish.
21. Click OK.
22. Restart the system.

### Enabling Circular Logging

1. Click Start→All Programs→Microsoft Exchange Server 2007→Exchange Management Console.
2. Expand Server Configuration, and click Mailbox.
3. Right-click First Storage Group, and click Properties.
4. Check the box beside Enable circular logging, and click OK.

### Disabling Maintenance Schedule

1. Click Start→All Programs→Microsoft Exchange Server 2007→Exchange Management Console.
2. Expand Server Configuration, and click Mailbox.
3. Right-click Mailbox Database, and click Properties.
4. Click Customize.
5. Double-click the empty gray box above Sunday.
6. Ensure that all cells on the graph turn white, and click OK.
7. Click OK.

## Installing and configuring the Web server (WebBench)

### Deploying WebBench data

WebBench includes data that must reside on the server and that the Web server must use. We used the following procedure to load that data, and set the Web server to use it:

1. Copy the file wbtrees.exe from the WebBench CD to the wwwroot directory on the server under test. (The wbtrees.exe file is on the WebBench CD at \wb50\workload. The wwwroot directory is located at C:\inetpub\wwwroot.)
2. On the server, execute the wbtrees.exe file. This program copies the WebBench workload to the server.
3. In the wwwroot folder on the server, create a new folder with the name CGI-BIN.
4. Copy the file simcgi.exe to the CGI-BIN folder.
5. Click Start→Programs→Administrative Tools→Computer Management to open the management console.
6. Go to Services and Applications→Internet Information Services (IIS) Manager→ServerName.
7. Double-click ISAPI and CGI Restrictions.
8. Click Add.
9. Enter the path for the simisapi.dll, and click the check box saying Allow extension path to execute.
10. Click OK.

### Configuring Internet Information Services (IIS)

We configured the Windows Internet Information Services Web server as follows:

1. Open Computer Management.
2. Go to Services and Applications→Internet Information Services (IIS) Manager→ServerName.
3. Double-click MIME Types.
4. In the MIME Types window, click Add.
5. In the Extension field, type \*.
6. In the MIME Type field, type application/octet-stream, and click OK.
7. Double-click the server name on the left side of the window.
8. Double-click ISAPI and CGI Restrictions.
9. Click Edit Feature Settings.
10. Click the check boxes beside Allow unspecified CGI module and Allow unspecified ISAPI modules.
11. Click OK.
12. Go to Services and Applications→Internet Information Services (IIS) Manager→ServerName.
13. Double-click Logging.
14. Click Disable.

### Installing certificate services

Because WebBench includes tests that involve security, we installed Windows Certificate Services as follows:

1. Go to Services and Applications→Internet Information Services (IIS) Manager→ServerName.

2. Double-click Server Certificates.
3. Click Create Self-Signed Certificate.
4. Name it Performance, and click OK.
5. Go to Services and Application→Internet Information Services (IIS) Manager→ServerName→Sites→Default Web Site.
6. Click Bindings...
7. Click the https entry, and click Edit.
8. Set the SSL Certificate to Performance, and click OK.
9. Click Add.
10. Set the type to http, and set the IP address to 192.168.1.1
11. Set the Port to 81, and click OK.
12. Click Add.
13. Set the type to https, and set the IP address to 192.168.1.1
14. Set the SSL Certificate to Microsoft Exchange.
15. Set the Port to 444, and click OK.
16. If a warning pops up, click Yes.
17. Click Close.
18. Double-click SSL settings.
19. Uncheck the Require SSL check box.
20. Click Apply.

### Creating SSL Communication

We enabled SSL communication as follows:

1. Go to Services and Applications→Internet Information Services (IIS) Manager→ServerName.
2. Expand the Default Web site.
3. Expand wbtrees.
4. Click Wbssl.
5. Double-click SSL Settings.
6. Check Require SSL.
7. Check Require 128-bit SSL.
8. Click Apply.

We then set the following operating system tuning parameters for optimum WebBench performance. When creating the following parameters, ensure that they are DWORD files, with decimal coding (rather than hexadecimal):

- HKLM\System\CurrentControlSet\Services\Inetinfo\Parameters\MaxCachesFileSize to 1048576
- HKLM\System\CurrentControlSet\Services\HTTP\Parameters\UriMaxUriBytes to 1048576
- HKLM\System\CurrentControlSet\Control\FileSystem\NtfsDisableLastAccess to 1
- HKLM\System\CurrentControlSet\Services\Tcpip\Parameters\MaxHashTableSize to 65535

### Installing SQL Server 2008 on the server

1. Insert the DVD into the physical DVD drive.
2. Click Run SETUP.EXE on the AutoPlay menu.
3. If the application prompts you to install the .NET Framework, click OK.
4. Select the Accept radio button, and click Install.
5. When the installation finishes, click Exit.
6. If the application prompts you, click OK to install a hotfix for Windows (KB942288).
7. Click Restart now to restart the server upon completion.
8. After rebooting, log into the server.
9. Click Start, and click Computer.
10. Double-click the CD/DVD drive.
11. Click Installation.
12. Click New SQL Server stand-alone installation.

13. At the Setup support rules screen, click OK.
14. Specify the Enterprise Evaluation free edition. Click Next.
15. Click the checkbox to accept the license terms. Click Next.
16. Click Install to install the setup support files.
17. You may see a Computer domain controller warning and a Windows Firewall warning. For now, ignore this, and click Next.
18. At the Feature Selection screen, select Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backward Compatibility, Management Tools –Basic, and Management Tools – Complete. Click Next.
19. At the Instance configuration screen, leave the default selection of default instance, and click Next.
20. At the Disk space requirements screen, click Next.
21. At the Server configuration screen, choose NT AUTHORITY\SYSTEM for SQL Server Agent, and choose NT AUTHORITY\SYSTEM for SQL Server Database Engine. Click Next.
22. At the Database Engine Configuration screen, select Mixed Mode.
23. Enter a password for the system administrator account.
24. Click Add Current user. This may take several seconds.
25. Click Next.
26. At the Error and usage reporting screen, click Next.
27. At the Installation rules screen, click Next.
28. At the Ready to Install screen, click Next.
29. After installation completes, click Start, All Programs, Microsoft SQL Server 2008, Configuration Tools, SQL Server Configuration Manager.
30. Expand the Network Configuration node, and select the relevant instance.
31. In the right pane, right-click TCP/IP, and choose Enable.
32. In the left pane, click SQL Server Services.
33. In the right pane, right-click the relevant instance, and select Restart.
34. Click Start, Administrative Tools, and Local Security Policy.
35. In the left pane, expand Local Policies, and click User Rights Assignment.
36. In the right pane, double-click Perform Volume Maintenance Tasks, and add the System account.
37. Double-click Lock Pages in Memory, and add the System account.
38. Create a SQL Server login for the ds2user (see the DVD Store setup section below for the specific script to use).
39. Place the DVD Store backup file you prepared in the default location for SQL Server: C:\Program Files\Microsoft SQL Server\MSSQL10.MSSQLSERVER\MSSQL\Backup.

### **Installing SQL Server 2008 SP1**

Service Pack 1 is available for download from

<http://www.microsoft.com/downloads/details.aspx?FamilyID=66ab3dbb-bf3e-4f46-9559-ccc6a4f9dc19&displaylang=en>.

1. Run SQLServer2008SP1-KB968369-x64-ENU.exe.
2. At the Welcome screen, click Next.
3. At the License terms screen, accept the license terms, and click Next.
4. At the Features screen, select available features, and click Next.
5. At the Check files in use screen, wait for the installer to complete its check, and click Next.
6. At the Update screen, click Update.
7. When the update completes, click Next, and click Close.

### **Setting the database recovery interval in SQL Server 2008 SP1**

1. Click Start→All Programs→Microsoft SQL Server 2008→SQL Server Management Studio.
2. Click Connect.
3. Right-click SERVER, and click Properties.
4. Click Database Settings.
5. Set Recovery interval (minutes) to 60.
6. Click OK, and close Microsoft SQL Server Management Studio.

Create the folders necessary for the database. We used <driveletter>:\SQLData for the SQL Server database volume and <driveletter>:\SQLLog for the SQL Server transaction log volume.

## Installing and configuring the database server (DVD Store)

### Data generation overview

We built the database schema using the scripts in the DS2 distribution package. The DS2 stress tool provides options to generate 10MB, 1GB, or 100GB datasets. We generated the 1GB data set for our testing. Note: We created our test data on a Linux system to take advantage of the larger RAND MAX.

### Generating the data for the 1GB database

We used shell scripts to run all four of the executables that generate the data.. We used the ds2\_create\_cust\_med.sh and ds2\_create\_orders\_med.sh shell scripts. The ds2\_create\_prod and ds2\_create\_inv executables did not ship with associated shell scripts, so we created shell scripts using the instructions in the readme files. We ran the shell scripts in the following order to generate the data for the 1GB database:

1. ds2\_create\_orders\_1gb.sh
2. ds2\_create\_inv\_1gb.sh
3. ds2\_create\_prod\_1gb.sh
4. ds2\_create\_cust\_1gb.sh

We waited until the processes finished before we moved onto the next step.

### Creating the database

We modified the database creation SQL Server scripts in the DVD Store distribution package to build the database schema, which includes the file structure, tables, indices, stored procedures, triggers, and so on. We built a master copy of the 1GB database version for SQL Server 2008, and then used that master copy to restore our test database to the Intel processor-based server between each test run. We stored the backup file on the C: drive for quick access.

We followed these steps to create the database:

1. We created the database and file structure using database creation scripts in the DS2 download. We made size modifications specific to our 1GB database and the appropriate changes to drive letters.
2. We created database tables, stored procedures, and objects.
3. We set the database recovery model to bulk-logged to prevent excess logging.
4. We loaded the data we generated into the database. For data loading, we used the import wizard in SQL Server Management Studio. Where necessary, we retained options from the original scripts, such as Enable Identity Insert.
5. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
6. We updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
7. On the default SQL Server instance, we created a ds2user SQL Server login using the following Transact SQL (TSQL) script:

```
USE [master]
GO
CREATE LOGIN [ds2user] WITH PASSWORD=N'',
DEFAULT_DATABASE=[master],
DEFAULT_LANGUAGE=[us_english],
CHECK_EXPIRATION=OFF,
CHECK_POLICY=OFF
GO
```

8. We set the database recovery model back to full.

We made the following changes in the build scripts:

- Because we varied the size of the datasets, we sized the files in our scripts to reflect the database size and the number of files per filegroup. We allowed for approximately 40 percent free space in our database files to ensure that filegrowth activity did not occur during the testing.
- We followed Microsoft's recommendation of having 0.25 to 1 file per filegroup per core. The Intel Core 2 Quad Processor Q8400 and the Intel Xeon Processors X3220 and X3380 have four cores each, while the Intel Xeon Processor X3450 has eight logical processors with hyper-threading enabled. We used two files per filegroup in all cases.
- We did not use the DBCC PINTABLE command for the CATEGORIES and PRODUCTS tables, both because Microsoft recommends against this practice and because the commands do nothing in SQL Server 2008.
- We added the FORCESEEK hint in the BROWSE\_BY\_ACTOR stored procedure because in initial testing we found that SQL Server 2008 was choosing an index scan instead of the preferred index seek, adding unnecessary overhead.
- We created a SQL Server login we called `ds2user` and mapped a database user to this login. We made each such user a member of the `db_owner` fixed database role.
- Using the DVD Store scripts as a reference, we created the full-text catalog and index on the PRODUCTS table manually in SQL Server Management Studio.

We then performed a full backup of the database. This backup allowed us to restore the databases to a pristine state relatively quickly between tests.

### Editing the workload script - `ds2sqlserverfns.cs` module

We changed the connection string to increase the number of available connections, to not use the default administrator ("sa") account, and to include a parameter for the database name. We raised the available connections limit from the default of 100 to 200 to allow room for experimentation. We created a user account we called `ds2User` and used that account.

The `ds2connect` routine in the `ds2sqlserverfns.cs` module defines `sConnectionString`. We used the following string; the changes we made appear in bold:

```
string sConnectionString = "User ID=ds2User;Initial Catalog="+dbname+";Max
Pool Size=200;Connection Timeout=120;Data Source=" + Controller.target;
```

### Recompiling the `ds2sqlserverdriver.exe` executable

We recompiled the `ds2xdriver.cs` and `ds2sqlserverfns.cs` module in Windows by following the instructions in the header comments. Because the DS2 instructions were for compiling from the command line, we used the following steps:

1. Open a command prompt.
2. Use the `cd` command to change to the directory containing our sources.
3. Run the batch file `C:\Program Files\Microsoft Visual Studio 9.0\Common7\Tools\vsvars32.bat`. This sets up the environment variables for us.
4. Execute the following command:

```
csc /out:ds2sqlserverdriver.exe ds2xdriver.cs ds2sqlserverfns.cs
/d:USE_WIN32_TIMER /d:GEN_PERF_CTRS
```

### Testing procedure

To perform the test, we used a series of batch files. We stored batch files either under the `C:\ServerShare` folder on the server or under the `C:\ClientShare` folder on the client machine. We used simple file sharing to copy files from machine to machine, as we needed.

The testing procedure consisted of the following steps:

1. Drop the database on SQL Server.

2. Restore the database on SQL Server.
3. Pause briefly to wait for background tasks to complete before rebooting the server.
4. The scripts reboot the client machine and server machine. We confirmed connectivity between the client and server after rebooting via a shared folder link in the startup folder of the server. Wait 10 additional minutes for any background tasks to complete.
5. Start the counter logs on client machines, and start the data collector set on the server under test.
6. Start the workload connections.
7. Start the workload ramp-up period.
8. Start the workload.
9. Stop the workload.
10. Copy all output files.

## Installing the mail test client (LoadGen)

We began our testing by installing a fresh copy of Microsoft Windows Server 2003 R2, Enterprise x64 Edition Service Pack 2 on the test client. Before following these instructions, make sure to statically assign an IP address for the client, and then plug that port into the system under test. This allows the client to correctly join the domain. We followed this process for each installation:

1. Assign a computer name of `Clientx` for the mail client, where `x` is the client number.
2. For the licensing mode, use the default setting of five concurrent connections.
3. For the administrator log on, enter a password.
4. Select Eastern Time Zone.
5. Use typical settings for the Network installation.
6. Assign a name of `Testbed` for the workgroup.

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

### Joining the domain

1. Right-click My Computer, and select Properties.
2. Under the Computer Name tab, click Change.
3. In the Computer Name Changes window, under the Member of section, select the Domain radial box, and type `test.lan`.
4. To start joining the domain, select OK.
5. When the window appears asking for a person qualified on the domain, type `Administrator` as the username and `Password1` as the password.
6. At the Welcome pop-up window and the window warning that you must reset the computer for the changes to take effect, click OK.
7. At the System Properties window, click OK.
8. When a pop-up appears asking if you want to restart now, click Yes.

### 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 Active Directory Services, 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 2007 and Load Generator

1. Insert the Microsoft Exchange Server 2007 CD. The CD should automatically launch the installation software.
2. Click the link to Step 1: Install .NET Framework 2.0.
3. When you arrive at the download link, download the x64 version of the .NET Framework, and install.
4. Click the link to Step 3: Install Microsoft Windows PowerShell to go to the download link.
5. When you arrive at the download link, download Microsoft Windows PowerShell, and install with defaults.
6. Search for and then download .NET 2.0 SP1 x64.
7. Install SP1 with all defaults.
8. Click the link to Step 4: Install Microsoft Exchange Server 2007 SP1.
9. Click Next to go past the introduction screen.
10. Accept the license agreement, and click Next.
11. Select No for error reporting, and click Next.
12. Select Custom Exchange Server Installation, and click Next.
13. Check Management Tools, and click Next.
14. After the check finishes, click Install to start the installation process.
15. Once the installation completes, click Finish.
16. Download and install Load Generator using all defaults.

## Preparing Load Generator

1. Select Start→All Programs→Microsoft Exchange→Exchange Load Generator.
2. When the Load Generator window appears, select Start a new test.
3. Select Create a new test configuration, and click Continue.
4. In the Specify test settings window, type `Password1` as the Directory Access Password and Mailbox Account Master Password, and click Continue with recipient management.
5. Make 75 users in the Mailbox Database, and click Continue.
6. To accept defaults for Advanced recipient settings, click Continue.
7. In the Specify test user groups window, select the plus sign (+) to add a user group.
8. Change the Client Type to Outlook 2007 Cached and the Action Profile to Average, and click Continue.
9. Leave defaults in Remote configurations, and click Continue.
10. Click Save the configuration file as, and name it `GastonAverage.cfg`.
11. Click Start the initialization phase (recommended before running the test) to start initialization. The initialization process might take a few hours.

## Backing up the mail database

On the test server, once you have set up LoadGen and created its initial mail database, you need to back up that database so you can have clean copies for each test. Use this process to back up that database:

1. Select Start→All Programs→Microsoft Exchange Server 2007→Exchange Management Console in the mail server.
2. In the left pane, under Server Configuration, click Mailbox.
3. In the right pane, right-click Mailbox Database, and select Dismount Database from the menu.
4. On the Do you want to continue? pop-up message, click Yes.
5. Right-click Public Folder Database, and select Dismount Database from the menu.
6. On the Do you want to continue? pop-up message, click Yes. The red arrow appears when you have dismounted the Public Folder Store.
7. Using Windows Explorer, create two new folders: `C:\backup\mailstore` and `C:\backup\publicstore`.
8. With Windows Explorer, copy all files from `C:\Program Files\Microsoft\Exchange Server\Mailbox\First Storage Group` to `C:\backup\mailstore`, and all the files from `C:\Program Files\Microsoft\Exchange Server\Mailbox\Second Storage Group` to `C:\backup\publicstore`. This process may take several minutes.
9. Close Windows Explorer.
10. In Exchange Management Console, right-click Mailbox Database, and select Mount Database from the menu.
11. Right-click the Public Folder Database, and select Mount Database from the menu.
12. Close Exchange System Manager.

## Running the test

To perform the test, we used a series of batch files. We stored batch files either under the C:\ServerShare folder on the server or under the C:\ClientShare folder on the clients. We use simple file sharing to copy files from machine to machine, as we needed.

We put batch files in the startup folder on the LoadGen and DVD Store clients. This way, when we rebooted the systems, they would start a batch file, which ran a loop script waiting for the server to copy a file to the client. To begin the test, we executed a script on the server.

Between tests, we ran a restore script, which dismounted the Mailstore and Database and then restored them from backup. After the restore finished, the script rebooted the server and all clients.

## Enabling write caching on the disk

1. Click Start→Computer.
2. Right-click Local Disk, and click Properties.
3. Click the Hardware tab.
4. Select Volume0, and click Properties.
5. Click the Policies tab.
6. Click the box beside Enable write caching on the disk, and click OK.
7. Click OK, and close the Computer window.

## Running WebBench

1. Restart the Web Controller.
2. On the desktop, double-click the Web Controller shortcut.
3. Go to the top bar, and click Clients→Start Log In...
4. Restart all of the Web Clients.
5. Wait for all of the Web Clients to appear on the left side of the WebBench Controller Program.
6. Click OK.
7. When the application prompts you to add a test suite, click Yes.
8. Select 45minute\_Gaston 12 client ecommerce\_api\_template.tst.
9. Give the run an appropriate name (e.g., Gaston\_WB\_Run1).
10. Click OK.
11. When the Would you like to start executing the test suites? Screen appears, do not click Yes or No. Instead, leave the screen.

## Running LoadGen

1. Restart the Mail Client.
2. Leave the screen sitting when it boots up.

## Starting DVD Store

We created a batch file to run the following parameters to begin the DVDStore test:

```
ds2sqlserverdriver.exe --target=10.1.5.250 --ramp_rate=10 --run_time=42 --  
n_threads=32 --db_size_str=M --think_time=0.3 --database_name=DS2 --  
n_searches=10
```

1. Restart the DVD Store client.
2. Leave the screen sitting when it boots up.

## Starting the test

1. Restart the system under test (SUT).
2. Let the SUT idle for 10 minutes.
3. Run c:\SBSbench\_run1.cmd.
4. When the script tells you to, start WebBench.
5. LoadGen and DVD Store will begin automatically in the next 5/15 minutes, respectively.

6. Run the restore\_all script between each run.

### **Network test bed configuration**

To generate the workload, we used a network with 22 client PCs. We split 20 of the clients into two segments, or subnets, of 10 clients each. We configured these clients with Windows XP Professional with Service Pack 2 and all critical updates available as of June 7, 2007. We connected each segment to the server under test via one NETGEAR GS724T Gigabit Smart Switch. To balance the load on the server and to prevent a network throughput bottleneck, we connected each segment to a separate network port. We used the remaining two clients for the DVD Store client and LoadGen client.

### **Measuring power**

To record each solution's power consumption during each test, we used an Extech Instruments ([www.extech.com](http://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.

We then recorded the power usage (in watts) for each system during the testing at 1-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results. See Figure 11 (workload power) for the results of these measurements.

## Appendix A – Price information

Figure 10 provides the list price information for components of the four servers as of August 13, 2009. Prices exclude tax and shipping costs.

Server	Intel Core 2 Quad Desktop Processor Q8400-based server	Intel Xeon Processor X3220-based server	Intel Xeon Processor X3380-based server	Intel Xeon Processor X3450-based server*
Price as of August 13, 2009	\$892.08	\$922.08	\$1,292.08	\$1,611.54

**Figure 10: List price information for the four Intel processor-based servers. Prices exclude tax and shipping costs.**

\*We base this price on the estimated average retail price provided by Intel. For testing, we used a different server chassis, but used the same chassis price for all systems.

## Appendix B – Test system configuration information

Figure 11 provides detailed configuration information about each of the four servers, which we list in alphabetical order.

Servers	Intel Core 2 Quad Desktop Processor Q8400-based server	Intel Xeon Processor X3220-based server	Intel Xeon Processor X3380-based server	Intel Xeon Processor X3450-based server
<b>Power supplies</b>				
Total number	1	1	1	1
Wattage of each (W)	350	350	350	1,000
<b>Cooling fans</b>				
Total number	2	2	2	4
<b>First fan</b>				
Dimensions (h x w)	4.75" x 4.75"	4.75" x 4.75"	4.75" x 4.75"	4.75" x 4.75"
Voltage (V)	12	12	12	12
Amps (A)	0.16	1.6	1.6	3.3
<b>Second fan</b>				
Dimensions (h x w)	3" x 3"	3" x 3"	3" x 3"	3.5" x 3.5"
Voltage (V)	12	12	12	12
Amps (A)	0.2	0.31	0.31	0.4
<b>Third fan</b>				
Dimensions (h x w)	N/A	N/A	N/A	4.75" x 4.75"
Voltage (V)	N/A	N/A	N/A	12
Amps (A)	N/A	N/A	N/A	1.6
<b>Fourth fan</b>				
Dimensions (h x w)	N/A	N/A	N/A	3" x 3"
Voltage (V)	N/A	N/A	N/A	12
Amps (A)	N/A	N/A	N/A	0.2
<b>General processor setup</b>				
Number of processor packages	1	1	1	1
Number of cores per processor package	4	4	4	4
Number of hardware threads per core	1	1	1	2
System power management policy	Balanced	Balanced	Balanced	Balanced
<b>CPU</b>				
Vendor	Intel	Intel	Intel	Intel
Name	Core 2 Quad Q8400	Xeon X3220	Xeon X3380	Xeon X3450
Stepping	R0	B3	E0	5
Socket type	LGA775	LGA775	LGA775	LGA1160
Core frequency (GHz)	2.66	2.40	3.16	2.66
Front-side bus frequency (MHz)	1,333	1,066	1,333	1,333
L1 cache	4 x 32 KB	4 x 32 KB	4 x 32 KB	4 x 32 KB
L2 cache	4 MB	8 MB	12 MB	4 x 256 KB

Servers	Intel Core 2 Quad Desktop Processor Q8400-based server	Intel Xeon Processor X3220-based server	Intel Xeon Processor X3380-based server	Intel Xeon Processor X3450-based server
L3 cache	N/A	N/A	N/A	8 MB
<b>Platform</b>				
Vendor and model number	Intel S3200SHV	Intel S3200SHV	Intel S3200SHV	Intel S3420GP
Motherboard Revision Number	00	00	00	11
Motherboard chipset	Intel S3200/S3210	Intel S3200/S3210	Intel S3200/S3210	Intel 3400 Chipset
BIOS name and version	Intel Corp. S3200X38.86B.00.0 0.0047 (03/13/2009)	Intel Corp. S3200X38.86B.00.0 0.0047 (03/13/2009)	Intel Corp. S3200X38.86B.00.0 0.0047 (03/13/2009)	Intel Corp. S3420GP.86B.01.0 0.0022 (07/23/2009)
BIOS settings	Matrix RAID	Matrix RAID	Matrix RAID	Matrix RAID
<b>Memory module(s)</b>				
Total RAM in system (GB)	4	4	4	6
Number of types of memory modules	1	1	1	1
Vendor and model number	Kingston KVR667D2E5/1G	Kingston KVR667D2E5/1G	Kingston KVR667D2E5/1G	Qimonda IMSH1GP03A1F1C-10F
Type	PC2-5300	PC2-5300	PC2-5300	PC3-8500R
Speed (MHz)	333	333	333	1,066
Speed in the system currently running @ (MHz)	333	333	333	800
Timing/latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15	5-5-5-15	5-5-5-15	6-6-6-16
Size (MB)	1,024	1,024	1,024	1,024
Number of RAM modules	4	4	4	6
Chip organization	Double-sided	Double-sided	Double-sided	Double-sided
Channel	Dual	Dual	Dual	Dual
<b>Hard disk</b>				
Vendor and model number	Hitachi HDP725050GLA360	Hitachi HDP725050GLA360	Hitachi HDP725050GLA360	Hitachi HDP725050GLA360
Number of disks in system	4	4	4	4
Size (GB)	500	500	500	500
Buffer size (MB)	16	16	16	16
RPM	7,200	7,200	7,200	7,200
Type	SATA	SATA	SATA	SATA
Controller	Intel ICH8R/ICH9R/ICH10R/DO SATA RAID Controller	Intel ICH8R/ICH9R/ICH10R/DO SATA RAID Controller	Intel ICH8R/ICH9R/ICH10R/DO SATA RAID Controller	Intel ICH8R/ICH9R/ICH10R/DO SATA RAID Controller

Servers	Intel Core 2 Quad Desktop Processor Q8400-based server	Intel Xeon Processor X3220-based server	Intel Xeon Processor X3380-based server	Intel Xeon Processor X3450-based server
Controller driver	Intel 8.8.0.1009 (2/11/2009)	Intel 8.8.0.1009 (2/11/2009)	Intel 8.8.0.1009 (2/11/2009)	Intel 8.8.0.1009 (2/11/2009)
<b>Operating system</b>				
Name	Windows Server Standard x64	Windows Server Standard x64	Windows Server Standard x64	Windows Server Standard x64
Build number	6001	6001	6001	6001
Service Pack	SP1	SP1	SP1	SP1
File system	NTFS	NTFS	NTFS	NTFS
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
<b>Graphics</b>				
Vendor and model number	Matrox G200e	Matrox G200e	Matrox G200e	Matrox G200e
Type	Integrated	Integrated	Integrated	Integrated
Memory size (MB)	32	32	32	32
Resolution	1,024 x 768	1,024 x 768	1,024 x 768	1,280 x 1024
Driver	Matrox Graphics 5.97.6.2 (1/29/2009)	Matrox Graphics 5.97.6.2 (1/29/2009)	Matrox Graphics 5.97.6.2 (1/29/2009)	Matrox Graphics 5.97.6.2 (1/29/2009)
<b>Network card/subsystem</b>				
Vendor and model number	Intel PRO/1000 MT	Intel PRO/1000 MT	Intel PRO/1000 MT	Intel 82574L Gigabit Network Connection
Type	Integrated	Integrated	Integrated	Integrated
Driver	Intel 8.3.15.0 (9/23/2008)	Intel 8.3.15.0 (9/23/2008)	Intel 8.3.15.0 (9/23/2008)	Intel 10.6.15.0 (3/5/2009)
Additional network adapter	Marvell Yukon 88E80553	Marvell Yukon 88E80553	Marvell Yukon 88E80553	Intel 82578DM Gigabit Network Connection
Type	Discrete	Discrete	Discrete	Integrated
Driver	Marvell 10.64.2.3 (8/18/2008)	Marvell 10.64.2.3 (8/18/2008)	Marvell 10.64.2.3 (8/18/2008)	Intel 10.7.31.0 (6/19/2009)
Additional network adapter	Marvell Yukon 88E80553	Marvell Yukon 88E80553	Marvell Yukon 88E80553	Marvell Yukon 88E80553
Type	Discrete	Discrete	Discrete	Discrete
Driver	Marvell 10.64.2.3 (8/18/2008)	Marvell 10.64.2.3 (8/18/2008)	Marvell 10.64.2.3 (8/18/2008)	Marvell 10.64.2.3 (8/18/2008)
<b>USB ports</b>				
Number of ports	4	4	4	6
Type of ports (USB 1.1, USB 2.0)	2.0	2.0	2.0	2.0

Figure 11: Detailed system configuration information for the four Intel processor-based servers.

## About Principled Technologies

We provide industry-leading technology assessment and fact-based marketing services. We bring to every assignment extensive experience with and expertise in all aspects of technology testing and analysis, from researching new technologies, to developing new methodologies, to testing with existing and new tools. 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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