Principled Technologies®

TEST REPORT
OCTOBER 2007

64-bit Black-Scholes financial workload performance on dual-processor Intel- and AMD-based servers

Executive summary

Intel® Corporation (Intel) commissioned Principled Technologies (PT) to measure the performance of the 64-bit Black-Scholes financial application-based workload on dual-processor servers using the following five processors:

- Dual-Core AMD Opteron 2220 (2.8GHz)
- Dual-Core Intel Xeon 5160 (3.0GHz)
- Quad-Core AMD Opteron 2347 (1.9GHz)
- Quad-Core Intel Xeon X5365 (3.0GHz)
- Quad-Core Intel Xeon X5460 (3.16GHz)

KEY FINDINGS

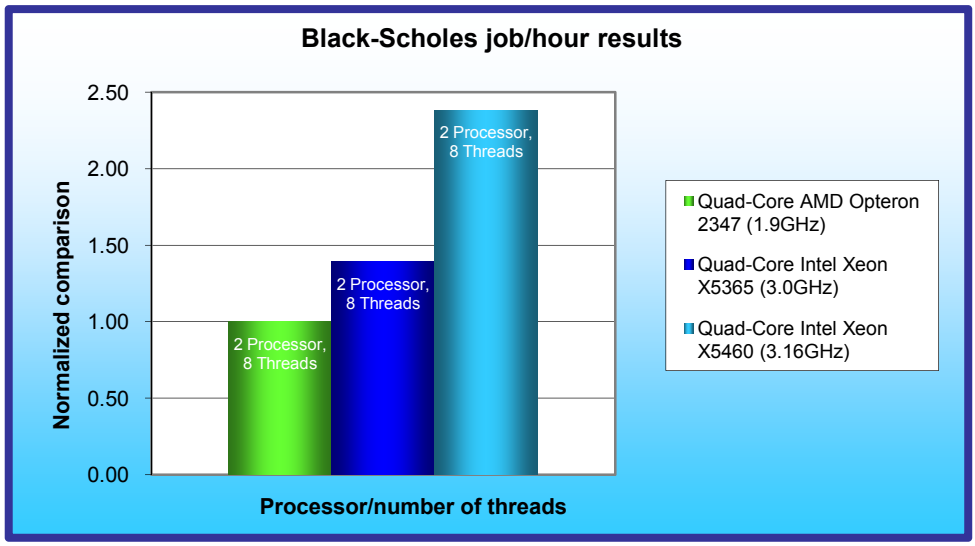
- The Quad-Core Intel Xeon X5460-based server achieved a 138.1 percent jobs/hour performance increase over the Quad-Core AMD Opteron 2347-based server using the Black-Scholes workload (see Figure 1).
- The Quad-Core Intel Xeon X5460-based server achieved a 71.2 percent jobs/hour performance increase over the Quad-Core Intel Xeon X5365-based server using the Black-Scholes workload (see Figure 1).

The Black-Scholes workload is multithreaded and allows users to specify the number of threads the program runs. Workload performance can increase as the number of threads increases, up to an optimum thread count, typically equal to the number of logical and physical processors available on the server. All five servers achieved their fastest completion times when the number of threads matched the number of cores, making eight threads the optimum thread-to-processor configuration for the quad-core based systems and four threads the optimum thread-to-processor configuration for the dual-core based systems.

In this section, we discuss the best results for each of the quad-core servers. For complete details of the performance of all servers with varying thread counts, see the Test results section.

Figure 1 presents the relative jobs/hour results of each quad-core server at its optimum thread count. To calculate jobs/hour, we used the following formula:

Jobs/hour = 3,600/Black-Scholes workload completion time in seconds



The Quad-Core Intel Xeon X5460-based server achieved 439.56 jobs/hour using the Black-Scholes workload. This is a 138.1 percent performance increase over the Quad-Core AMD Opteron 2347-based server, which achieved a result of 184.62 jobs/hour using the same workload.

The Quad-Core Intel Xeon X5460-based server produced a 71.2 percent performance increase over the Quad-Core Intel Xeon X5365-based server, which achieved 256.78 jobs/hour.

Figure 1: Normalized peak (dual-processor) performance of the servers with the optimum thread-to-processor configurations with the Black-Scholes workload. Higher numbers are better.

Workload

The Black-Scholes kernel workload is based on a financial modeling algorithm for the pricing of European-style options. After its publication in 1973 by Fisher Black, Myron Scholes, and Robert Merton, its impact was enormous and rapid. The benchmark consists of a kernel that implements a derivative of the Black and Scholes technique. SunGard developed the code, which uses a continuous-fraction technique that is more accurate than the traditional polynomial approximation technique. Intel provided an enhanced 32-bit version of the Black-Scholes Kernel to www.2cpu.com, which created a 64-bit version. Intel then provided the www.2cpu.com 64-bit source code we used to build the executables we employed in this report.

We reviewed the source and found no changes designed to favor one processor architecture over another. In the Test methodology section, we present the details of how we compiled this source code.

Test results

Figure 2 details the results of our tests with 2, 4, 8, and 16 threads using the Black-Scholes workload. For each test, we present the median run of the three individual test runs we executed. The test produces the time, in seconds, the server took to complete the workload; lower completion times are better.

As Figure 2 shows, all servers achieved their fastest completion times when the number of threads matched the number of cores. Because all systems were dual-processor servers, eight threads was the optimum thread-to-processor configuration for the three quad-core based systems, and four threads was the optimum thread-to-processor configuration for the two dual-core based systems.

The Quad-Core Intel Xeon X5460-based server finished the Black-Scholes workload in 8.19 seconds, 58.0 percent faster than the Quad-Core AMD Opteron 2347-based server, which finished the same workload in 19.50 seconds. This speed difference means a user would receive a solution 11.31 seconds faster with the Quad-Core Intel Xeon X5460-based server.

The Quad-Core Intel Xeon X5460-based server finished the Black-Scholes workload 41.6 percent faster than the Quad-Core Intel Xeon X5365-based server, which finished the same workload in 14.02 seconds.

The Quad-Core Intel Xeon X5460-based server finished the Black-Scholes workload 237.1 percent faster than the Dual-Core AMD Opteron 2220-based server, which finished the same workload in 27.61 seconds.

The Quad-Core Intel Xeon X5460-based server finished the Black-Scholes workload 242.1 percent faster than the Dual-Core Intel 5160-based server, which finished the same workload in 28.02 seconds.

Processor	2 threads	4 threads	8 threads	16 threads
Dual-Core AMD Opteron 2220 (2.8GHz)	55.19	27.61	29.13	27.73
Dual-Core Intel Xeon 5160 (3.0GHz)	56.03	28.02	28.06	28.08
Quad-Core AMD Opteron 2347 (1.9GHz)	78.02	39.02	19.50	20.78
Quad-Core Intel Xeon X5365 (3.0GHz)	55.81	28.02	14.02	15.42
Quad-Core Intel Xeon X5460 (3.16GHz)	32.61	16.36	8.19	8.95

Figure 2: Median completion times (in seconds) of the servers with varying thread counts using the Black-Scholes workload. Lower times are better.

Figure 3 shows the completion times in jobs/hour. All servers achieved their highest job/hour results when the number of threads matched the number of cores.

Processor	2 threads	4 threads	8 threads	16 threads
Dual-Core AMD Opteron 2220 (2.8GHz)	65.23	130.39	123.58	129.82
Dual-Core Intel Xeon 5160 (3.0GHz)	64.25	128.48	128.30	128.21
Quad-Core AMD Opteron 2347 (1.9GHz)	46.14	92.26	184.62	173.24
Quad-Core Intel Xeon X5365 (3.0GHz)	64.50	128.48	256.78	233.46
Quad-Core Intel Xeon X5460 (3.16GHz)	110.40	220.05	439.56	402.23

Figure 3: Median completion times (in jobs/hour) of the servers with varying thread counts using the Black-Scholes workload. Higher numbers are better.

Test methodology

Figure 4 summarizes some key aspects of the configurations of the five server systems; Appendix A provides detailed configuration information.

Server	Dual-Core AMD Opteron 2220 (2.8GHz)	Dual-Core Intel Xeon 5160 (3.0GHz)	Quad-Core AMD Opteron 2347 (1.9GHz)	Quad-Core Intel Xeon X5365 (3.0GHz)	Quad-Core Intel Xeon X5460 (3.16GHz)
Processor frequency (GHz)	2.8	3.0	1.9	3.0	3.16
Front-side bus frequency (MHz)	2,000 HyperTransport	1,333	2,000 HyperTransport	1,333	1,333
Number of processor packages	2	2	2	2	2
Number of cores per processor package	2	2	4	4	4
Number of hardware threads per core	1	1	1	1	1
Motherboard	Supermicro H8DMU+	Supermicro X7DBE+	Supermicro H8DMU+	Supermicro X7DBE+	Supermicro X7DBE+
Chipset	nForce Pro 3600	Intel 5000P	nForce Pro 3600	Intel 5000P	Intel 5000P
RAM	PC2-5300 DIMM	PC2-5300 FB-DIMM	PC2-5300 DIMM	PC2-5300 FB-DIMM	PC2-5300 FB-DIMM
Hard drive	Western Digital WD1600YD	Western Digital WD1600YD	Western Digital WD1600YD	Western Digital WD1600YD	Western Digital WD1600YD

Figure 4: Summary of some key aspects of the server configurations.

Intel configured and provided all five servers.

With the following exceptions we used the default BIOS settings on each server. On the Quad-Core Intel Xeon X5365-based server and the Dual-core Intel Xeon 5160-based server, we disabled Hardware Prefetcher and High Bandwidth FSB. On the Quad-Core Intel Xeon X5460-based server we disabled Hardware Prefetcher. We changed the ACPI Version Features to ACPI v3.0 on the Quad-Core AMD Opteron 2347-based server and on the Dual-core AMD Opteron 2220-based server.

We began our testing by installing a fresh copy of Microsoft* Windows* Server 2003 R2, Enterprise* x64 Edition Service Pack 2 on each server. We followed this process for each installation:

1. Assign a computer name of “Server”.
2. For the licensing mode, use the default setting of five concurrent connections.
3. Enter a password for the administrator log on.
4. Select Eastern Time Zone.
5. Use typical settings for the Network installation.
6. Use “Testbed” for the workgroup.

We applied the following updates from the Microsoft Windows Update site:

- Security Update for Internet Explorer 7 for Windows Server 2003 x64 Edition (KB938127)
- Cumulative Security Update for Internet Explorer 6 for Windows Server 2003 x64 Edition (KB939653)
- Windows Internet Explorer 7 for Windows Server 2003 x64 Edition and Windows XP x64 Edition
- Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB941202)
- Security Update for Windows Server 2003 x64 Edition (KB933729)
- Windows Malicious Software Removal Tool x64 - October 2007 (KB890830)
- Security Update for Windows Server 2003 x64 Edition (KB936021)
- Update for Windows Server 2003 x64 Edition (KB933360)
- Security Update for Windows Server 2003 x64 Edition (KB938127)
- Security Update for Windows Server 2003 x64 Edition (KB921503)
- Security Update for Windows Server 2003 x64 Edition (KB936782)
- Update for Windows Server 2003 x64 Edition (KB932596)
- Security Update for Windows Server 2003 x64 Edition (KB926122)
- Security Update for Windows Media Player 6.4 (KB925398)
- Update for Windows Server 2003 x64 Edition (KB936357)
- Cumulative Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB929123)
- Security Update for Windows Server 2003 x64 Edition (KB935839)
- Security Update for Windows Server 2003 x64 Edition (KB935840)
- Security Update for Windows Server 2003 x64 Edition (KB924667)
- Update for Windows Server 2003 x64 Edition (KB927891)
- Security Update for Windows Server 2003 x64 Edition (KB932168)
- Security Update for Windows Server 2003 x64 Edition (KB930178)
- Security Update for Windows Server 2003 x64 Edition (KB925902)

After the installation of the Microsoft updates, we made the following changes to the system:

- Changed the power scheme to “Server Balanced Processor Power and Performance”.
- Disabled screensaver.

We then installed the Microsoft .NET* Framework, version 3.0.4506.30 with the default options; it is available at http://msdn.microsoft.com/netframework/.

Installation of the Black-Scholes 64-bit version kernel workload

Intel supplied the Black-Scholes 64-bit kernel workload compressed in a zip file. We unzipped the file’s contents into a directory on a system separate from the servers under test. The folder contained C++ source code files and make files.

We used Microsoft Visual Studio* 2005 and Intel compiler version 10.0.023 to build the 64-bit versions of the workload. To create the executables we used the following commands with both the AMD and Intel make files.

- nmake –f Makefile.Intel all
- nmake –f Makefile.AMD all

Once we built the executables, we created a folder on each server under test called BlackScholes and stored the executables in that folder.

Make file for the server with AMD processors

```
#
# Application Name
#

APPNAME = black_scholes_custom_2pass

#
# compiler
#

CC = icl

#
# compilation options
#

CFLAGS = -c -O3 -Qparallel -Zi -Ob2
CPASS1 = -Qprof_gen
CPASS2 = -Qprof_use

#
# ARCH
#

ARCH = amd

#
# linker
#

LINK = xilink

#
# linker options
#

LOPTS = /out:$(APPNAME)_$(ARCH).exe /FIXED:no

#
# executable
#

all:    $(APPNAME)_$(ARCH).exe

clean:
        del BenchFunction.obj ConsoleTest.obj $(APPNAME)_$(ARCH).exe *.dyn *.dpi

BenchFunction.obj: BenchFunction.cpp
        $(CC) $(CFLAGS) $(CPASS1) BenchFunction.cpp

ConsoleTest.obj : ConsoleTest.cpp
        $(CC) $(CFLAGS) $(CPASS1) ConsoleTest.cpp

$(APPNAME)_$(ARCH).exe: clean BenchFunction.obj ConsoleTest.obj
        $(LINK) BenchFunction.obj ConsoleTest.obj $(LOPTS)
        $(APPNAME)_$(ARCH).exe 2

        $(CC) $(CFLAGS) $(CPASS2) BenchFunction.cpp
        $(CC) $(CFLAGS) $(CPASS2) ConsoleTest.cpp
        $(LINK) BenchFunction.obj ConsoleTest.obj $(LOPTS)
        $(APPNAME)_$(ARCH).exe 8
```

Make file for the servers with Intel processors

```
#
# Application Name
#

APPNAME = black_scholes_custom_2pass

#
# compiler
#

CC = icl

#
# compilation options
#

CFLAGS = -c -O3 -Qparallel -Zi -Ob2
CPASS1 = -Qprof_gen
CPASS2 = -Qprof_use

#
# ARCH
#

ARCH = intel

#
# linker
#

LINK = xilink

#
# linker options
#

LOPTS = /out:$(APPNAME)_$(ARCH).exe /FIXED:no

#
# executable
#

all:    $(APPNAME)_$(ARCH).exe

clean:
        del BenchFunction.obj ConsoleTest.obj $(APPNAME)_$(ARCH).exe *.dyn *.dpi

BenchFunction.obj: BenchFunction.cpp
        $(CC) $(CFLAGS) $(CPASS1) BenchFunction.cpp

ConsoleTest.obj : ConsoleTest.cpp
        $(CC) $(CFLAGS) $(CPASS1) ConsoleTest.cpp

$(APPNAME)_$(ARCH).exe: clean BenchFunction.obj ConsoleTest.obj
        $(LINK) BenchFunction.obj ConsoleTest.obj $(LOPTS)
        $(APPNAME)_$(ARCH).exe 8

        $(CC) $(CFLAGS) $(CPASS2) BenchFunction.cpp
        $(CC) $(CFLAGS) $(CPASS2) ConsoleTest.cpp
        $(LINK) BenchFunction.obj ConsoleTest.obj $(LOPTS)
        $(APPNAME)_$(ARCH).exe 8
```

Black-Scholes kernel workload switches/parameters

This workload provides the following switches, which we set as appropriate for each test run:

- */numThreads* or */t* This option designates the number of threads the workload should run. We set this to the number of threads we wanted in each test.
- *Number of steps* This option designates the number of steps the workload should use to calculate the option price.

By default, the workload assumes the following values:

- Number of threads: 4
- Number of steps: 100,000,000

This workload defaults to four threads regardless of the number of logical processors available on the server.

Running the Black-Scholes kernel workload

We rebooted the server before each individual test and then followed this process to run the test:

1. Open a DOS command window.
2. Navigate to the C:\BlackScholes folder.
3. Enter the following command:
   "blackscholes.exe ,<# of threads> 1000000000 > <server name>_<# of threads>_<run no.>.txt, where
   a. 1000000000 is the number of steps
   b. <server name> is server name as appropriate
   c. <# of threads> is either 2, 4, 8, or 16 as appropriate
   d. <run no.> is either 1, 2, or 3 (we ran each test three times)

Each execution of the workload generates a text file that includes how long the workload took to complete. We recorded that time as the result for each run.

Appendix A – Test system configuration information

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

Servers	Dual-Core AMD Opteron 2220 (2.8GHz)	Dual-Core Intel Xeon 5160 (3.0GHz)	Quad-Core AMD Opteron 2347 (1.9GHz)	Quad-Core Intel Xeon X5365 (3.0GHz)	Quad-Core Intel Xeon X5460 (3.16GHz)
General processor setup					
Number of processor packages	2	2	2	2	2
Number of cores per processor package	2	2	4	4	4
Number of hardware threads per core	1	1	1	1	1
System Power Management Policy	Server Balanced Processor Power and Performance	Server Balanced Processor Power and Performance	Server Balanced Processor Power and Performance	Server Balanced Processor Power and Performance	Server Balanced Processor Power and Performance
CPU					
Vendor	AMD	Intel	AMD	Intel	Intel
Name	Opteron 2220	Xeon 5160	Opteron 2347	Xeon X5365	Xeon X5460
Stepping	3	4	BA	G	C
Socket type	Socket F (1207)	771 LGA	Socket F (1207)	771 LGA	771 LGA
Core frequency (GHz)	2.8	3.0	1.9	3.0	3.16
Front-side bus frequency (MHz)	2,000 HyperTransport	1,333	2,000 HyperTransport	1,333	1,333
L1 cache	64 KB + 64 KB (per core)	32 KB + 32 KB (per core)	64 KB + 64 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	2 x 1 MB	4 MB (shared by 2 cores	4 x 512 KB (512 KB per core)	2 x 4 MB (each 4 MB shared by two cores)	2 x 6 MB (each 6 MB shared by two cores)
L3 cache	N/A	N/A	2 MB (shared by all four cores)	N/A	N/A
Thermal design power (TDP, in watts)	95	80	95	120	120
Platform					
Vendor and model number	Supermicro SuperServer 2021M-UR+B	Supermicro SuperServer 6025B-TR+	Supermicro SuperServer 2021M-UR+B	Supermicro SuperServer 6025B-TR+	Supermicro SuperServer 6025B-TR+
Motherboard model number	H8DMU+	X7DBE+	H8DMU+	X7DBE+	X7DBE+
Motherboard chipset	nForce Pro 3600	Intel 5000P	nForce Pro 3600	Intel 5000P	Intel 5000P

Servers	Dual-Core AMD Opteron 2220 (2.8GHz)	Dual-Core Intel Xeon 5160 (3.0GHz)	Quad-Core AMD Opteron 2347 (1.9GHz)	Quad-Core Intel Xeon X5365 (3.0GHz)	Quad-Core Intel Xeon X5460 (3.16GHz)
Motherboard revision number	1.00	2.01	1.00	2.01	2.01
BIOS name and version	American Megatrends (2.0c)	Phoenix Technologies (1.3c)	American Megatrends (2.0c)	Phoenix Technologies (1.3c)	Phoenix Technologies (1.3c)
BIOS settings	ACPI Version Features to ACPI v3.0	Disabled Hardware Prefetcher and High Bandwidth FSB	ACPI Version Features to ACPI v3.0	Disabled Hardware Prefetcher and High Bandwidth FSB	Disabled Hardware Prefetcher
Chipset INF driver	NVIDIA 4.57	Intel 8.2.0.1008	NVIDIA 4.57	Intel 8.2.0.1008	Intel 8.2.0.1008
Memory module(s)					
Vendor and model number	Hyundai HYMP525P72B P4-Y5	Kingston KVR667D2D4 F5/2G	Hyundai HYMP525P72B P4-Y5	Kingston KVR667D2D4 F5/2G	Kingston KVR667D2D4 F5/2G
Type	PC-5300 DDR2	PC2-5300 FB-DDR2	PC-5300 DDR2	PC2-5300 FB-DDR2	PC2-5300 FB-DDR2
Speed (MHz)	667 MHz	667 MHz	667 MHz	667 MHz	667 MHz
Speed in the system currently running @ (MHz)	667 MHz	667 MHz	667 MHz	667 MHz	667 MHz
Timing/Latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15	5-5-5-15	5-5-5-15	5-5-5-15	5-5-5-15
Size	16,384 MB	16,384 MB	16,384 MB	16,384 MB	16,384 MB
Number of RAM modules	8	8	8	8	8
Chip organization	Double-sided	Double-sided	Double-sided	Double-sided	Double-sided
Hard disk					
Vendor and model number	Western Digital WD1600YD	Western Digital WD1600YD	Western Digital WD1600YD	Western Digital WD1600YD	Western Digital WD1600YD
Number of disks in system	1	1	1	1	1
Size	160 GB	160 GB	160 GB	160 GB	160 GB
Buffer size	16 MB	16 MB	16 MB	16 MB	16 MB
RPM	7,200	7,200	7,200	7,200	7,200
Type	SATA-II	SATA-II	SATA-II	SATA-II	SATA-II
Controller	NVIDIA MCP55 SATA Controller	Intel 631xESB/6321ESB Serial ATA Storage Controller	NVIDIA MCP55 SATA Controller	Intel 631xESB/6321 ESB Serial ATA Storage Controller	Intel 631xESB/6321 ESB Serial ATA Storage Controller
Driver version	5.2.3790.1830	8.2.0.1008	5.2.3790.1830	8.2.0.1008	8.2.0.1008

Servers	Dual-Core AMD Opteron 2220 (2.8GHz)	Dual-Core Intel Xeon 5160 (3.0GHz)	Quad-Core AMD Opteron 2347 (1.9GHz)	Quad-Core Intel Xeon X5365 (3.0GHz)	Quad-Core Intel Xeon X5460 (3.16GHz)
Operating system					
Name	Microsoft Windows Server 2003 R2, Enterprise x64 Edition	Microsoft Windows Server 2003 R2, Enterprise x64 Edition	Microsoft Windows Server 2003 R2, Enterprise x64 Edition	Microsoft Windows Server 2003 R2, Enterprise x64 Edition	Microsoft Windows Server 2003 R2, Enterprise x64 Edition
Build number	3790	3790	3790	3790	3790
Service Pack	SP2	SP2	SP2	SP2	SP2
File system	NTFS	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI Multiprocessor x64-based PC	ACPI Multiprocessor x64-based PC	ACPI Multiprocessor x64-based PC	ACPI Multiprocessor x64-based PC	ACPI Multiprocessor x64-based PC
Language	English	English	English	English	English
Microsoft DirectX version	9.0c	9.0c	9.0c	9.0c	9.0c
Graphics					
Vendor and model number	ATI ES1000 (RN50)	ATI ES1000 (RN50)	ATI ES1000 (RN50)	ATI ES1000 (RN50)	ATI ES1000 (RN50)
Chipset	ES1000	ES1000	ES1000	ES1000	ES1000
BIOS version	BK-ATI VER008.005.007.001	BK-ATI VER008.005.007.001	BK-ATI VER008.005.007.001	BK-ATI VER008.005.007.001	BK-ATI VER008.005.007.001
Type	Integrated	Integrated	Integrated	Integrated	Integrated
Memory size	16 MB	16 MB	16 MB	16 MB	16 MB
Resolution	1,024 x 768	1,024 x 768	1,024 x 768	1,024 x 768	1,024 x 768
Driver version	8.24.3.0	8.24.3.0	8.24.3.0	8.24.3.0	8.24.3.0
Network card/subsystem					
Vendor and model number	NVIDIA nForce Networking Controller	Intel PRO/1000 EB Network Connection with I/O Acceleration	NVIDIA nForce Networking Controller	Intel PRO/1000 EB Network Connection with I/O Acceleration	Intel PRO/1000 EB Network Connection with I/O Acceleration
Type	Integrated	Integrated	Integrated	Integrated	Integrated
Driver version	NVIDIA 65.3.1.0	Intel 9.7.34.0	NVIDIA 65.3.1.0	Intel 9.7.34.0	Intel 9.9.8.0/Intel 10.0.15.0
Optical drive					
Vendor and model number	MATSHITA DVD-ROM SR-8178	MATSHITA DVD-ROM SR-8178	MATSHITA DVD-ROM SR-8178	MATSHITA DVD-ROM SR-8178	MATSHITA DVD-ROM SR-8178

Servers	Dual-Core AMD Opteron 2220 (2.8GHz)	Dual-Core Intel Xeon 5160 (3.0GHz)	Quad-Core AMD Opteron 2347 (1.9GHz)	Quad-Core Intel Xeon X5365 (3.0GHz)	Quad-Core Intel Xeon X5460 (3.16GHz)
USB ports					
Number	4	4	4	4	4
Type	USB 2.0	USB 2.0	USB 2.0	USB 2.0	USB 2.0
Power supplies					
Total number	2	2	2	2	2
Wattage of each	700W	700W	700W	700W	700W
Cooling fans					
Total number	3	3	3	3	3
Dimensions	80mm	80mm	80mm	80mm	80mm
Voltage	12V	12V	12V	12V	12V
Amps	1.1 A	1.1 A	1.1 A	1.1 A	1.1 A

Figure 5: Detailed system configuration information for the five test servers.

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