Dell™ OpenManage™ Power Center

⚡ **Provided precise power limiting**

⚡ **Simplified power management**

on the Dell PowerEdge™ R720

More efficient and accurate than HP Insight Control, so you can better allocate resources and reduce data center costs.

In your data center, you need both strong and continuous performance to handle the needs of your employees and customers, and advanced management technologies to keep operational expenses down. High among these operational expenses are the power costs related to running and cooling your servers.

We tested two applications—Dell OpenManage Power Center managing a Dell PowerEdge R720 server and HP Insight Control managing an HP ProLiant DL380p Gen8 server—with the goal of understanding the ways that their respective power management tools affect performance and power usage in the data center. We focused on the tools' approaches to setting power limits, also known as power capping.

In our tests, the Dell OpenManage Power Center provided more precise power limiting than HP Insight Control. The difference between the actual power used by the Dell solution and the power limit we set was 2 percent or less, versus a difference of approximately 10 percent with the HP solution. The smaller gap lets administrators maximize the number of servers that can fit within the data center's total power capacity. Increasing data center density in this way saves money. Dell OpenManage Power Center also offered greater management flexibility out of the box, including the ability to easily set priorities among servers and to initiate emergency power response.

The Dell PowerEdge R720 also offered greater performance per watt and supports a much higher working temperature, through the Dell Fresh Air initiative, than the HP ProLiant DL380p Gen8. These energy-saving features can lead to significant data center energy cost savings for your enterprise.

THE POWER OF POWER LIMITS

One of the biggest sources of return from an investment in the latest equipment and management software is being able to take advantage of new power-saving technologies. In the typical server, power utilization increases as the server load increases. Being able to limit or cap the amount of power a server or group of servers consumes offers great flexibility, often without decreasing performance.

Power management tools let you as the administrator set power limits at the data center, room, aisle, rack, or server level. You can also set different power limits for different times. For example, you can give a server a lower power limit in the evenings when less work is taking place and a higher limit during the day, when greater performance is needed. Being able to set these limits can dramatically boost data center rack density as you can now safely add extra servers to the same circuit without fear of tripping the breaker.

Two approaches to power management: Dell OpenManage Power Center and HP Insight Control

Dell OpenManage Power Center, using Intel Node Manager Technology, lets IT administrators look at the data center power usage. Power Center is an open, standards-based power management application that can read power usage information from Dell PowerEdge servers, power distribution units, uninterruptable power supplies, or Dell PowerEdge blade server chassis.

As an IT administrator, you know that you can only manage power utilization if you can collect data related to it. OpenManage Power Center offers many advanced features for monitoring your data center power utilization. You can view instantaneous power usage or temperature and examine power usage over specific time increments (15 minutes, 1 hour, 1 day, 1 week, 1 month, 3 months, or 1 year). OpenManage Power Center shows peak, average, and minimum power across the data center, room, aisle, rack, or server. Understanding your power utilization opens a wide range of opportunities for server density, power savings, and uptime improvements.

To learn more about Dell OpenManage Power Center, visit http://www.dell.com/us/enterprise/p/dell-openmanage-power-center/pd, or see additional reports from Principled Technologies, at: http://www.principledtechnologies.com/clients/reports/Dell/R720_power_0312.pdf

According to the HP Web site, "HP Insight Control delivers essential infrastructure management that can help save time and money by making it easy to deploy, migrate, monitor, control, and optimize your IT infrastructure through a single, simple management console for your ProLiant ML/DL/SL and BladeSystem servers.

"Delivered on Insight Management or Insight Software DVD #1, Insight Control uses an integrated installer to deploy and configure core HP management software quickly and consistently.

"The Insight Control for Microsoft System Center and Insight Control for VMware® vCenter™ Server are located on separate media and each has its own installer."

For more detailed information on Insight Control, visit http://www.hp.com/go/insightcontrol.

WHAT WE FOUND

When looking at a power management solution, it is important to understand how the application lets you set power limits for optimum data center and system management. Dell OpenManage Power Center and HP Insight Control handle power limiting differently, with the main difference being the size of the gap between the intended power limit and the actual power usage.

To understand this difference and its importance, you must first understand what these two numbers mean. The intended power limit is the setting you enter in the management software as a level not to be exceeded. For example, an intended limit of 80 percent means the server should never use more than 80 percent of its maximum capacity at any time. The actual power limit is the amount of power the server actually uses. Note that the actual power limit average should always be below the intended limit.

To illustrate the difference between these two levels, we present graphs of both systems' actual power usage under two conditions: when we set the intended power limit to 80 percent of their total power and when we set no power limit. We used a Dell PowerEdge R720 with Dell OpenManage Power Center and an HP ProLiant DL380p Gen8 with the HP Insight Control for this evaluation. Because the two servers have different power draws, the intended limits of the two servers differ accordingly. We chose this approach to avoid unfairly penalizing either of the servers by setting an identical limit on both systems.

Figure 1 shows the power usage at 1-second intervals over a 2-minute period for the Dell PowerEdge R720 with an 80 percent power limit of 304 watts and with no power limit. (Note: To magnify the power variations during the run, we do not start the vertical axis of the chart at zero.) As Figure 1 shows, with the 304-watt intended limit, actual power usage of the Dell PowerEdge R720 averaged slightly over 302 watts. While it did reach the 304-watt limit, it never went over. The maximum difference between the intended 80 percent of faceplate power (304 watts) and the actual power limit was 2 percent.

Figure 1: Actual power usage of the Dell PowerEdge R720 with an 80 percent power limit stayed within 2 percent of the limit. (To magnify the power variations during the run, we do not start the vertical axis at zero.)
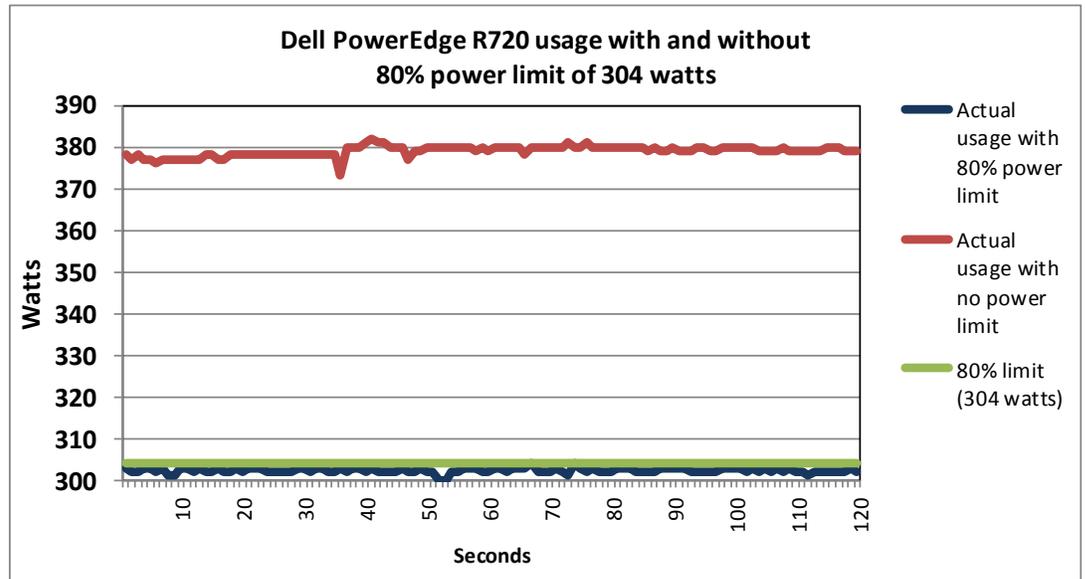
Figure 2 shows the power usage at 1-second intervals over a 2-minute period for the HP ProLiant DL380p Gen8 with a 342-watt power limit and with no power limit. (As in Figure 1, to magnify the power variations during the run, we do not start the vertical axis of the chart at zero.) As Figure 2 shows, with the 342-watt intended limit, actual power usage averaged around 312 watts, roughly 10 percent lower than intended power limit.

While a larger difference between the intended and actual power limit does guarantee that the power will not exceed the set limit, it also means that you cannot configure a server rack as densely. For example, 10 servers with a 342-watt power limit would be a total of 3,420 watts, while the actual power used would be 3,120 watts. This means that 300 watts are allocated but unused. In this example, if percentage difference between the intended limit and actual power were closer, as with the Dell PowerEdge R720, you could essentially put another server in the rack using the same total power limit.

HP ProLiant DL380p Gen8 usage with and without 80% power limit of 342 watts

Figure 2: Actual power usage of the HP ProLiant DL380p Gen8 with an 80 percent power limit was roughly 10 percent lower than the limit. (To magnify the power variations during the run, we do not start the vertical axis at zero.)

Legend:
- Actual usage with 80% power limit
- Actual usage with no power limit
- 80% limit (342 watts)
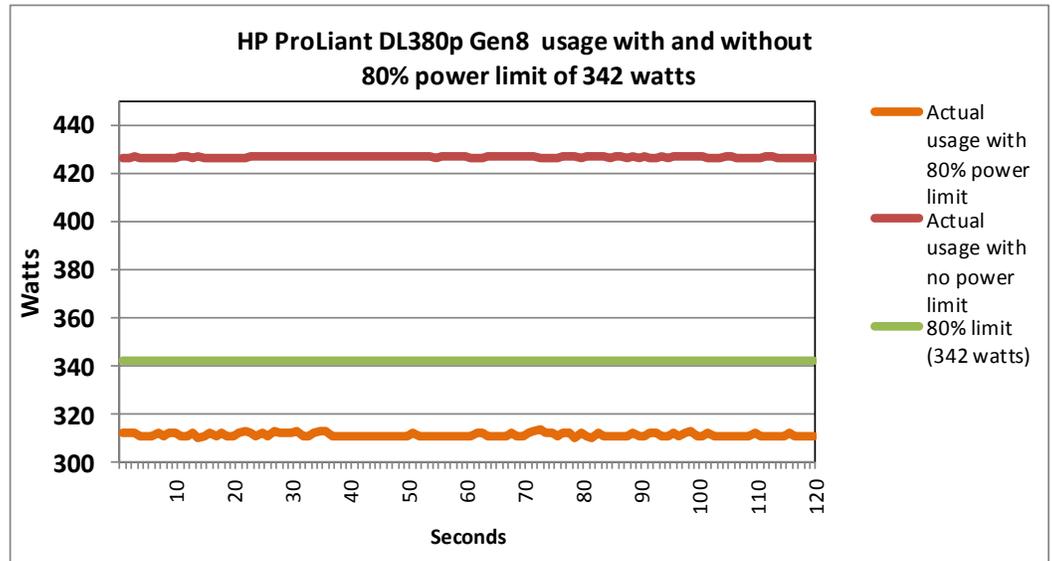
The impact of power limiting

In addition to evaluating how both applications handle power limiting, we looked at the performance impact of applying a power limit. As Figure 3 shows, when we reduced power by 20 percent during a real-world database workload test with significant I/O, performance on the Dell PowerEdge R720 decreased by less than 1 percent, whereas on the HP ProLiant DL380p Gen8, performance dropped 35.2 percent.

Figure 3: Setting an 80 percent power limit on the HP ProLiant DL380p Gen8 decreased performance by more than a third, whereas doing so on the Dell PowerEdge R720 decreased performance by only 1 percent.

Performance impact of limiting power usage

Legend:
- Dell PowerEdge R720
- HP ProLiant DL380p Gen8
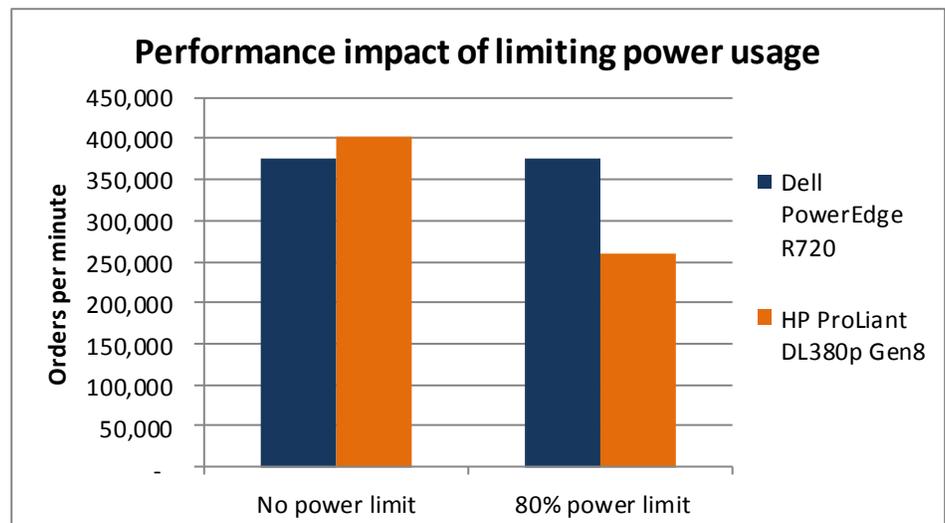
This difference in performance illustrates another advantage of the smaller gap between the intended and actual power limits. The peak power usage of the Dell PowerEdge R720 running at maximum performance was 377 watts, so an 80 percent power limit would be 304 watts. When running a real-world workload using around 80

percent processor utilization, the Dell PowerEdge R720 used 292 watts of power. When we applied the 304-watt power limit, the performance barely changed.

In comparison, the peak power for the HP ProLiant DL380p Gen8 running at maximum performance is 427 watts, so the 80 percent limit would be 342 watts. When running a real-world workload, the HP ProLiant DL380p Gen8 used 292 watts. Due to the high percentage difference between the intended and actual power limits, performance dropped 35.2 percent.

To test the limit feature, we used DVD Store 2.1 (DS2), which reports performance in orders per minute (OPM), running Microsoft SQL Server 2008 R2 with 6GB databases on both servers. For the 100 percent workload testing, we used four database instances with two DVD Store databases. We used one client for each database for a total of eight clients. For the 80 percent workload testing, we used only two database instances with two DVD Store databases per instance. We used one client for each database, for a total of four clients. (For details about that workload, see Appendix B.) Figure 4 shows the results from our test.

	Total OPM	CPU %	Power set point (W)	Power utilization (W)		Perf/ watt
				Peak	No activity	
Dell PowerEdge R720						
Maximum performance with no power limit	473,737	99.0	N/A	377	109	1,256.6
Real-world performance (80% CPU utilization) with no power limit	375,438	82.6	N/A	292	109	1,284.4
Real-world performance with 80% power limit	375,233	82.4	304	298	108	1,259.2
HP ProLiant DL380p Gen8						
Maximum performance with no power limit	464,308	99.1	N/A	427	128	1,087.4
Real-world performance (80% CPU utilization) with no power limit	402,302	76.3	N/A	397	133	1,013.4
Real-world performance with 80% power limit	260,736	94.1	342	292	130	892.9

Figure 4: DVD Store results with CPU and power utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

We also looked at the performance-per-watt advantages of the new Dell PowerEdge R720 server at different power levels compared to the HP ProLiant DL380p Gen8 server. As Figure 5 shows, running the PowerEdge R720 at as much as a 40 percent power reduction provides significant performance-per-watt advantages over the HP ProLiant DL380p Gen8. In fact, running the PowerEdge R720 with a 30 percent power reduction provides the highest performance-per-watt advantage. One practical application of the data is with CPU-intensive nightly batch jobs, where it does not

matter if the job takes a few more minutes. Our findings show that you could run most efficiently if you limited the power at 70 percent.

Figure 5: Setting power limits increased performance per watt on the Dell PowerEdge R720 whereas doing so on the HP ProLiant DL380p Gen8 decreased performance per watt.
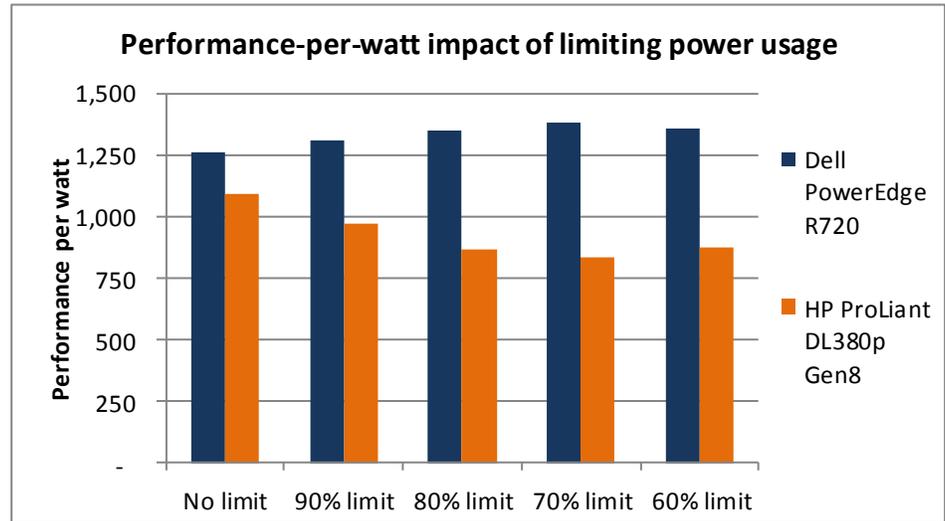
To test the limit feature, we used DVD Store 2.1 running eight Microsoft SQL Server 2008 R2 6GB databases on both servers. To find the maximum performance per watt, we ran each system as close to 100 percent processor utilization as possible. Figure 6 shows the results from our test.

| | Total OPM | CPU % | Power set point (W) | Power utilization (W) | | Perf/ watt |
				Peak	No activity	
Dell PowerEdge R720						
No power limit	473,737	99.0	NA	377	108.9	1,256.6
90% power limit	443,318	99.0	342	338	109.1	1,311.6
80% power limit	406,205	99.0	304	302	109.1	1,345.0
70% power limit	363,644	99.0	266	264	109.2	1,377.4
60% power limit	307,349	98.8	228	226	109.3	1,360.0
HP ProLiant DL380p Gen8						
No power limit	464,308	99.1	NA	427	127.6	1,087.4
90% power limit	343,858	99.0	384	354	127.9	971.4
80% power limit	267,191	98.7	342	308	128.0	867.5
70% power limit	225,148	97.9	299	270	127.9	833.9
60% power limit	198,836	98.0	256	227	128.0	875.9

Figure 6: DVD Store results with CPU and power utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

Reliability during a power outage

Data center servers must stay up and available for users. Both Dell OpenManage Power Center and HP Insight Control offer a feature to reduce power in the event of an emergency such as drop in data center power or cooling.

Dell OpenManage has an option called Emergency Power Reduction (EPR). The administrator can initiate EPR by simply clicking a button in the management console to initiate the power reduction. This feature is available at all levels from the data center down to an individual server, which enables administrators to be extremely precise in selecting what to slow down.

To apply this feature in HP Insight Control requires the administrator to set up rules, which requires several steps. For testing, we created a rule to change the server's power policy from HP Dynamic Power Saving Mode to HP Static Low Power Mode.

To test the power reduction feature on both servers, we ran a database workload using 100 percent processor utilization on the servers while running on battery backup. First, we ran the server with no power limits. We then repeated the test after selecting the power reduction option.

As Figure 6 shows, both servers ran longer with the emergency power reduction feature enabled. However, the Dell PowerEdge R720 ran much longer and the Dell OpenManage Power Center EPR feature was easier to use, as we only had to click a button to initiate it. In contrast, the HP option required several more steps to create and initiate rules.

Figure 7: Running on battery backup with the emergency power reduction feature enabled let the Dell PowerEdge R720 run much longer than the HP ProLiant DL380p G8.

Operation time using battery backup
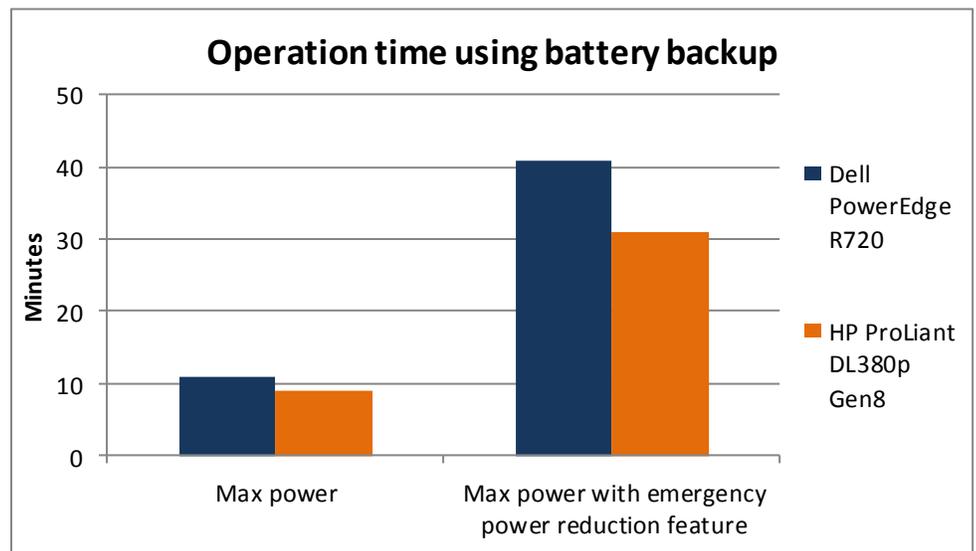
DELL OPENMANAGE KEY FEATURES

Power limit response time

Because Dell OpenManage Power Center offers a low percentage difference between the intended and actual limit, it is important for the software to react quickly in the event the power demand exceeds the intended limit. This fast reaction time allows administrators to increase the server density on circuits without fear of overloading. To test this feature, we implemented a power limit of 225 watts on the server and then began the database workload. As the workload ran, the server power increased up to the 225-watt limit. Figure 8 shows that within 300 milliseconds of going over the power limit, the power came back down and stayed within 1 percent of the power limit. (Note: To magnify the power variations during the run, we do not start the vertical axis of the chart at zero.)
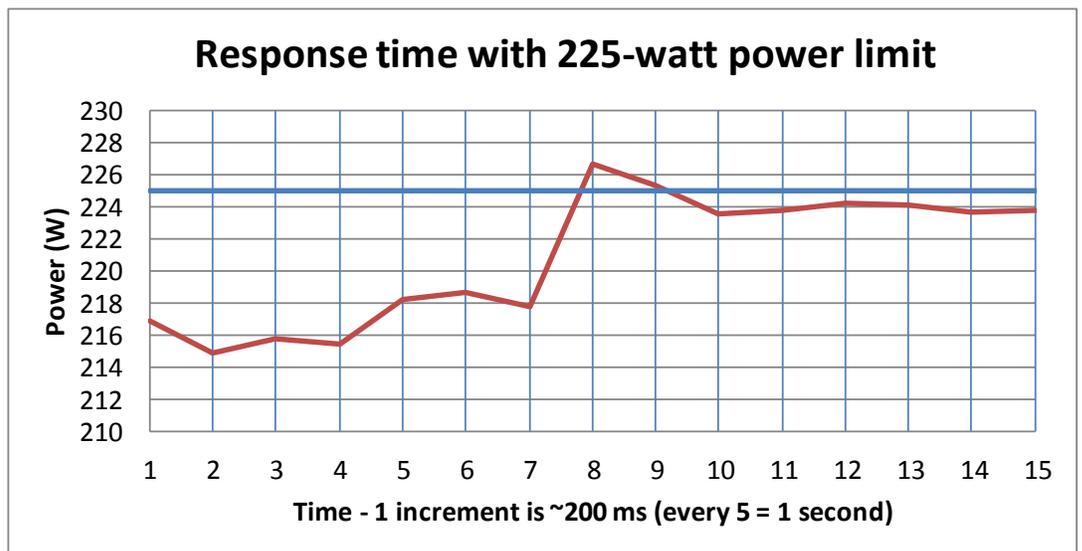
Figure 8: When power usage on the Dell PowerEdge R720 exceeded the limit, it came back down in less than half a second. (To magnify the power variations during the run, we do not start the vertical axis at zero.)

Response time with 225-watt power limit

Power (W) vs Time - 1 increment is ~200 ms (every 5 = 1 second)

Thermal balancing

Another major advantage of the Dell PowerEdge R720 server over the HP ProLiant DL380p Gen8 server is its ability to operate at much higher temperatures. Through the Dell Fresh Air initiative, Dell servers are now rated to operate at up to 113 degrees Fahrenheit, allowing data centers to save substantially on cooling costs.[1] Published specifications for the HP ProLiant DL380p Gen8[2] indicate that it supports operation at only 95 degrees. This significant difference in allowable operating

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[1] http://en.community.dell.com/dell-blogs/direct2dell/b/direct2dell/archive/2012/03/06/12-things-you-need-to-know-about-dell-poweredge-12th-generation-servers-and-solutions-part-iii.aspx
[2] http://h18000.www1.hp.com/products/quickspecs/14212_na/14212_na.html (Note: See System Inlet Temperature section for operating temperature.)

temperature positions the Dell PowerEdge R720 as an excellent choice for the most modern higher-temperature data centers.

For most data center managers, the best approach will be to examine temperature and usage patterns to determine the "sweet spot" where the data center is providing the highest possible energy savings. For more information on the Dell Fresh Air initiative, see www.dell.com/freshair.

Implementing server priority on the Dell PowerEdge R720

When using power limiting, it is important to provide proper server performance to your applications. OpenManage Power Center offers the ability to set a dynamic limit and to set priorities at the room, aisle, or server rack levels. When applying the dynamic limit, you specify a priority of high, medium, or low for each group based on its performance and power needs. For example, if applying a dynamic limit on a server rack, you specify which servers are higher or lower priority.

To test this feature, we used the SPECjbb®2005 benchmark[3] to apply a constant workload on three servers in a rack. We ran each server at 100 percent CPU utilization. The three Dell PowerEdge R720 servers consumed approximately 1,150 total watts. We set a dynamic limit of 850 watts and gave each server a different priority—one high, one medium, and one low. As Figure 9 shows, total power usage dropped precipitously when the limit was applied, and the usage of the three servers varied according to their priority.

We then stopped the workload on the high-priority server. Once OpenManage Power Center identified available watts for the medium- and low-priority serves, they were allowed to consume more power up to the limit of 850 total watts.

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[3] SPECjbb2005 is an industry-standard benchmark created by the Standard Performance Evaluation Corp. (SPEC) to measure a server's Java performance. (Note: SPEC and SPECjbb2005 are trademarks of the Standard Performance Evaluation Corporation.)

Power utilization by priority during dynamic power limit

Figure 9: With Dell PowerEdge R720 servers, you can implement a total power limit for the group, saving power on lower-priority servers and maintaining availability for higher-priority servers
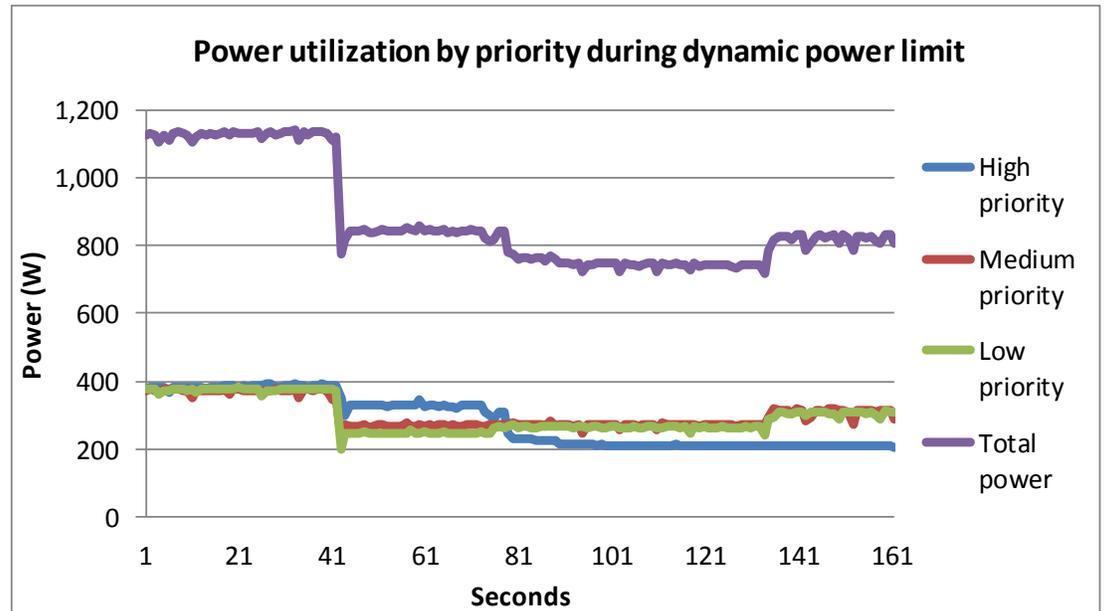
The server priority feature is included with Dell OpenManage Power Center and works automatically with your existing power distribution units (PDU), so other than the purchase of the Dell PowerEdge servers, no special hardware is required.

According to HP support department, HP offers no similar features without the purchase of specific PDU hardware.

CONCLUSION

As data centers grow, their power needs increase and space becomes more and more of a premium. These rising costs make it essential to manage your data center as effectively as possible.

Using Dell OpenManage Power Center with Intel Node Manager Technology in conjunction with the latest Dell PowerEdge servers offers a completely new approach to data center power usage. Dell OpenManage Power Center allows managers to collect, observe, and optimize power utilization to increase uptime and make better power-usage decisions.

In our testing, we saw a gap of only 2 percent between actual usage and the intended power limit; this small difference can let you fit more servers into your data center without exceeding your total available power. While implementing power limits, the Dell PowerEdge R720 maintained consistent performance and delivered up to 65 percent more performance per watt than the HP ProLiant DL380p Gen8 managed by HP Insight Control.

Dell OpenManage Power Center features extended operation time using battery backup—up to 32 percent more than HP Insight Control—and permitted us to implement server prioritizing with no additional purchases.

In addition, through the Dell Fresh Air initiative the latest Dell PowerEdge R720 servers allow you to run at higher temperatures—up to 113 degrees—which can lead to significant data center cost savings.

Together, the many features of Dell OpenManage Power Center work to give you a high degree of knowledge about and control over your servers' power usage and to bring cost savings to your data center.

APPENDIX A – SERVER AND STORAGE CONFIGURATION INFORMATION

Figure 10 provides configuration information for the two servers we tested.

System	Dell PowerEdge R720	HP ProLiant DL380p Gen8
Power supplies		
Total number	2	2
Vendor and model number	Dell D750E-S1	HP DPS-750RB
Wattage of each (W)	750	750
Cooling fans		
Total number	6	6
Vendor and model number	AVC® DBTC0638B2V	Delta PFR0612XHE
Dimensions (h x w) of each	2.5" x 2.5"	2.5" x 2.5"
Volts	12	12
Amps	1.2	3.30
General		
Number of processor packages	2	2
Number of cores per processor	8	8
Number of hardware threads per core	2	2
System power management policy	Balanced	Balanced
CPU		
Vendor	Intel®	Intel
Name	Xeon®	Xeon
Model number	E5-2680	E5-2680
Stepping	C1	C1
Socket type	LGA2011	LGA2011
Core frequency (GHz)	2.70	2.70
Bus frequency (GT/s)	8.0	8.0
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	256 KB (per core)	256 KB (per core)
L3 cache	20 MB	20 MB
Platform		
Vendor and model number	Dell PowerEdge R720	HP ProLiant DL380p Gen8
Motherboard model number	00W9X3	FXNESSN-001P
BIOS name and version	Dell 0.3.38	HP P70, 2/25/2012
BIOS settings	Default	Default
Memory module(s)		
Total RAM in system (GB)	64	64
Vendor and model number	Hynix HMT31GR7BFR4A-H9	Hynix HMT31GR7CFR4A
Type	PC3L-10600R	PC3L-10600R
Speed (MHz)	1,333	1,333
Speed running in the system (MHz)	1,333	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-36	9-9-9-36
Size (GB)	8	8
Number of RAM modules	8	8

System	Dell PowerEdge R720	HP ProLiant DL380p Gen8
Chip organization	Double-sided	Double-sided
Rank	Dual	Dual
Operating system		
Name	Windows Server 2008 R2	Windows Server 2008 R2
Build number	7601	7601
File system	NTFS	NTFS
Language	English	English
Graphics		
Vendor and model number	Matrox® G200e	Matrox G200eH
Driver	Matrox 2.4.1.0	Matrox 1.2.1.0
RAID controller		
Vendor and model number	PERC H710P Mini	Smart Array P420i
Firmware version	3.130.05-1311	2.14
Driver version	Dell 5.1.90.64	HP 6.24.0.64
Cache size	1 GB	1 GB
Hard drive # 1		
Vendor and model number	Seagate ST9300605SS	HP EG0300FBDBR
Number of disks in system	2	2
Size (GB)	300	300
Buffer size (MB)	64	64
RPM	10,000	10,000
Type	SAS	SAS
Hard drive # 2		
Vendor and model number	Pliant® LB 150S	Pliant LB 150S
Number of disks in system	2	2
Size (GB)	150	150
Buffer size (MB)	N/A	N/A
RPM	N/A	N/A
Type	SAS	SAS
Ethernet adapters		
Vendor and model number	Intel I350 Gigabit Controller	HP 331FLR
Type	Integrated	Integrated
Driver	Intel 11.14.42.0	HP 15.2.0.5
Optical drive(s)		
Vendor and model number	TEAC DV-28SW	DS-8D3SH
Type	DVD-ROM	DVD-ROM
USB ports		
Number	4 external, 1 internal	5 external, 1 internal
Type	2.0	2.0

Figure 10: System configuration information for the test servers.

APPENDIX B – CONFIGURING POWER-LIMITING SOFTWARE

For testing, we used Dell OpenManage Power Center version 1.0.2.7253 to control the Dell PowerEdge R720 server. OpenManage communicated with the PowerEdge R720 through the onboard iDRAC 7 Enterprise variant, running software version 1.20.20. We used the isolated management port for iDRAC communication.

Installing Dell OpenManage Power Center

We installed OpenManage on a Dell PowerEdge 2950 III with dual Intel Xeon processors E5405 and 16 GB of system memory. We used the default options for the OpenManage installation as the installation document outlined. After installation, we used the Discovery option to locate and configure our test servers.

Setting the power limit for Dell OpenManage Power Center

1. Select the server or rack as needed for testing.
2. Click the Policies tab.
3. Click the Create New Policy button to create a power limit.
4. Enter the desired limit in the Power Cap Value box.
5. Click Next through the remaining wizard windows.
6. After creating the limit, use the Enable/Disable button on the Policies tab to enable or disable the power limit.
7. Click the Emergency Power Reduction button on the same page to enable EPR for testing.

Installing HP Insight Control

For the HP Insight Control installation, we installed HP Systems Insight Manager 7.0.1 and HP Insight Control 7.0.1 on a HP ProLiant DL380 G7 with dual Intel Xeon processors X5570 and 12GB system memory. We installed HP Systems Insight Manager and Insight Control with default installation options, as the installation documentation outlined. We followed the Pre-installation Worksheet prior to the main installation to ensure proper configuration.

HP Insight Control communicated with the HP ProLiant DL380p Gen8 through the iLO 4 management port. Our test systems used an iLO4 Advanced license and firmware version 1.05. We used the Discovery option found on the Options drop-down menu in HP Insight Control to discover the ProLiant DL380p Gen8 system.

Setting the power limit for HP Insight Control

1. In the left pane, select the server from the System and Event Collections.
2. In the right pane, select the Power/Thermal tab.
3. Expand the Power Management Actions menu.
4. Click the Power Control button.
5. Under Power Cap, enter the desired power limit in the box.
6. Click the box to the left to enable the limit.
7. Click Next through the menus to enable the limit.
8. To disable the limit, click Power Control from the same location and uncheck the box.

Emergency power UPS testing

1. From the Tools drop-down menu, select Data Center Power Control.
2. Click the Define Rules tab.
3. Select New Rule and title the rule Low Power.
4. In the New Rule creation menu, click New Step and select Power Level from the Action drop-down menu.
5. Select Low Power as the desired power level.
6. Select the ProLiant DL380p Gen8 as the act on systems and save the rule.
7. In the Invoke Rules tab, click on the newly created low power rule to enable it.

APPENDIX C – DATABASE WORKLOAD

To build the workload, we used DVD Store Version 2.1 (DS2), an open-source simulation of an online e-commerce DVD store. DS2 has database components and Web server components, and includes driver programs that place heavy loads on these components. A new feature of DVD Store Version 2.1 uses the ability to target multiple databases from one source client. We used this functionality to record the orders per minute output from each specific database target.

The Dell PowerEdge R720 and HP ProLiant DL380p Gen8 ran two Microsoft SQL Server 2008 R2 instances, with two 6GB databases per instance for the real-world 80 percent processor utilization testing. The servers ran four Microsoft SQL Server 2008 R2 instances, with two 6GB databases per instance for the 100 percent processor utilization testing.

The main DS2 metric is orders per minute, which the driver program calculates and records to a text file on the client machines. The DVD Store client application outputs OPM at 10-second intervals. We ran this workload on the server for 30 minutes and report the last OPM score the benchmark reported.

A DS2 order consists of a customer login; a search for movies by title, actor, or category; and a purchase. The workload also performs other actions, such as adding new customers, to exercise a wide range of database functions.

As we note above, because our goal was to isolate and test database server performance, we did not use the front-end Web client component of DS2. Instead, we ran a compiled driver on client machines directly via its command-line interface. We used the default DS2 parameters and setup configuration, with the exceptions we note in the Setting up DVD Store version 2.1 sections below.

We used eight client machines with one client going to each of the eight databases. In the real-world testing, we only used four client machines. Each client machine ran a single instance of DS2, with 16 threads to simulate a heavily loaded environment; the load-generating client machines used a 5 percent new customer setting and ran with no think time, processing requests as quickly as the servers were able.

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

Setting up the servers for DVD Store

Our DVD Store test bed consisted of a Dell PowerEdge R720 or HP ProLiant DL380p Gen8 as the server under test and eight Intel-based clients. Each client had an Intel Pentium 4 3.00GHz processor, 1 GB of system memory, and a Gigabit network card in default configurations. We connected the systems via one Gigabit network switch. We installed a fresh copy of Windows Server 2008 R2 Enterprise Edition on the server.

Installing Windows Server 2008 R2 Enterprise Edition
1. Boot the server, and insert the Windows Server 2008 R2 installation DVD in the DVD-ROM drive.
2. At the Language Selection screen, click Next.
3. Click Install Now.
4. Select Windows Server 2008 R2 Enterprise (Full Installation), and click Next.
5. Click the I accept the license terms check box, and click Next.
6. Click Custom.
7. At the Where to Install Windows screen, click Drive options (advanced).
8. Ensure you select the proper drive, and click New.
9. Enter the partition size, and click Apply. (We used the entire disk.)
10. At the pop-up informing you Windows will create additional partitions, click OK.

11. At the Where to Install Windows screen, click Next.
12. At the User's password must be changed before logging on warning screen, click OK.
13. Enter a password as the new password in both fields, and click the arrow to continue.
14. At the Your password has been changed screen, click OK.

Setting up the network configuration on the server
1. Click Start→Control Panel→Network and Internet→Network and Sharing Center, and click Change Adapter Settings.
2. Right-click on the network adapter, and select Properties from the drop-down menu.
3. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
4. At the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
5. Enter a valid static IP address, subnet mask, and default gateway.
6. Click OK to close the window.
7. At the Local Area Connection Properties window, click Close.
8. Close the Network Connection window.

Installing system updates in Windows Server 2008 R2
We installed all critical updates on the server using the Windows Update feature.

Installing SQL Server 2008 R2 on the server
1. Insert the installation DVD for SQL Server 2008 R2 into the DVD drive.
2. If Autoplay does not begin the installation, navigate to the SQL Server 2008 DVD, and double-click.
3. If prompted with a .NET installation prompt, click OK to enable the .NET Framework Core role.
4. At the SQL Server Installation Center screen, click Installation.
5. Click New installation or add features to an existing installation.
6. At the Setup Support Rules screen, click OK.
7. At the Product Key screen, specify the free Enterprise Edition evaluation, and click Next.
8. At the License Terms screen, accept the license terms, and click Next.
9. At the Setup Support Files screen, click Install.
10. At the Setup Support Rules screen, click Next.
11. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
12. At the SQL Server 2008 R2 Feature Selection screen, select the following features: Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backwards Compatibility, Management Tools – Basic, Management Tools – Complete; and click Next.
13. At the Installation Rules screen, click Next.
14. At the Instance Configuration screen, leave the defaults, and click Next.
15. At the Disk Space Requirements screen, click Next.
16. At the Server Configuration screen, change SQL Server Agent and SQL Server Database Engine to NT AUTHORITY\SYSTEM, and click Next.
17. At the Database Engine Configuration screen, select Mixed Mode, fill in a password for the system administrator (sa) account, click Add Current User, and click Next.
18. At the Error Reporting screen, click Next.
19. At the Installation Configuration Rules screen, click Next.
20. At the Installation screen, click Install.
21. At the Complete screen, click Close.
22. Important: Repeat the installation process three more times to create four total instances of SQL Server 2008 R2.
23. Install SQL Server 2008 R2 Service Pack 1, and patch all instances.

Configuring SQL Server 2008 R2

After installing SQL Server 2008 R2, we enabled the SQL Server Browser and TCP/IP. We followed this process for these configurations:

1. Click Start→Administrative Tools→Services.
2. In the right pane, right-click SQL Server Browser, and select Properties from the drop-down menu.
3. At the Startup type drop-down menu, select Automatic, and click OK.
4. Close the Services window.
5. Click Start→All Programs→Microsoft SQL Server 2008 R2→Configuration Tools→SQL Server Configuration Manager.
6. In the left pane, select SQL Server Services.
7. In the right pane, right-click SQL Server Browser, and select Start from the drop-down menu.
8. In the left pane, expand SQL Server Network Configuration, and select Protocols for MSSQLSERVER (where MSSQLSERVER is the name of the first SQL Server instance).
9. In the right pane, right-click TCP/IP, and select Enable from the drop-down menu.
10. Repeat Step 9 for the remaining three SQL Server instances.
11. In the left pane, select SQL Server Services.
12. In the right pane, right-click SQL Server (MSSQLSERVER), and select Restart from the drop-down menu.
13. Repeat step 12 for the remaining three SQL Server instances.

Installing and configuring the database clients

For the DS2 scripts, we used eight clients to simulate a number of users putting a load on the server. Each client server had a single drive on which we installed a fresh copy of Windows Server 2003 R2 Enterprise Edition. We installed the .NET 3.5 SP1 framework on each client, as the DS2 test executable requires at least .NET2.0. After the installation, we created two folders on the server, one for each client instance, to store the DS2 executable. We followed this process for each installation:

1. Install Microsoft Windows Server 2003 R2 Enterprise x86 Edition with Service Pack 2 on the client.
2. Assign a computer name of `Clientx` for the database client, where x is the client number.
3. For the licensing mode, use the default setting of five concurrent connections.
4. Enter a password for the administrator logon.
5. Select Eastern Time Zone.
6. Use typical settings for the Network installation.
7. Type `Workgroup` for the workgroup.
8. Install Windows Updates, .NET 3.5 SP1 framework, and copy the DVD Store client executable into each of the two folders.

Creating scripts on the database clients

To simplify testing, we created batch files named test.bat on all eight clients to start the DVD Store executable with the correct parameters. We put the batch files on the clients: c:\clientshare. The batch files in c:\clientshare on four of the clients contained the text below. The batch files on the other four clients contained the same text, but the driver pointed to the different database with –database_name=ds2-1.

```
c:\clientshare\ds2sqlserverdriver.exe --target=192.168.2.120 --ramp_rate=10 --
run_time=30 --n_threads=16 --db_size=6GB --think_time=0 --database_name=ds2 --
detailed_view=Y --warmup_time=1 --pct_newcustomers=5 --
output_path=c:\clientshare\opmoutds2.txt
```

Setting up DVD Store version 2.1

Data generation overview

We generated the data using the Install.pl script included with DVD Store version 2.1, providing the parameters for our 6GB database size and the database platform on which we ran - Microsoft SQL Server. We ran the Install.pl script on a utility system running Linux. The Install.pl script also generated the database schema.

After processing the data generation, we transferred the data files and schema creation files to a Windows-based system running SQL Server 2008 R2 SP1. We built the 6GB database in SQL Server 2008 R2 SP1, and then performed a full backup, storing the backup file on the C: drive for quick access. We used that backup file to restore on the server between test runs.

The only modification we made to the schema creation scripts were the specified file sizes for our database. We deliberately set the file sizes higher than necessary to ensure that no file-growth activity would affect the outputs of the test. Besides this file size modification, the database schema was created and loaded according to the DVD Store documentation. Specifically, we followed the steps below:

1. We generated the data and created the database and file structure using database creation scripts in the DS2 download. We made size modifications specific to our 6GB database and the appropriate changes to drive letters.
1. We transferred the files from our Linux data generation system to a Windows system running SQL Server.
2. We created database tables, stored procedures, and objects using the provided DVD Store scripts.
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 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.
9. We created the necessary full text index using SQL Server Management Studio.
10. We created a database user and mapped this user to the SQL Server login.
11. 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.

Figure 11 shows our initial file size modifications.

Logical name	Filegroup	Initial size (MB)
Database files		
primary	PRIMARY	8
cust1	DS_CUST_FG	675
cust2	DS_CUST_FG	675
cust3	DS_CUST_FG	675
cust4	DS_CUST_FG	675
cust5	DS_CUST_FG	675
cust6	DS_CUST_FG	675
cust7	DS_CUST_FG	675
cust8	DS_CUST_FG	675
ind1	DS_IND_FG	418
ind2	DS_IND_FG	418
ind3	DS_IND_FG	418
ind4	DS_IND_FG	418
ind5	DS_IND_FG	418
ind6	DS_IND_FG	418
ind7	DS_IND_FG	418
ind8	DS_IND_FG	418
ds_misc1	DS_MISC_FG	200
ds_misc2	DS_MISC_FG	200
ds_misc3	DS_MISC_FG	200
ds_misc4	DS_MISC_FG	200
ds_misc5	DS_MISC_FG	200
ds_misc6	DS_MISC_FG	200
ds_misc7	DS_MISC_FG	200
ds_misc8	DS_MISC_FG	200
orders1	DS_ORDERS	370
orders2	DS_ORDERS	370
orders3	DS_ORDERS	370
orders4	DS_ORDERS	370
orders5	DS_ORDERS	370
orders6	DS_ORDERS	370
orders7	DS_ORDERS	370
orders8	DS_ORDERS	370
Log files		
ds_log	Not Applicable	15,360

Figure 11: Our initial file size modifications.

Editing the workload script – ds2xdriver.cs module

A new feature of DVD Store version 2.1 is the ability to target multiple targets from one source client. We used this functionality. In order to record the orders per minute output from each specific database target, we modified the ds2xdriver to output this information to log files on each client system. To do this, we used the StreamWriter method to create a new text file on the client system, and the WriteLine and Flush methods to write the relevant outputs to the files during the tests. We also added the capabilities to target differently named databases.

After making these changes, we recompiled the ds2xdriver.cs and ds2sqlserverfns.cs module in Windows by following the instructions in the DVD Store documentation. Because the DS2 instructions were for compiling from the command line, we used the following steps on a system with Visual Studio installed:

1. Open a command prompt.
2. Use the `cd` command to change to the directory containing our sources.
3. Execute the following command:

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

Setting up disk drives for the database

We installed two Pliant LB 150S SSD drives in both servers for the database and log files. We configured the drives as two individual disks and named them volume1 (E:) and volume2 (F:). We put the database and logs on different volumes. For example, the database 1 files were on volume1 and the log files were on volume2. We reversed this for the next database, so database 2 files were on volume2 and the log files were on volume1. We repeated these steps for the remaining database instances. This setup ensured equal disk activity on both RAID volumes.

APPENDIX D – JAVA WORKLOAD

SPECjbb2005 configuration

We used SPECjbb2005 version 1.07, dated March 15, 2006. We followed SPEC's run rules. (For more information about SPECjbb2005 and its run rules, see www.spec.org/jbb2005/docs/RunRules.html.) We installed SPECjbb2005 by copying the contents of the SPECjbb2005 CD to the directory C:\SPECjbb2005v1.07 on the server's hard disk.

SPECjbb2005 requires a Java Virtual Machine on the system under test. We used Java HotSpot 64-bit Server VM (build 20.6-b01 for this testing and left the default installation settings.

For an official SPECjbb2005 run, as per the run rules, the end user should edit the SPECjbb_config.props file in the root SPECjbb2005 directory to include disclosure information about the server and our license information. We did not do this step, as our goal was to create a server load and not produce actual SPECjbb2005 results. We modified the SPECjbb.props file to change the number of JVM instances to two. This change allows a server to run two JVM instances during testing.

We created a batch file, which we placed in the root SPECjbb2005 directory, to issue the Java run command to launch the benchmark. During testing, we used the command prompt window within Microsoft Windows Server 2003 x64 Edition to run this batch file. The contents of this file are shown below.

```
@echo off
set path="C:\Java\bin";%path%

set JVM=2
:: Set JAVA_HOME to Java.exe path.
set JAVA_HOME="C:\Java\bin"

:stage1
set PROPFILE=SPECjbb.props
set JAVAOPTIONS= -Xms512m -Xmx512m
rem set JBBJARS=.\jbb.jar;.\check.jar
set JBBJARS=.\jbb.jar;.\jbb_no_precompile.jar;.\check.jar;.\reporter.jar
set CLASSPATH=%JBBJARS%;%CLASSPATH%

:stage2
echo Using CLASSPATH entries:
for %%c in ( %CLASSPATH% ) do echo %%c
@echo on
start /b C:\Java\bin\java.exe %JAVAOPTIONS% spec.jbb.Controller -propfile
%PROPFILE%
@echo off
set I=0
:LOOP
set /a I=%I + 1
echo.
echo Starting JVM Number %I% with Affinity to CPU %J%
echo.

@echo on
start /B C:\Java\bin\java.exe -Xmx18g -Xms18g -Xmn16g -XX:SurvivorRatio=60 -
XX:TargetSurvivorRatio=90 -XX:ParallelGCThreads=8 -
```

```
XX:AllocatePrefetchDistance=192 -XX:AllocatePrefetchLines=4 -
XX:LoopUnrollLimit=45 -XX:InitialTenuringThreshold=12 -XX:MaxTenuringThreshold=15
-XX:InlineSmallCode=5500 -XX:MaxInlineSize=220 -XX:FreqInlineSize=2500 -
XX:+UseLargePages -XX:+UseParallelOldGC -XX:+UseCompressedStrings -verbose:class
-XX:+AggressiveOpts spec.jbb.JBBmain -propfile %PROPFILE% -id %I% > multi.%I%
      @echo off
      IF %I% == %JVM% GOTO END
      GOTO LOOP
      :END
```

APPENDIX E – MEASURING POWER

Measuring workload power

To record each server's power consumption during the workload 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 120-volt power outlet.

We used the Power Analyzer's Data Acquisition Software (version 2.11) to capture all recordings. We installed the software on a separate Intel processor-based PC, which we connected to the Power Analyzer via an RS-232 cable. We captured power consumption at one-second intervals.

To gauge the power usage with no OS activity, we recorded the power usage for 2 minutes while each server was running the operating system but no applications running.

We then recorded the power usage (in watts) for each server during the testing at one-second intervals. To compute the average power usage, we averaged the power usage during the time the server was producing its peak performance results. We call this time the power measurement interval.

Measuring response time power

To record the power limit response time, we used a Yokogawa® WT210 with WTViewer 8.11 software. We connected a power strip to the Yokogawa WT210 and recorded the Dell PowerEdge R720 server using a 120-volt supply voltage. We connected the WT210 to a desktop via an RS-232 cable. We set the recording time intervals to 100ms inside WTViewer. Note: WTViewer records data at a minimum interval of 200ms due to the RS-232 interface.

ABOUT PRINCIPLED TECHNOLOGIES

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