Principled Technologies®

TEST REPORT
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Linpack performance on Red Hat Enterprise Linux 5.1 and 3 AS Intel-based servers

Executive summary

Red Hat, Inc. (Red Hat) commissioned Principled Technologies (PT) to measure the Linpack HPL performance of the following three systems:

- Red Hat Enterprise Linux AS 3 server on the Dual-Core Intel Xeon processor 7140M-based (3.4 GHz) server
- Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server on the Quad-Core Intel Xeon processor X7350-based (2.93 GHz) server
- Red Hat Enterprise Linux 5.1 server on the Quad-Core Intel Xeon processor X7350-based (2.93 GHz) server

In this section, we discuss the best results for each system. For complete details of the performance of each benchmark for each system, see the Test results section.

Linpack HPL produces performance results as the number of billions of floating point operations per second (Gigaflops per second, or Gflops/s).

Figure 1 shows the average Linpack Benchmark results, in Gflops/s, across the six Linpack benchmarks we ran on the test systems. We ran each of the six benchmarks three times on each system and identied the median run for each. Higher Linpack scores are better, because they indicate that the system performed more floating point operations per second.

KEY FINDINGS

- Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server delivered 193.1 percent more performance than Red Hat Enterprise Linux AS 3 on the Dual-Core Intel Xeon processor 7140M-based server (see Figure 1).
- Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server delivered a 139.6 percent performance increase over Red Hat Enterprise Linux AS 3 on the Dual-Core Intel Xeon processor 7140M-based server (see Figure 1).
- Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server only delivered 18.2 percent less performance than running native on Red Hat Enterprise Linux 5.1 on the same server (see Figure 1).

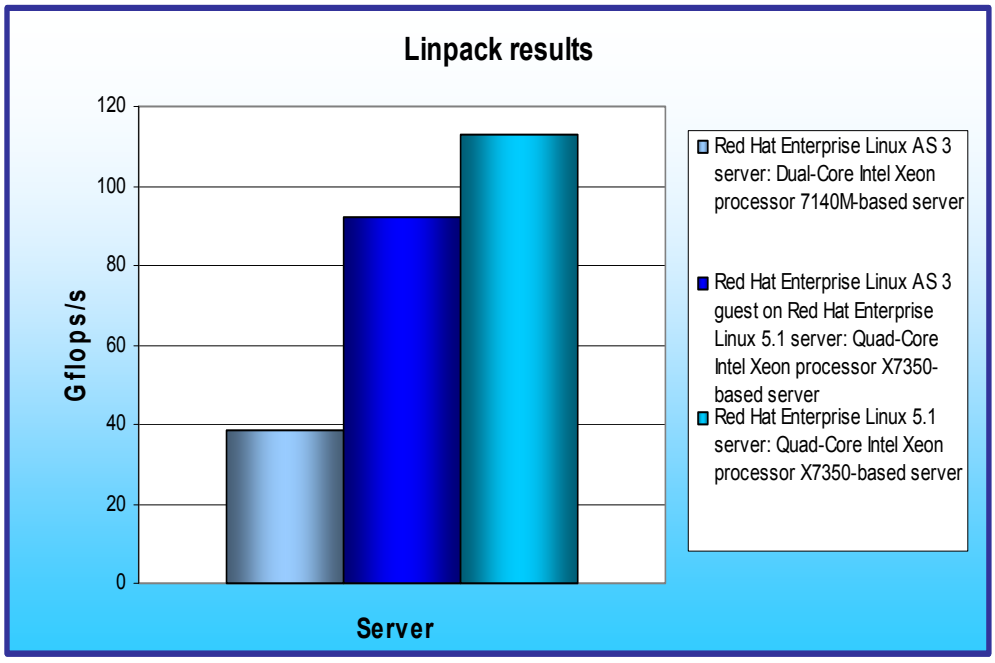

Figure 1: Average Linpack HPL results, in Gflops/s, across the six benchmarks we ran on the test servers. Higher numbers of Gflops/s are better.

Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server produced the highest results, 112.98 Gflops/s, while Red Hat Enterprise Linux AS 3 Dual-Core Intel Xeon processor 7140M-based server achieved 38.55 Gflops/s. The Red Hat Enterprise Linux 5.1 server thus delivered a 193.1 percent performance increase over the Red Hat Enterprise Linux AS 3 server. Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server achieved 92.38 Gflops/s, which is only 18.2

percent slower than running native, but a 139.6 percent performance increase over the Red Hat Enterprise Linux AS 3 server.

Figure 2 shows the complete median Linpack HPL run results, in Gflops/s, for each of the six benchmarks we ran on the three systems.

Test name	Red Hat Enterprise Linux AS 3 server: Dual-Core Intel Xeon processor 7140M-based server	Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server	Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server
WR00L2L2	38.62	90.71	112.00
WR00L2L4	38.56	95.30	114.10
WR00C2L2	38.57	90.81	112.80
WR00C2L4	38.56	92.88	113.20
WR00R2L2	38.58	91.16	112.40
WR00R2L4	38.42	93.43	113.40
Average	**38.55**	**92.38**	**112.98**

Figure 2: Median Linpack HPL run results of all six benchmarks, in Gflops/s, for each server. Higher numbers are better.

Workload

The Linpack benchmark is an industry-standard benchmark Jack Dongarra created in 1979. The Linpack benchmark solves linear equations and uses the speed of the system under test at that task as a measure of the system's floating-point performance. Linpack reports its results in billions of floating point operations per second, or Gflops/s.

We used the HPL version of the Linpack Benchmark. HPL is a portable implementation of the High Performance Computing Linpack benchmark that generates, solves, checks, and times the solution process of a random dense linear system of equations. The HPL software package uses 64-bit floating point arithmetic and portable routines for linear algebra operations and message passing. The HPL code offers the advantage of allowing testers to select from among multiple factorization algorithms.

Test results

Figure 3 shows the Linpack HPL results for Red Hat Enterprise Linux AS 3 on the Dual-Core Intel Xeon processor 7140M-based server for all three runs.

Red Hat Enterprise Linux AS 3 server: Dual-Core Intel Xeon processor 7140M-based server			
Test name	**Run 1**	**Run 2**	**Run 3**
WR00L2L2	38.97	38.62	38.52
WR00L2L4	38.56	38.34	38.65
WR00C2L2	38.73	38.57	38.51
WR00C2L4	38.56	38.57	38.50
WR00R2L2	38.58	38.55	38.66
WR00R2L4	38.28	38.42	38.73

Figure 3: Linpack HPL benchmark results, in Gflops/s, for Red Hat Enterprise Linux AS 3 on the Dual-Core Intel Xeon processor 7140M-based server. Higher numbers are better.

Figure 4 shows the Linpack HPL results for Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server for all three runs.

Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server			
Test name	**Run 1**	**Run 2**	**Run 3**
WR00L2L2	90.71	90.18	93.66
WR00L2L4	95.76	92.75	95.30
WR00C2L2	90.81	93.83	90.61
WR00C2L4	92.27	92.88	95.54
WR00R2L2	91.16	93.05	90.87
WR00R2L4	92.99	95.43	93.43

Figure 4: Linpack HPL benchmark results, in Gflops/s, for Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor E7340-based server. Higher numbers are better.

Figure 5 shows the Linpack HPL results for Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server for all three runs.

Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server			
Test name	**Run 1**	**Run 2**	**Run 3**
WR00L2L2	111.50	112.00	112.50
WR00L2L4	113.00	114.50	114.10
WR00C2L2	112.90	112.80	111.70
WR00C2L4	112.70	113.50	113.20
WR00R2L2	111.40	112.70	112.40
WR00R2L4	113.60	113.10	113.40

Figure 5: Linpack HPL benchmark results, in Gflops/s, for Red Hat Enterprise Linux 5.1 on the Quad-Core Intel Xeon processor X7350-based server. Higher numbers are better.

Test methodology

Figure 6 summarizes some key aspects of the configurations of the server systems; Appendix A provides detailed configuration information.

Server	Red Hat Enterprise Linux AS 3 server: Dual-Core Intel Xeon processor 7140M-based server	Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server	Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server
Processor frequency (GHz)	3.4 GHz	2.93 GHz	2.93 GHz
Front-side bus frequency (MHz)	800 MHz	1,066 MHz	1,066 MHz
Number of processor packages	4	4	4
Number of cores per processor package	2	4	4
Number of hardware threads per core	2	1	1
Motherboard	Intel SE8500HW4	Intel S7000FC4UR	Intel S7000FC4UR
Chipset	Intel SE8500	Intel ID3600	Intel ID3600
RAM (16 GB in each)	16 GB (16 x 1GB) PC2-5300 DDR2	16 GB (16 x 1GB) PC2-5300 FB-DDR2	16 GB (16 x 1GB) PC2-5300 FB-DDR2
Hard Drive	Seagate ST3146854LC	Seagate ST973401SS	Seagate ST973401SS

Figure 6: Summary of some key aspects of the server configurations.

Red Hat configured and provided the systems.

With the following exceptions, we used the default BIOS settings on each server: disabling HW Prefetcher and Adjacent Cache Line Prefetcher on the Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server and Red Hat Enterprise Linux 5.1 server. We enabled HW Prefetcher and Adjacent Cache Line Prefetcher on the Red Hat Enterprise Linux AS 3 server.

We began by installing a fresh copy of Red Hat Enterprise Linux on the test systems. For the RHEL 3 installation, we used all default settings except for disabling the firewall. For the RHEL 5.1 installation, we installed only the Software Development package, and disabled the firewall and SELinux. We used the same installation method for the RHEL 3 guest on RHEL 5.1; however, during this installation we elected to install virtualization. We made no additional changes to the default installation options.

Linpack configuration

We used the following three software components for this test:

- MVAPICH2-0.9.8p3 (source: http://nowlab.cse.ohio-state.edu/projects/mpi-iba/)
- GotoBLAS 1.12 (source: http://www.tacc.utexas.edu/resources/software/)
- HPL (source: http://www.netlib.org/benchmark/hpl/)

In addition to the above software, we used the following compilers:

- GCC version 3.2.3 20030502 (Red Hat Enterprise Linux AS 3 server on the Dual-Core Intel Xeon processor 7140M-based server and Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server on the Quad-Core Intel Xeon processor X7350-based server)

- GCC version 4.1.2 20070626 (Red Hat Enterprise Linux 5.1 server on the Quad-Core Intel Xeon processor X7350-based server)
- binutils-2.14.90.0.4 (Red Hat Enterprise Linux AS 3 server on the Dual-Core Intel Xeon processor 7140M-based server)
- binutils-2.17.50.0.6 (Red Hat Enterprise Linux 5.1 server on the Quad-Core Intel Xeon processor X7350-based server and Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server on the Quad-Core Intel Xeon processor X7350-based server)

For all servers and all software components, we compiled the components from source. We then created our work directory under the root directory on each server. To simplify the description below, we will refer to the working directory as $HPL_HOME.

To build MVAPICH2, we did the following:

1. Unpack the MVAPICH2-0.9.8p3.tar.gz archive in $HPL_HOME. This step creates the mvaich2-0.9.8p3 directory.
2. Type “mv mvapich2-0.9.8p3 mpi”. This renames the MVAPICH2 directory to “mpi”.
3. Type "cd $HPL_HOME/mpi".
4. Type “./configure”.
5. Type “make”.
6. Set the PATH environment variable to include “$HPL_HOME/mpi/bin”.
7. Verify MVAPICH2 is working by typing the following commands:
   - mpd & (launches the mpi daemon)
   - mpdtrace (will show you the systems it's running on)
   - mpdallexit (kills the daemon)

To build GotoBLAS, we did the following:

1. Unpack the GotoBLAS-1.12.tar.gz archive in $HPL_HOME. This creates the GotoBLAS directory.
2. Type "cd $HPL_HOME/GotoBLAS".
3. Run “./quickbuild.64bit”.

To build HPL, we did following:

1. Unpack the hpl.gz archive in $HPL_HOME. This step creates the hpl directory.
2. Type "cd $HPL_HOME/hpl".
3. Create the Make.em64t appropriate for the system (see Appendix B).
4. Type “make arch=em64t”.
5. After you install the benchmark, use the HPL.dat file in Appendix B.

To run HPL, we did the following:

1. Set the PATH environment variable to include “$HPL_HOME/mpi/bin”.
2. Type “mpd &” to start the mpi daemon.
3. Type “cd $HPL_HOME/hpl/bin/em64t“.
4. Type “mpirun -n 4 ./xhpl".
5. By default, the output goes to the screen. Either redirect the output to a file to save it or copy it from the console window after the test.

Appendix A – Test system configuration information

This appendix provides detailed configuration information about each of the test server systems.

Servers	Red Hat Enterprise Linux AS 3 server: Dual-Core Intel Xeon processor 7140M-based server	Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server	Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server
General processor setup			
Number of processor packages	4	4	4
Number of cores per processor package	2	4	4
Number of hardware threads per core	2	1	1
CPU			
Vendor	Intel	Intel	Intel
Name	Dual-Core Intel Xeon MP 7140M	Quad-Core Intel Xeon X7350	Quad-Core Intel Xeon X7350
Stepping	8	B	B
Socket type	mPGA604	mPGA604	mPGA604
Core frequency (GHz)	3.4 GHz	2.93 GHz	2.93 GHz
Front-side bus frequency (MHz)	800 MHz	1,066 MHz	1,066 MHz
L1 Cache	12 KB + 16 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 Cache	2 x 1 MB	2 x 4 MB (each 4 MBs shared by two cores)	2 x 4 MB (each 4 MBs shared by two cores)
L3 Cache	16 MB	NA	NA
Platform			
Vendor and model number	Intel	Intel	Intel
Motherboard model number	SR4850HW4x	S7000FC4UR	S7000FC4UR
Motherboard chipset	Intel SE8501	Intel ID3600	Intel ID3600
Motherboard revision number	11	01	01
BIOS name and version	Intel Corporation SHW40.86B.P.12.00.0076, 02/15/2007	Intel SFC4UR.86B.01.00.0010.050420071510	Intel SFC4UR.86B.01.00.0010.050420071510
BIOS settings	Disabled HW Prefetcher/enabled adjacent cache line Prefetcher	Disabled HW Prefetcher and adjacent cache line Prefetcher/enabled high bandwidth	Disabled HW Prefetcher and adjacent cache line Prefetcher/enabled high bandwidth
Memory module(s)			
Vendor and model number	ELPIDA EBE10RD4AGFA-6E-E	Kingston KVR667D2D8F5/1G	Kingston KVR667D2D8F5/1G
Type	PC2-5300 DDR2	PC2-5300 FB-DDR2	PC2-5300 FB-DDR2
Speed (MHz)	667 MHz	667 MHz	667 MHz
Speed in the system currently running @ (MHz)	400 MHz	667 MHz	667 MHz

Servers	Red Hat Enterprise Linux AS 3 server: Dual-Core Intel Xeon processor 7140M-based server	Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server	Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server
Timing/Latency (tCL-tRCD-iRP-tRASmin)	3-3-3-9	5-5-5-15	5-5-5-15
Size	16,382 MB	16,382 MB	16,382 MB
Number of RAM modules	16	16	16
Chip organization	Double-sided	Double-sided	Double-sided
Hard disk			
Vendor and model number	Seagate ST3146854LC	Seagate ST973401SS	Seagate ST973401SS
Number of disks in system	1	1	1
Size	146.8 GB	73.4 GB	73.4 GB
Buffer Size	8 MB	8 MB	8 MB
RPM	15,000	10,000	10,000
Type	SCSI	SAS	SAS
Controller	LSI Logic PCI-X Ultra320 SCSI	Intel 631xESB/6321ESB/3100 Chipset Serial ATA Storage Controller – 2680	Intel 631xESB/6321ESB/3100 Chipset Serial ATA Storage Controller – 2680
Operating system			
Name	Red Hat Enterprise Linux 3 Advanced Server	Red Hat Enterprise Linux 5 Advanced Server	Red Hat Enterprise Linux 5 Advanced Server
Build number	RHEL 3 update 9	RHEL 5.1/RHEL 3 update 9	RHEL 5.1
File system	ext3	ext3	ext3
Kernel	2.4.21-50.EL (x86_64)	2.4.21-50.EL (x86_64)	2.6.18-36.el5 (x86_64)
Language	English	English	English
Graphics			
Vendor and model number	ATI Radeon 7000	ATI ES1000	ATI ES1000
Chipset	ATI Radeon 7000 PCI	ES1000	ES1000
BIOS version	BK-ATI VER008.004.037.001	BK-ATI VER008.005.031.000	BK-ATI VER008.005.031.000
Type	Integrated	Integrated	Integrated
Memory size	16 MB	32 MB	32 MB
Resolution	1024x768	1024x768	1024x768
Network card/subsystem			
Vendor and model number	Broadcom BCM5704 dual NetXtreme Gigabit Adapter	Intel PRO/1000 EB/Intel 82575EB	Intel PRO/1000 EB/Intel 82575EB
Type	Integrated	Integrated	Integrated

Servers	Red Hat Enterprise Linux AS 3 server: Dual-Core Intel Xeon processor 7140M-based server	Red Hat Enterprise Linux AS 3 guest on Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server	Red Hat Enterprise Linux 5.1 server: Quad-Core Intel Xeon processor X7350-based server
Optical drive			
Vendor and model number	Philips SDR089	Optiarc DVD-ROM DDU810A	Optiarc DVD-ROM DDU810A
USB ports			
Number	5	5	5
Type	USB 2.0	USB 2.0	USB 2.0

Figure 7: Detailed system configuration information for the three test servers.

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