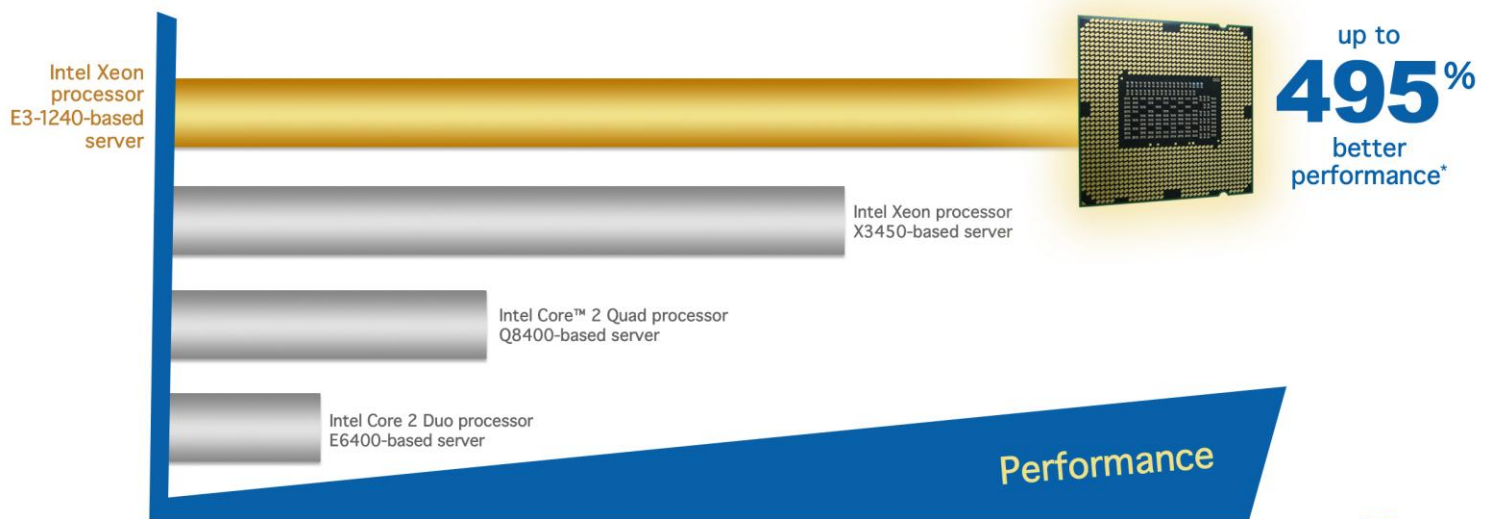


PERFORMANCE OF FOUR INTEL-BASED SMB SERVERS RUNNING WEB, EMAIL, AND DATABASE APPLICATIONS

An Intel® Xeon® processor E3-1240-based server delivered



while simultaneously providing Web, email, and database service



*Greatest performance improvement was in comparison to the Intel Core 2 Duo processor E6400-based server.

OUR FINDINGS

The latest Intel® Xeon® processor E3-1240-based small-to-medium business (SMB) server delivers significantly better performance and performance per watt than previous-generation Intel processor-based SMB servers while running typical office applications. In our tests, the Intel Xeon processor E3-1240-based server delivered up to 495 percent better performance than three previous-generation Intel processor-based servers did. This superior performance, for comparatively little increase in cost, makes the new Intel Xeon processor E3-1240-based server a wise choice for any small business seeking an all-in-one SMB server.

OUR PROCESS

We measured the performance and performance per watt of four different Intel processor-based SMB servers running simultaneous workloads that exercised three of the functions a typical small business server may have to handle: Web, email, and database services. Our tests reflect the priorities of SMB owners: increased efficiency and increased cost savings. Better workload performance results in more accomplished in less time, and better performance per watt results in lower power bills. We wanted to see if the new Intel Xeon processor E3-1240-based SMB server could deliver both.



PROJECT OVERVIEW

Hardware ages out. As workloads become more demanding, older servers, and older desktop systems acting as servers, are increasingly unable to run them efficiently. SMB owners find their servers becoming bottlenecks to productivity, and even liabilities as they start to break down.

Nonetheless, small businesses that are outgrowing their servers still question the performance benefits of newer servers. Can they continue to use their older desktop systems as servers? Were they to invest in a new server, how substantial would the performance gains in Web, email, and database applications be; how substantial would the power savings be; and what would the price differences be?

In our tests, we address these questions by comparing a new Intel Xeon processor E3-1240-based server with that of several older Intel processor-based servers. The Intel Core 2 Quad processor Q8400-based server and Intel Core 2 Duo processor E6400-based server are intended to represent desktop systems acting as servers.

We tested four one-socket servers with the following processors:

- Intel Xeon processor E3-1240-based server (3.30 GHz, 8MB L3 cache)
- Intel Xeon processor X3450-based server (2.66 GHz, 8MB L3 cache)
- Intel Core 2 Quad processor Q8400-based server (2.66 GHz, 4MB L2 cache)
- Intel Core 2 Duo processor E6400-based server (2.13 GHz, 2MB L2 cache)

We used WebBench to

simulate Web traffic,

Microsoft® Exchange Load

Generator (LoadGen) to

simulate email activity, and

DVD Store Version 2 (DS2) to

simulate database activity. All

servers ran Microsoft

Windows Server® 2008 R2

Standard Edition with

Microsoft Exchange 2010 and

Microsoft SQL Server® 2008 R2

Enterprise Edition.

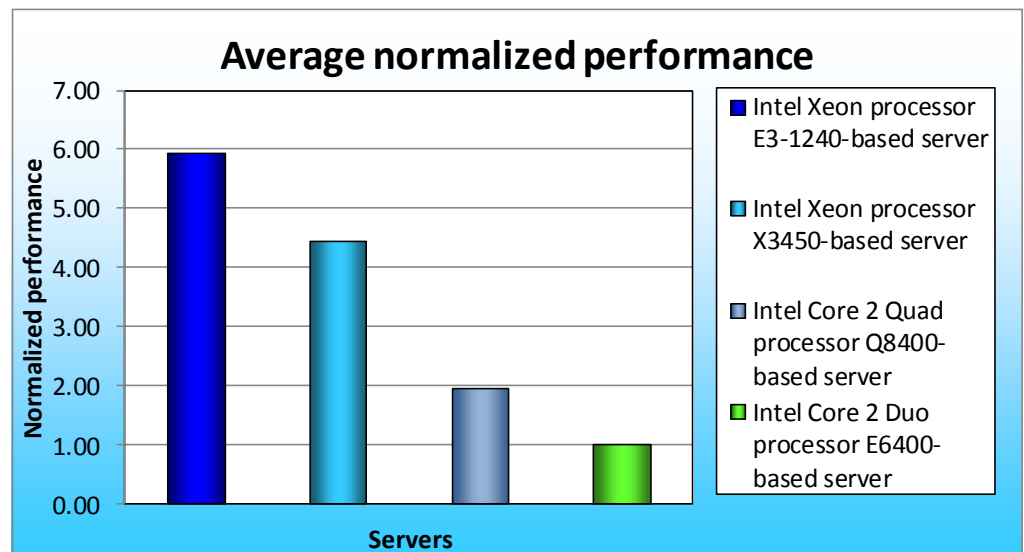


Figure 1: Performance of the Intel processor-based servers across the three benchmarks relative to the Intel Core 2 Duo processor E6400-based server. Higher numbers are better.

WHAT WE FOUND

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 Duo processor E6400-based server. While running the three benchmarks, the Intel Xeon processor E3-1240-based server delivered the following performance increases: 33.8 percent better than the Intel Xeon processor X3450-based server, 203.3 percent better than the Intel Core 2 Quad processor Q8400-based server, and 494.9 percent better than the Intel Core 2 Duo processor E6400-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 Duo processor E6400-based server for the three benchmarks and averaged them.

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 Duo processor E6400-based server.

As Figure 2 illustrates, the Intel Xeon processor E3-1240-based server produced the following performance-per-watt increase: 61.1 percent better than the Intel Xeon processor X3450-based server, 215.7 percent better than the Intel Core 2 Quad processor Q8400-based server, and 550.3 percent better than the Intel Core 2 Duo processor E6400-based server.

As of February 15, 2011, the prices for each Intel-processor based server are as follows:

- Intel Xeon processor E3-1240-based server: \$1,383.60
- Intel Xeon processor X3450-based server: \$1,344.09
- Intel Core 2 Quad processor Q8400-based server: \$985.26

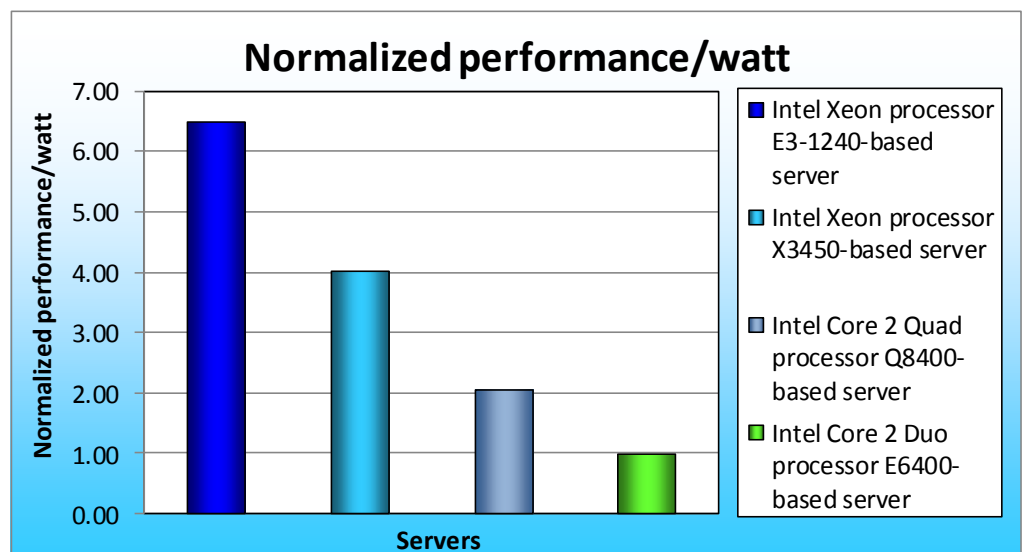


Figure 2: Normalized performance-per-watt results of the Intel processor-based servers across the three benchmarks relative to the Intel Core 2 Duo processor E6400-based server. Higher numbers are better.

- Intel Core 2 Duo processor E6400-based server: \$926.86

Figure 3 presents a comparison of price and performance increase of the Intel Xeon processor E3-1240-based server relative to the other Intel processor-based servers. The Intel Xeon processor E3-1240-based server’s 33.8 percent performance increase over the Intel Xeon processor X3450-based represents a substantial performance increase for a small increase in price. We present more detailed price listings in Appendix B.

Comparison	Price increase	Performance increase
Intel Xeon processor E3-1240-based server vs. Xeon processor X3450-based server	\$39.51	33.8%
Intel Xeon processor E3-1240-based server vs. Core 2 Quad processor Q8400-based server	\$398.34	203.3%
Intel Xeon processor E3-1240-based server vs. Core 2 Duo processor E6400-based server	\$456.74	494.9%

Figure 3: Price and performance increase for the Intel Xeon processor E3-1240-based server relative to the other Intel processor-based servers.

WHAT WE TESTED

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 the WebBench 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 the same number of clients, with 10 engines per client for the entire test. This allowed us to keep a constant Web load on the server. We used 45 clients on the Intel Xeon processor E3-1240-based server and the Intel Xeon processor X3450-based server, and scaled back to 30 clients on the Intel Core 2 Quad processor Q8400-based server and the Intel Core 2 Duo processor E6400-based server because these processors were unable to manage the greater workload. We performed only nine mixes for testing to limit the amount of time WebBench ran. To avoid any bottlenecks in the network cards, we used a ratio of 15 WebBench clients per NIC and added network adapters to the server hardware configuration as needed.

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 R2 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 2008 R2 Standard. The client machine ran a single instance of DS2, which spawned 32 threads on the Intel Xeon E3-1240 and Intel Xeon processor X3450-based servers, and scaled back to 16 threads on the Intel Core 2 Quad Q8400 and Intel Core 2 Duo processor E6400-based servers because these processors were unable to manage the greater workload, and ran 10 searches per order on all servers. 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 How we tested 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>.

Microsoft Exchange Load Generator

Microsoft Exchange Load Generator (LoadGen) is an industry-standard tool for benchmarking a Microsoft Exchange 2003, 2007 or 2010 mail server. LoadGen performs tasks to simulate a standard user generating mail activity. While the workload was ongoing, we measured response time, or the time in milliseconds necessary for the Exchange mail server to complete a request, using a remote procedure call (RPC) performance counter. Specifically, we used the RPC Averaged Latency counter, which records the average time it takes the server to process the last 1,024 packets. In other words, the counter provides data about the shortest period that client computers wait for a response from the server.

LoadGen 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 email loads. The simulator uses a client machine to send multiple message requests to the server running Exchange, resulting in a mail load.

We created a custom workload and adjusted it for 75 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 the client machine, we used a server running Microsoft Windows Server 2008 R2 Standard for testing the servers.

For more details about LoadGen, see

<http://www.microsoft.com/downloads/en/details.aspx?FamilyID=cf464be7-7e52-48cd-b852-ccfc915b29ef>.

SYSTEM COMPARISON

Figure 4 shows a side-by-side comparison of the key hardware differences among the four servers. Appendix A provides detailed configuration information for the servers.

Hardware specifications	Intel Xeon processor E3-1240-based server	Intel Xeon processor X3450-based server	Intel Core 2 Quad processor Q8400-based server	Intel Core 2 Duo processor E6400-based server
CPU	Intel Xeon E3-1240 processor	Intel Xeon X3450 processor	Intel Core 2 Quad Q8400 processor	Intel Core 2 Duo E6400 processor
CPU speed (GHz)	3.30	2.66	2.66	2.13
Number of processor packages	1	1	1	1
Number of cores per processor package	4	4	4	2
Number of hardware threads per core	2	2	1	1
Memory type	PC3-10600E	PC3-10600E	PC2-5300	PC2-4200
Total memory (GB)	8	8	4	4

Figure 4: System configuration information for the four Intel processor-based servers.

DETAILED FINDINGS

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 5 shows a timeline for the benchmark runs. To obtain the final results, we removed the first parts of the WebBench run, and computed the results based on the 30 minutes of peak performance during the LoadGen run. We identified the median run based on the LoadGen score.

To make sure each server achieved its optimum results, we allowed each to sit idle for 5 minutes before starting the workload.

Multiple benchmark timeline 45 minutes total time

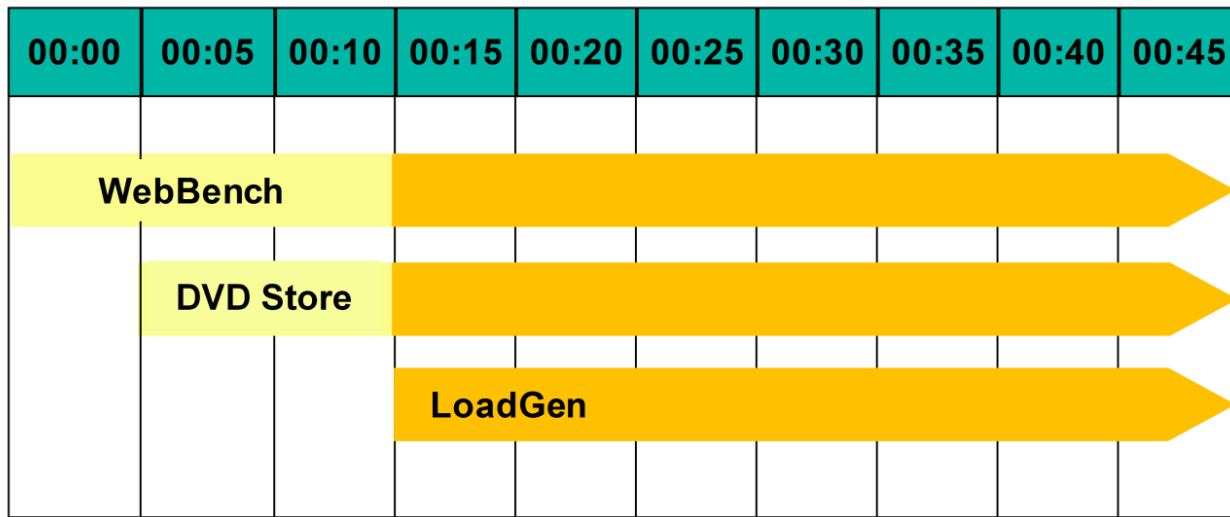


Figure 5: The timeline we followed when starting the benchmarks for the multiple-benchmark runs on all Intel processor-based servers. The shaded areas from 00:15 to 00:45 represent the period during which we measured performance.

Figure 6 presents results for the servers on the three benchmarks relative to the lowest-performing server, the Intel Core 2 Duo processor E6400-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 Duo processor E6400-based server for the three benchmarks and averaged them. As Figure 6 shows, the Intel Xeon processor E3-1240-based server provided better performance than the other servers did, across all workloads.

Server	Web requests per second	Email response time	OPM	Average Web, email, and database scores	Percentage CPU utilization
Intel Xeon processor E3-1240-based server	2.97	1.58	13.30	5.95	85.88
Intel Xeon processor X3450-based server	2.54	1.47	9.33	4.45	85.73
Intel Core 2 Quad processor Q8400-based server	1.99	1.42	2.47	1.96	96.79
Intel Core 2 Duo processor E6400-based server	1.00	1.00	1.00	1.00	99.90

Figure 6: Performance for the Intel processor-based servers on the three benchmarks, relative to the Intel Core 2 Duo processor E6400-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 4 illustrates.

Figure 7 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 Xeon processor E3-1240-based server	161,752,123.72	16,572.55	2.97
Intel Xeon processor X3450-based server	138,421,163.50	14,179.48	2.54
Intel Core 2 Quad processor Q8400-based server	108,265,654.10	11,090.45	1.99
Intel Core 2 Duo processor E6400-based server	54,509,923.03	5,580.24	1.00

Figure 7: Median WebBench results for the four Intel processor-based servers. Higher numbers are better.

* Relative to the Intel Core 2 Duo processor E6400-based server

DVD Store results

Figure 8 shows the number of OPM each server achieved during our measurement period of the DVD Store test on the median run. We determined the scores by taking the OPM value 30 minutes into the test period.

Server	Orders per minute (raw)	Orders per minute*
Intel Xeon processor E3-1240-based server	32,364	13.30
Intel Xeon processor X3450-based server	22,715	9.33
Intel Core 2 Quad processor Q8400-based server	6,022	2.47
Intel Core 2 Duo processor E6400-based server	2,434	1.00

Figure 8: Median DVD Store results for the four Intel processor-based servers. Higher numbers are better.

* Relative to the Intel Core 2 Duo processor E6400-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 9 shows the average Exchange 2010 Mail Server RPC average latency for the four servers. Each result is the median of three runs.

Server	RPC average latency in milliseconds (raw)	RPC average latency in milliseconds*
Intel Xeon processor E3-1240-based server	2.81	1.58
Intel Xeon processor X3450-based server	3.57	1.47
Intel Core 2 Quad processor Q8400-based server	3.87	1.42
Intel Core 2 Duo processor E6400-based server	6.70	1.00

Figure 9: Median LoadGen results for the four Intel processor-based servers. Lower response time is better.

* Relative to the Intel Core 2 Duo processor E6400-based server

To simulate the typical activity of a mail server, we created a custom workload using the average with a custom task distribution. Each of the 75 users had a mailbox of approximately 100 MB and used the average action profile. Figure 10 shows the configured distribution we used in our custom workload.

Task name	Configured distribution	Task name	Configured distribution
BrowseCalendar	12	BrowseContacts	10
Logon	1	CreateContact	0
Logoff	0	BrowseTasks	0
SendMail	17	CreateTask	0
ReadAndProcessMessages	59	EditRules	0

Task name	Configured distribution	Task name	Configured distribution
MoveMail	0	DownloadOab	0
DeleteMail	0	EditSmartFolders	0
ExportMail	0	SynchronizeFolders	0
CreateFolder	0	Search	0
PublicFolderPost	0	InitializeMailbox	1
BrowsePublicFolder	0	UserInit	0
PostFreeBusy	0	UserTerm	0
RequestMeeting	0	ModuleInit	0
MakeAppointment	0	ModuleTerm	0
Total 100			

Figure 10: Configured distribution for LoadGen tasks.

Figure 11 shows the power results during the median run of the four servers. Lower numbers are better.

Server	Workload power
Intel Xeon processor E3-1240-based server	140.74
Intel Xeon processor X3450-based server	169.49
Intel Core 2 Quad processor Q8400-based server	146.49
Intel Core 2 Duo processor E6400-based server	153.83

Figure 11: Average workload power results, in watts, for the four Intel processor-based 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.

HOW WE TESTED

Setting up the new server

We used the BIOS RAID configuration utility to create one RAID 10 volume on the test servers.

Following the operating system installation, we installed all important Windows® updates through January 14, 2011.

Installing Windows Server 2008 R2

1. Insert the installation DVD for Windows Server 2008 R2 into the DVD drive.
2. Choose the language, time and currency, and keyboard input. Click Next.
3. Click Install Now.
4. Choose Windows Server Standard (Full Installation). Click Next.
5. Accept the license terms, and click Next.
6. Click Custom.
7. Click the Disk, and click Drive options (advanced).
8. Click New, Apply, Format, and click Next.
9. After the installation completes, click OK to set the Administrator password.

10. Enter the administrator password twice, and click OK.

General OS settings

1. Turn off User Account Control:
 - a. Click Start, type `Change User Account Control Settings` and press Enter.
 - b. In the User Account Control Settings window, move the slider on the left down to Never notify.
 - c. Click OK.
 - d. Reboot the system.
2. Edit power settings:
 - a. Click Start, type `change power-saving settings` and press Enter.
 - b. Click Change plan settings next to the selected power plan (Balanced).
 - c. Set Turn off the display to Never.
 - d. Set Put the computer to sleep to Never.
 - e. Click Save changes, and close the Power Options window.
3. Turn off Windows Firewall:
 - a. Click Start, type `Windows Firewall with Advanced Security` and press Enter.
 - b. In the center pane under Overview, click Windows Firewall Properties.
 - c. Under the Domain Profile, Private Profile, and Public Profile tabs, set the Firewall state to Off.
 - d. Click OK.
4. Set static IP addresses:
 - a. Right-click the network icon in the quick-launch bar, and choose Open Network and Sharing Center.
 - b. Click Change adapter settings.
 - c. Right-click the local area connection, and choose Properties.
 - d. Click Internet Protocol Version 4 (TCP/IPv4), and click Properties.
 - e. Select Use the following IP Address, and input the following numbers:
IP Address: `192.168.1.1`
Subnet mask: `255.255.255.0`
 - f. In the Internet Protocol (TCP/IP) Properties, click Advanced.
 - g. In IP addresses, click Add.
 - h. Input the following numbers:
IP Address: `10.1.5.1`
Subnet mask: `255.255.255.0`
 - i. Click OK.
 - j. Click OK.
 - k. Repeat steps c through e 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`
5. Give the computer a name:
 - a. Click Start, right-click Computer, and click Properties.

- b. Click Change Settings.
- c. Click Change.
- d. Type a name (e.g. `new-server`) in the Computer name field, and click OK.
- e. In the Computer Name/Domain Changes pop-up window, click OK.
- f. Click OK.
- g. Click Close.
- h. In the Microsoft pop-up window, click Restart Now.

Installing Active Directory® and the domain controller

Promote the mail server to domain controller by following these steps:

1. Select Start→Command Prompt.
2. Type `dcpromo`
3. At the Welcome pop-up window, click Next.
4. At the Operating System Compatibility screen, click Next.
5. At the Choose a Deployment Configuration screen, select the Create a new domain in a new forest radio button, and click Next.
6. At the Name the Forest Root Domain screen, type a domain name (i.e., `test.local`), and click Next.
7. At the Set Forest Functional Level screen, choose Windows Server 2003 from the drop-down menu, and click Next.
8. At the Set Domain Functional Level screen, choose Windows Server 2003 from the drop-down menu, and click Next.
9. At the Additional Domain Controller Options screen, accept the defaults, and click Next.
10. When the Static IP assignment window pops up, click Yes, the computer will use a dynamically assigned IP address.
11. When the Active Directory domain Services Installation Wizard window pops up, click Yes.
12. At the Location for Database, Log Files, and SYSVOL screen, click Next.
13. At the Directory Services Restore Mode Administrator Password screen, enter and confirm a password, and click Next.
14. At the Summary screen, review the selections, and click Next.
15. If the installation software prompts you to do so, insert the OS CD, and click OK.
16. At the Completing the Active Directory Installation Wizard screen, click Finish.
17. When the system prompts you to reboot the server, click Restart Now.
18. After the server reboots, log into the system.

Setting up the Application Server

1. Click Start→Administrative Tools→Server Manager.
2. Click Roles on the left side.
3. Click Add Roles.
4. At the Before You Begin screen, click Next.
5. Click the Application Server check box.
6. When the Add features required for Application Server? screen appears, click Add Required Features.
7. Click Next.
8. Click Next.
9. At the Select Role Services page for Application Server, click the Web Server (IIS) Support check box.
10. When the Add features required for Web Server (IIS) Support? screen appears, click Add Required Features.

11. Click Next.
12. Click Next.
13. At the Select Role Services page for Web Server (IIS), click IIS 6 Management Compatibility, ASP, and CGI check boxes. Click Next.
14. Click Install.
15. Click Close.

Installing .NET Framework 3.5.1 Features and Internet Information Services

1. Select Start→Administrative Tools→Server Manager.
2. Click Features.
3. Click Add Features.
4. Select .NET Framework 3.5.1 Features.
5. Click Next.
6. Click Install.
7. At the Installation Results screen, click Close.

Installing Microsoft Filter Pack 1.0

1. Download the Microsoft Filter Pack 1.0.
(<http://www.microsoft.com/downloads/en/details.aspx?familyid=60c92a37-719c-4077-b5c6-cac34f4227cc&displaylang=en>)
2. Run FilterPackx64.EXE.
3. Click Next.
4. Click I accept the terms in the License Agreement, and click Next.
5. Click OK once installation is complete.

Installing Exchange Server 2010

1. Click Start→Administrative Tools→Services.
2. Right-click the Net.Tcp Port Sharing service, and click Properties.
3. Change the Net.Tcp Port Sharing startup type to Automatic, and click OK.
4. Insert the Exchange Server 2010 DVD.
5. When the Autoplay window appears, click Run Setup.EXE.
6. The installer should consider steps 1 and 2 complete, and gray them out.
7. Click the link to Step 3: Choose Exchange Language Option.
8. Click Install only languages from the DVD.
9. Click the link to Step 4: Install Microsoft Exchange Server 2010.
10. Click Next to go past the introduction screen.
11. Accept the license agreement, and click Next.
12. Select No for error reporting, and click Next.
13. Select Custom Exchange Server Installation, and click Next.
14. Select Mailbox Role, Client Access Role and Hub Transport Role (Exchange will automatically select Management Tools as well). Click Next.
15. Leave the organization name at default (First Organization), and click Next.
16. At the question about client computers running Outlook 2003 or Entourage, select Yes, and click Next.
17. Click Next to accept defaults for Configure Client Access server external domain.
18. At the Customer Experience Improvement Program screen, select I don't wish to join the program at this time, and click Next.

19. If a warning about a lack of SMTP appears after the check finishes, ignore it.
20. Click Install to start the installation process.
21. Once installation is complete, click Finish. Exchange should automatically open the Exchange Management Console.

Configuring Exchange Server 2010 roles

1. If Exchange does not automatically open the Exchange Management Console, click Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console.
2. In the left pane, expand Microsoft Exchange On-Premises, expand Organization Configuration, and select Hub Transport.
3. In the Actions pane on the far right, select New Send Connector.
4. Name the send connector `SMTP`, select the intended use as Internet, and click Next.
5. In the Address space window, click Add.
6. In the SMTP Address Space window, type `*` as the address, ensure that the installer has checked Include all subdomains, and click OK.
7. Click Next.
8. On the Network settings page, select Use domain name system (DNS) "MX" records to route mail automatically, and click Next.
9. Accept the defaults in the Source Server window, and click Next.
10. At the New Connector page, click New to create the connector.
11. Click Finish to close the New SMTP Send Connector wizard.

Configuring the Exchange Server 2010 Mailbox role

Creating a new user

1. Click Start→Administrative Tools→Active Directory Users and Computers.
2. In the Active Directory Users and Computers window, select the server in the left pane, and open Users in the right pane.
3. Right-click a blank area in the Users folder, and select New→User.
4. In the New Object - User window, complete the name fields as you wish (we used first name: test, last name: tester, logon name: tester), and select Next.
5. Enter a secure password (we used Password1), and check Password never expires.
6. In the pop-up information window, click OK.
7. Click Next and click Finish to close the New Object - User window.
8. Double-click the new user to bring up the Properties window.
9. Under the Member Of tab, click Add.
10. In the Enter the object names to select dialog box, type `Domain Admins; Enterprise Admins; Organization Management` select Check Names to verify, and click OK.
11. Click OK to close the User Properties window and close the Active Directory Users and Computers window.

Configuring the Mailbox role

1. Click Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console.
2. In the left pane of the Exchange Management Console window, expand Microsoft Exchange On-Premises, and select Recipient Configuration; in the right pane, select New Mailbox.
3. In the New Mailbox window, select User Mailbox, and click Next.
4. In the User Type page, select Existing users, and click Add.
5. Select the new account you created earlier, and click OK to add it to selection box.

6. Click Next.
7. In the Mailbox Settings page, type `tester` in the Alias textbox, check the box next to Specify the mailbox database rather than using a database automatically selected, and select Browse in the Mailbox database selection spot.
8. In the Select Mailbox database window, select Mailbox Database, and click OK.
9. Click Next.
10. Click New.
11. Click Finish.
12. In the left windowpane, expand Organization Configuration and click Mailbox so Database Management tab is visible.
13. Right-click Mailbox Database, and select Properties.
14. Select the Maintenance tab.
15. Check the Enable circular logging box.
16. Check the box beside This database can be overwritten by a restore.
17. Click Customize next to Maintenance interval.
18. Remove all blue from the boxes so the system will not perform maintenance, and click OK.
19. Click OK.
20. Click OK to any warnings about circular logging being applied after the database is remounted.
21. Click Move Database Path on the far right panel.
22. Change the Database file and Log folder path locations to `C:\Loadgen\[filename]` and `C:\Loadgen` respectively, and click Move.
23. Click Yes if the application prompts you to dismount.
24. Click Finish.
25. In the Database Management tab, right-click Public Folder Database, and select Properties.
26. Check the Enable circular logging box.
27. Check the This database can be overwritten by a restore box.
28. Click Customize next to Maintenance interval.
29. Remove all blue from the boxes so the system will not perform maintenance, and click OK.
30. Click OK.
31. Click OK to any warnings about circular logging being applied after the database is remounted.
32. Click Move Database on the far right panel.
33. Change the Database file and Log folder path locations to `C:\Loadgen\Public Folder Database\[filename]` and `C:\Loadgen\Public Folder Database` respectively, and click Move.
34. Click Yes if the application prompts you to dismount.
35. Click Finish.

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 `wbtree.exe` from the WebBench CD to the `wwwroot` directory on the server under test. (The `wbtree.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 `wbtree.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 files simcgi.exe and simisapi.dll to the CGI-BIN folder.
5. Click Start→Programs→Administrative Tools→Computer Management to open the management console.
6. Go to Services and Application→Internet Information Services (IIS) Manager→[server name].
7. Under IIS double-click ISAPI and CGI Restrictions.
8. Click Add.
9. Enter the path for the simccgi.exe, 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→[server name].
3. Under IIS, double-click MIME Types.
4. Under the Actions pane, click Add.
5. In the Extension field, type *
6. In the MIME Type field, type application/octet-stream and click OK.
7. Click the server name on the left side of the window.
8. Under IIS, 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. Click the server name on the left side of the window.
13. Under IIS, 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→[server name].
2. Under IIS, double-click Server Certificates.
3. Click Create Self-Signed Certificate.
4. Name it Performance and click OK.
5. In the left side of the window, expand [server name], expand Sites, and select Default Web Site.
6. Under the Actions pane, 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 Port to 444

15. Set the SSL Certificate to Microsoft Exchange, and click OK.
16. If a warning pops up, click Yes.
17. Click Close.
18. Under IIS, double-click SSL settings.
19. Uncheck the Require SSL check box.
20. In the Actions pane, click Apply.

Creating SSL Communication

We enabled SSL communication as follows:

1. Go to Services and Applications→Internet Information Services (IIS) Manager→[server name].
2. Expand the Default Web site.
3. Expand wbtrees.
4. Click Wbssl.
5. Double-click SSL Settings.
6. Check Require SSL.
7. In the Actions pane, 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 and configuring SQL Server 2008 R2 Enterprise

Installing SQL Server 2008 R2 on the server

1. Insert the DVD.
2. At the AutoPlay menu, click Run SETUP.EXE.
3. Click Installation in the left pane.
4. Click New installation or add features to an existing installation.
5. At the Setup Support Rules screen, wait for the check to complete. If there are no failures or relevant warnings, click OK.
6. Select the Specify a free edition radio button, and choose Evaluation from the drop down menu. Click Next.
7. Click the checkbox next to I accept the license terms. Click Next.
8. Click Install to install the setup support files.
9. If there are no failures displayed, click Next. You may see a Computer domain controller warning and a Windows Firewall warning. For now, ignore these.
10. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
11. At the Feature Selection screen, select Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backwards Compatibility, Management Tools –Basic, and Management Tools – Complete. Click Next.
12. At the Installation Rules screen, click Next once the check completes.

13. At the Instance configuration screen, leave the default selection of default instance, and click Next.
14. At the Disk space requirements screen, click Next.
15. At the Server configuration screen, choose NT AUTHORITY\SYSTEM in the Account Name column for both SQL Server Agent and SQL Server Database Engine. Click Next.
16. At the Database Engine Configuration screen, select Mixed Mode.
17. Enter and confirm a password for the system administrator account.
18. Click Add Current user. This may take several seconds.
19. Click Next.
20. At the Error Reporting screen, click Next.
21. At the Installation Configuration rules screen, check that there are no failures or relevant warnings, and click Next.
22. At the Ready to Install screen, click Install.
23. After installation completes, click Close.

Configuring SQL Server

1. Create a SQL Server login for the ds2user (use the following steps or see the Configuring the database server (DVD Store) section for the specific script to use):
 - a. Click Start→All Programs→Microsoft SQL Server 2008 R2→SQL Server Management Studio.
 - b. In the Connect to Server window, enter the Server name, and click Connect.
 - c. In the left hand pane, expand [server name], expand Security, right-click Logins, and click New Login.
 - d. In the Login – New window, type `ds2user` for the Login name.
 - e. Select the SQL Server authentication radio button, and leave the password fields blank. If you receive a warning, click Yes.
 - f. Uncheck the box next to Enforce password policy.
 - g. For Default language, select English from the dropdown menu.
 - h. Click OK.
2. Click Start→All Programs→Microsoft SQL Server 2008 R2→Configuration Tools→SQL Server Configuration Manager.
3. Expand the SQL Server Network Configuration node, and select Protocols for MSSQLSERVER.
4. In the right pane, right-click TCP/IP, and choose Enable. At the warning, click OK.
5. In the left pane, click SQL Server Services.
6. In the right pane, right-click SQL Server (MSSQLSERVER), and click Restart.
7. Click Start→Administrative Tools→Local Security Policy.
8. In the left pane, expand Local Policies, and click User Rights Assignment.
9. In the right pane, double-click Perform volume maintenance tasks.
10. In the window that opens, click Add User or Group under the Local Security Setting tab.
11. Type `System` as the object name to select, click Check Names to verify, and choose SYSTEM in the Multiple Names Found window.
12. Click OK.
13. Click OK.
14. 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.
15. Run Windows Updates one more time and get all critical updates through 1-14-2011.

Installing and configuring the Exchange 2010 mail test client (LoadGen)

To create the mail client, you must install several software components. Before following these instructions, make sure to statically assign an IP address for the client, and to then plug that port into the system under test. This allows the client to join the Active Directory domain. We followed this process for each installation:

Installing Windows Server 2008 R2

1. Insert the installation DVD for Windows Server 2008 R2 into the DVD drive.
2. Choose the language, time and currency, and keyboard input. Click Next.
3. Click Install Now.
4. Choose Windows Server Standard (Full Installation). Click Next.
5. Accept the license terms, and click Next.
6. Click Custom.
7. Click the Disk, and click Drive options (advanced).
8. Click New, Apply, Format, and click Next.
9. After the installation completes, click OK to set the Administrator password.
10. Enter the administrator password twice, and click OK.
11. Click Start, type `change power-saving settings` and press Enter.
12. Click Change plan settings.
13. Change the Turn off the display drop-down menu to Never.
14. Click Save changes, and close the Power Options, Screen Saver Settings, and Personalization windows.

Joining the domain

1. Select Start→Control Panel→Network Connections→Local Area Connection.
2. Click Properties.
3. Highlight Internet Protocol (TCP/IP), and click Properties.
4. Select the Use the following DNS server addresses radio button, and enter the IP of the DNS server in the Preferred DNS server field. Click OK.
5. Right-click My Computer, and select Properties.
6. Under the Computer Name tab, click Change.
7. In the Computer Name Changes window, under the Member of section, select the Domain radial box, and type the appropriate domain name.
8. Select OK to start joining the domain.
9. When the window appears asking for a person qualified on the domain, type `Tester` as the username and `Password1` as the password.
10. At the welcome pop-up window and the window warning that you must reset the computer for the changes to take effect, click OK.
11. At the System Properties window, click OK.
12. When a pop-up appears asking if you want to restart now, click Yes to restart your computer.

Installing Internet Information Services

1. Click Start→Administrative Tools→Server Manager.
2. Click Roles on the left-side window pane.
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. Click Next.
10. Click Next.
11. At the Select Role Services page for Web Server (IIS), click IIS 6 Management Compatibility, ASP, and CGI check boxes; and click Next.
12. Click Install.
13. Click Close.

Installing Load Generator

Download and install Load Generator using all defaults.

Preparing Load Generator

1. Log into the MailClient using the tester account.
2. Select Start→All Programs→Microsoft Exchange→Exchange Load Generator 2010.
3. When the Load Generator window appears, select Start a new test.
4. Select Create a new test configuration, and click Continue.
5. Change total length of simulation to 30 minutes.
6. Verify that tester is the account name.
7. In the Specify test settings window, type `Password1` as the Directory Access Password and Mailbox Account Master Password, and click Continue with recipient management.
8. Make 75 users in each Mailbox Database, and click Continue.
9. To accept defaults for Advanced recipient settings, click Continue.
10. In the Specify test user groups window, select the plus sign to add a user group.
11. Change the Client Type to Outlook 2007 Cached, the Action Profile to Average, and the Mailbox size to 100MB.
12. Check the PreTestLogon check box, and click Continue.
13. Leave defaults in Remote configurations, and click Continue.
14. Click Save the configuration file as, and name it `averagecfg.xml`
15. After saving the configuration file, check the Initialize public store as well checkbox and click Start the initialization phase (recommended before running the test).

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 the database so you can have clean copies for each test.

1. Select Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console in the mail server.
2. In the left pane, expand Organization Configuration and Mailbox.
3. In the right pane, right-click Mailbox Database, and select Dismount Database from the menu.
4. At 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. At 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 database and public folder files from F:\ to C:\backup. 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.

Measuring power

To record each solution'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.

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 for the results of these measurements.

APPENDIX A – TEST SYSTEM CONFIGURATION INFORMATION

Figure 12 provides detailed configuration information about each of the four servers, which we list in order of newest to oldest.

Servers	Intel Xeon processor E3-1240-based server	Intel Xeon processor X3450-based server	Intel Core 2 Quad processor Q8400-based server	Intel Core 2 Duo processor E6400-based server
Power supplies				
Total number	1	1	1	1
Wattage of each (W)	460	1,000	350	600
Cooling fans				
Total number	2	3	2	2
First fan				
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)	1.6	3.3	1.6	0.8
Second fan				
Dimensions (h x w)	3" x 3"	4.75" x 4.75"	3" x 3"	4.75" x 4.75"
Voltage (V)	12	12	12	12
Amps (A)	0.4	1.6	1.5	0.8
Third fan				
Dimensions (h x w)	N/A	3" x 3"	N/A	N/A
Voltage (V)	N/A	12	N/A	N/A
Amps (A)	N/A	0.4	N/A	N/A
General processor setup				
Number of processor packages	1	1	1	1
Number of cores per processor package	4	4	4	2
Number of hardware threads per core	2	2	1	1

Servers	Intel Xeon processor E3-1240-based server	Intel Xeon processor X3450-based server	Intel Core 2 Quad processor Q8400-based server	Intel Core 2 Duo processor E6400-based server
System power management policy	Balanced	Balanced	Balanced	Balanced
CPU				
Vendor	Intel	Intel	Intel	Intel
Name	Xeon processor E3-1240	Intel Xeon processor X3450	Core 2 Quad processor Q8400	Core 2 Duo processor E6400
Stepping	D2	B1	R0	B2
Socket type	LGA 1155	LGA 1156	LGA 775	LGA 775
Core frequency (GHz)	3.30	2.66	2.66	2.13
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	256 KB (per core)	256 KB (per core)	4 MB (shared)	2 MB (shared)
L3 cache	8 MB	8 MB	N/A	N/A
Platform				
Vendor and model number	Intel S1200BTL ¹	Intel S3420GP	Intel S3200SH	Intel S3000AH
Motherboard chipset	Intel C200	Intel 3400	Intel 3200/3210	Intel 3000
BIOS name and version	Intel Corp. S1200BT.86B.01.00.0 012 (11/21/2010)	Intel Corp. S3420GP.86B.01.00.0 047 (11/16/2010)	Intel Corp. S3200X38.86B.00.00.0051 (05/11/2010)	Intel Corp. S3000.86B.02.00.005 4 (06/11/2009)
BIOS settings	Intel Rapid Storage Technology	Intel Matrix Storage Technology	Intel Matrix Storage Technology	Intel Matrix Storage Technology
Memory module(s)				
Total RAM in system (GB)	8	8	4	4
Number of types of memory modules	1	1	1	1
Vendor and model number	Hynix HMT125U7BFR8C-H9	Hynix HMT125U7BFR8C-H9	Kingston KVR667D2E5/1G	Kingston KVR533D2E4/2G
Type	PC3-10600E	PC3-10600E	PC2-5300	PC2-4200

¹ Intel® Server Board S1200BT (Beartooth Pass) – Overview
<http://www.intel.com/products/server/motherboards/S1200BT/S1200BT-overview.htm>.

Servers	Intel Xeon processor E3-1240-based server	Intel Xeon processor X3450-based server	Intel Core 2 Quad processor Q8400-based server	Intel Core 2 Duo processor E6400-based server
Speed (MHz)	1,333	1,333	667	533
Speed in the system currently running @ (MHz)	1,333	1,333	667	533
Timing/latency (tCL-tRCD-iRP-tRASmin)	9-9-9-24	9-9-9-24	5-5-5-15	4-4-4-12
Size (MB)	2,048	2,048	1,024	2,048
Number of RAM modules	4	4	4	2
Chip organization	Double-sided	Double-sided	Double-sided	Double-sided
Channel	Triple	Triple	Dual	Dual
Hard disk				
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 ICH7R/DH SATA RAID Controller
Controller driver	Intel 8.6.2.1012 (4/08/2009)	Intel 8.6.2.1012 (4/08/2009)	Intel 8.6.2.1012 (4/08/2009)	Intel 8.6.2.1012 (4/8/2009)
Operating system				
Name	Windows Server 2008 R2 Standard	Windows Server 2008 R2 Standard	Windows Server 2008 R2 Standard	Windows Server 2008 R2 Standard
Build number	7600	7600	7600	7600
Service Pack	N/A	N/A	N/A	N/A
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-Based PC	ACPI x64-Based PC	ACPI x64-Based PC	ACPI x64-Based PC

Servers	Intel Xeon processor E3-1240-based server	Intel Xeon processor X3450-based server	Intel Core 2 Quad processor Q8400-based server	Intel Core 2 Duo processor E6400-based server
Language	English	English	English	English
Microsoft DirectX® version	11	11	11	11
Graphics				
Vendor and model number	Matrox® G200e	Matrox G200e	Matrox G200e	ATI ES1000
Type	Integrated	Integrated	Integrated	Integrated
Resolution	1,024 x 768	1,024 x 768	1,024 x 768	1024 x 768
Driver	Microsoft 6.1.7600.16385 (6/21/2006)	Matrox Graphics 2.0.9.0 (8/12/2010)	Matrox Graphics 2.0.9.0 (8/12/2010)	Microsoft 6.1.7600.16385 (6/21/2006)
Network card/subsystem				
Network adapter 1				
Vendor and model number	Intel 82574L Gigabit Network Adapter	Intel 82574L Gigabit Network Adapter	Intel PRO/1000 MT Network Adapter	Intel PRO/1000 MT Network Adapter
Type	Integrated	Integrated	Integrated	Integrated
Driver	Intel 11.7.32.0 (9/29/2010)	Intel 11.7.32.0 (7/8/2010)	Intel 8.3.15.0 (9/23/2008)	Intel 8.3.15.0 (09/23/2008)
Network adapter 2				
Vendor and model number	Intel 82579LM Gigabit Network Adapter	Intel 82578DM Gigabit Network Adapter	Intel PRO/1000 PT Server Adapter	Intel PRO/1000 PM Network Adapter
Type	Integrated	Integrated	PCIe	Integrated
Driver	Intel 11.8.81.0 (10/28/2010)	Intel 11.6.92.0 (4/12/2010)	Intel 9.13.41.0 (3/26/2010)	Intel 9.3.41.0 (03/26/2010)
Network adapter 3				
Vendor and model number	Intel PRO/1000 PT Server Adapter	Intel PRO/1000 PT Server Adapter	Intel PRO/1000 PT Server Adapter	Intel PRO/1000 PT Server Adapter
Type	PCIe	PCIe	PCIe	PCIe
Driver	Intel 9.13.41.0 (3/26/2010)	Intel 9.13.41.0 (3/26/2010)	Intel 9.13.41.0 (3/26/2010)	Intel 9.13.41.0 (3/26/2010)
Network adapter 4				
Vendor and model number	Intel PRO/1000 PT Server Adapter	Intel PRO/1000 PT Server Adapter	N/A	N/A
Type	PCIe	PCIe	N/A	N/A

Servers	Intel Xeon processor E3-1240-based server	Intel Xeon processor X3450-based server	Intel Core 2 Quad processor Q8400-based server	Intel Core 2 Duo processor E6400-based server
Driver	Intel 9.13.41.0 (3/26/2010)	Intel 9.13.41.0 (3/26/2010)	N/A	N/A
USB ports				
Number of ports	6	6	4	2
Type of ports (USB 1.1, USB 2.0)	2.0	2.0	2.0	2.0

Figure 12: Detailed system configuration information for the four Intel processor-based servers.

APPENDIX B – TEST SYSTEM CONFIGURATION INFORMATION

Figure 13 provides the price information for the Intel processor-based servers as of February 15, 2011.

Prices do not include shipping costs or tax.

Servers	Intel Xeon processor E3-1240-based server	Intel Xeon processor X3450-based server	Intel Core 2 Quad processor Q8400-based server	Intel Core 2 Duo processor E6400-based server
Price as of February 15, 2011				
Motherboard	\$215.00 ¹	\$175.00 ⁴	\$199.99 ⁴	\$330.00 ²
Processor	\$265.00 ¹	\$265.49 ⁴	\$168.23 ⁴	\$70.00 ²
Drives	\$240.00 ²	\$240.00 ²	\$240.00 ²	\$240.00 ²
Memory	\$363.12 ³	\$363.12 ³	\$76.56 ⁴	\$74.12 ⁴
Case	\$125.00 ²	\$125.00 ²	\$125.00 ²	\$125.00 ²
NICs ⁵	\$175.48 ⁴	\$175.48 ⁴	\$175.48 ⁴	\$87.74 ⁴
Total price	\$1,383.60	\$1,344.09	\$985.26	\$926.86

Figure 13: Price information for the for Intel processor-based servers.

Notes

¹ Obtained from Intel.

² Price from www.serversupply.com.

³ Price from www.upgradebay.com.

⁴ Price from www.amazon.com.

⁵ For the Intel Core 2 Duo processor E6400-based server, we used a single PCIe NIC, which accounts for the lower price.

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