

Advanced power management with Dell™ OpenManage™ Power Center



When it comes to your data center, two things make a difference: strong and continual server 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.

Dell latest servers with iDRAC7 Enterprise, Intel Node Manager Technology and Dell OpenManage Power Center offer customers a completely new view into 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, Uninterruptible Power Supplies or Dell PowerEdge blade server chassis. From the room, to the rack, to the server, managers can now collect, observe, and optimize power utilization to increase uptime, improve server density, and make better power-usage decisions.

In our labs at Principled Technologies, we set up several Dell PowerEdge R720 servers to see firsthand the potential impact of Power Center in the data center. The result? We found that Dell OpenManage Power Center is an easy-to-use, full featured tool that gave us wide control of our power utilization.



DELL OPENMANAGE POWER CENTER

One of the biggest advantages of investing in the latest equipment and management software is being able to take advantage of new power saving technology. Dell OpenManage Power Center is a power management solution that allows system administrators to monitor and manage power consumption and temperature data on Dell servers throughout your data center. It lets you set threshold notifications, and create policies to intelligently limit server power utilization.

A view into the data center

Before you can manage power utilization, you must first be able to 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 or examine power usage over specific time increments: 15 minutes, 1 hour, 1 day, 1 week, 1 month, 3 months, and 1 year. OpenManage Power Center shows peak, average, and minimum power across the data center, room, aisle, rack or server. Understanding what your power utilization looks like opens a wide range of opportunities for server density, power savings and uptime improvements.

What is power capping?

In the typical server, power utilization increases as the server load increases. Being able to set a stopping point, or “power cap,” for the power consumption of a server or group of servers offers great flexibility and does not necessarily negatively affect performance.

Using OpenManage Power Center with the latest Dell Servers, such as Dell PowerEdge R720, allows administrators to set caps from the data center, room, aisle, rack, or server level. In addition, they can set different caps for different times. For example, you can give a server a lower power cap in the evenings when less work is taking place and a higher utilization cap during the day, when greater performance is needed.

You can set power caps in a variety of ways. To start, the latest generation of Dell servers, such as the Dell PowerEdge R720, run a test during the boot process to find the maximum power they can draw. This data then goes to the OpenManage Power Center as the “upper bound.” This is not a theoretical number or a figure based on approximate server specifications from a data sheet; it is a tested number that changes when the hardware characteristics of your server change.

In the most basic type of capping, the administrator can assign a percentage of the upper bound as a cap. For example, if a server has an upper bound power of 600 watts and the administrator sets a cap of 50 percent, the server would use no more than 300 watts of power at any time.

Administrators also have the option of designating a fixed number of watts as the cap. For example, if you enter 350 watts, the server will not exceed that level. When setting this kind of static power cap, it is very helpful to refer to the actual average usage over various periods. For instance, you can use the power monitor feature to see that over last two months, the server has never exceeded a specific power level. You can then cap the server at this level. This capping ability can have a serious impact on server density as you can now safely add extra servers to the same circuit without the fear of tripping the breaker.

Impact of power capping

Depending on your server's workload, you can implement a power cap with only minimal performance impact. As Figure 1 shows, when we reduced power by 20 percent during a real-world database workload test, performance decreased by less than 1 percent.

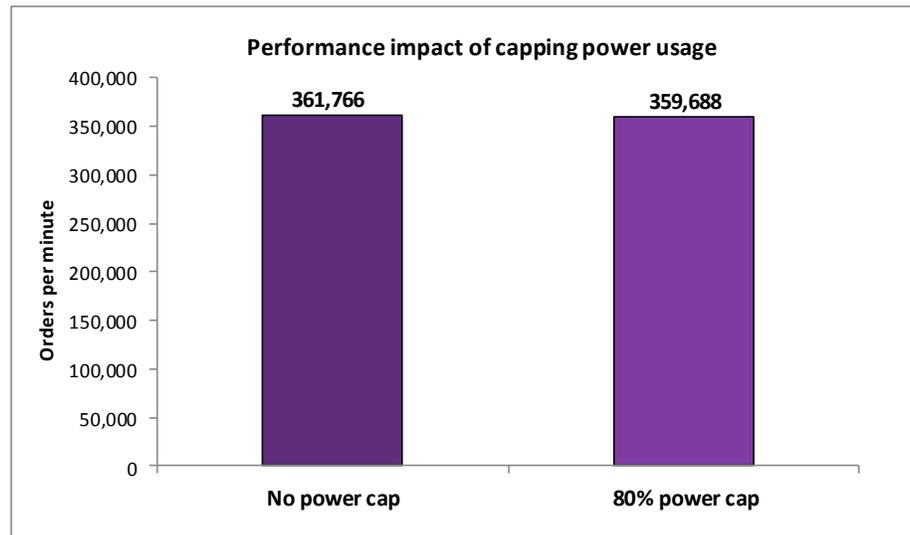


Figure 1: DVD Store results with and without a power cap running a real-world workload of around 80 percent processor utilization. Higher numbers are better.

To test the cap feature, we used DVD Store 2.1 running four Microsoft SQL Server 2008 R2 6GB databases on a Dell PowerEdge R720 server. (For details about that workload, see [Appendix B](#).) Figure 2 shows the results from our test.

We first ran the server at maximum performance, with close to 100 percent CPU utilization, and recorded the average peak power. We used this as our peak power set point. Then we ran a more real-world workload, with roughly 80 percent processor utilization, and did not set a power cap. Next, we set a 20 percent power reduction cap based on the average peak power above. As expected, running at 20 percent less power had minimal impact, less than 1 percent, on the total database performance.

PowerEdge R720	Total OPM	CPU %	Power set point (W)	Power utilization (W)		Perf/watt
				Peak	No activity	
Maximum performance with no power cap	463,625	98.3	NA	363.3	112.0	1,276
Real-world performance (80% CPU utilization) with no power cap	361,766	79.0	NA	293.2	113.4	1,233
Real-world performance with 80% power cap	359,688	81.1	291	286.6	112.8	1,255

Figure 2: 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 and how it compared to the previous-generation Dell PowerEdge R710 server. As Figure 3 shows, running the PowerEdge R720 at as much as a 40 percent power reduction provides a significant performance-per-watt advantages over the PowerEdge R710. In fact, running the PowerEdge R720 with a 20 percent power reduction provides the highest performance-per-watt advantage. A practical application of the data can be 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 more efficiently if you capped the power at 80 percent. In fact, running our database workload on a PowerEdge R720 with the 80 percent cap would take only 35.9 minutes, 5.9 minutes longer than the 30 minutes it would take to run the workload on the same server with no cap, while providing a 20 percent power reduction and offering increased savings.

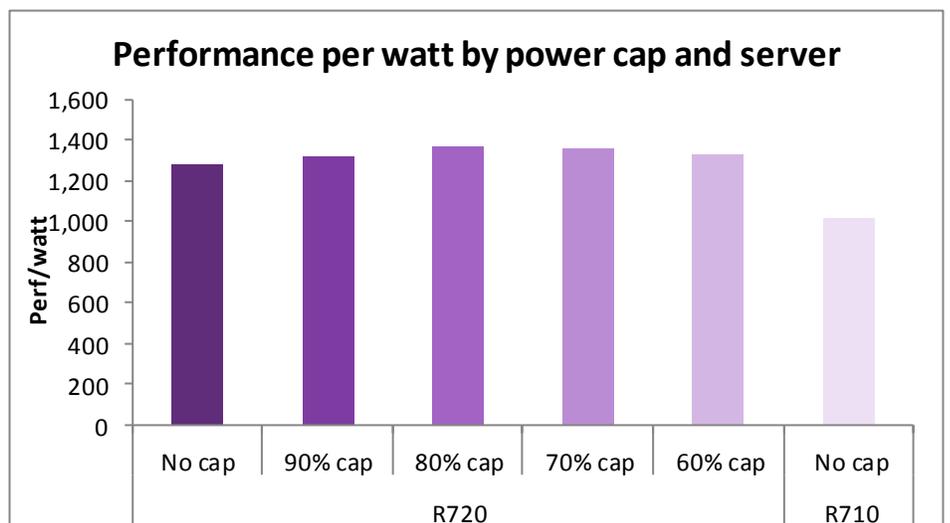


Figure 3: Performance per watt for Dell PowerEdge R720 was highest with the 80 percent power cap and higher than for the PowerEdge R710 across the board. Higher numbers are better.

To test the cap feature, we used DVD Store 2.1 running eight Microsoft SQL Server 2008 R2 6GB databases on a Dell PowerEdge R720 server. To find the maximum

performance per watt, we ran each system as close to 100 percent processor utilization as possible. Figure 4 shows the results from our test.

PowerEdge R720	Total OPM	CPU %	Power set point (W)	Power utilization (W)		Perf/watt
				Peak	No activity	
No power cap	463,625	98.3	NA	363.3	112.0	1,276
90% power cap	423,782	98.5	327	322.0	111.9	1,316
80% power cap	387,031	98.4	291	283.2	111.6	1,367
70% power cap	339,574	98.3	254	249.9	111.7	1,359
60% power cap	283,589	98.2	218	214.0	111.7	1,325

Figure 4: Dell PowerEdge R720 DVD Store results with CPU and power utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

Next, we tested the previous-generation Dell PowerEdge R710 server without a power cap. Figure 5 shows the results.

PowerEdge R710	Total OPM	CPU %	Power set point (W)	Power utilization (W)		Perf/watt
				Peak	No activity	
No power cap	335,078	97.9	No limit	330.0	146.0	1,015

Figure 5: Dell PowerEdge R710 DVD Store results with CPU and power utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

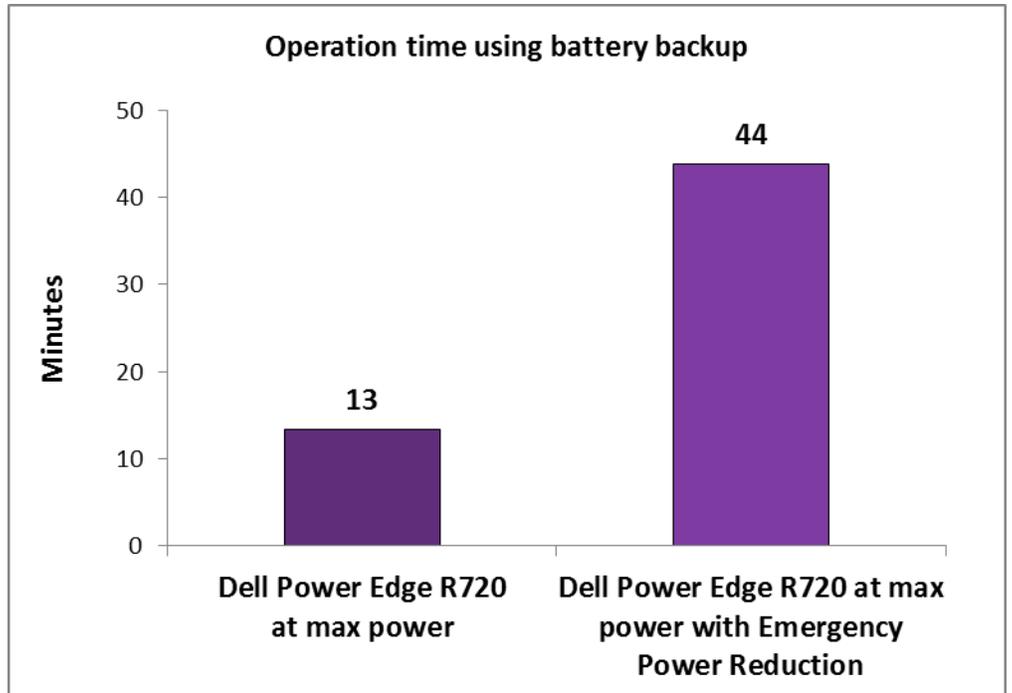
Reliability during power outage

Data center servers must stay up and available for users. OpenManage offers a feature called Emergency Power Reduction, which lets administrators quickly lower the power draw of systems in the event of a change in power.

To test this feature, we ran a database workload using 100 percent processor utilization on the PowerEdge R720 while running on battery backup. First, we ran the server using no power capping. We then repeated the test after selecting the Emergency Power Reduction option. In our tests, the time from selecting Emergency Power Reduction to seeing its impact on the servers was just a few seconds.

As Figure 6 shows, with Emergency Power Reduction, the server ran for more than three times as long. While cutting the power does lower the server performance due to the power drop, keeping the server in a working state for a longer time minimizes complete user interruption in the event of a power change.

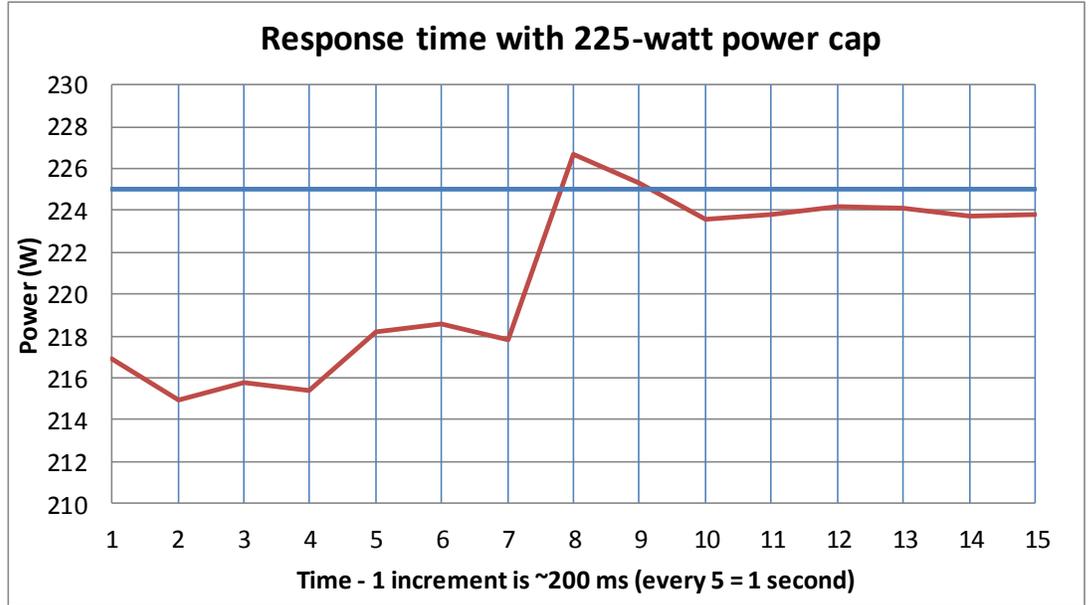
Figure 6: Operation time of the Dell PowerEdge R720 while running on battery backup at maximum power and using OpenManage Power Center Emergency Power Reduction. Higher numbers are better.



Power cap response time

OpenManage Power Center offers the ability to implement a sub-second rapid response time to implement a power cap. This ability is necessary in order for administrators to increase the server density on circuits; they need to be certain that power will not exceed any cap by a significant amount and that the cap will be enforced almost immediately once it is reached. To test this feature, we implemented a power cap 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 cap. Figure 7 shows that within 300 milliseconds of going over the power cap, the power came back down and stayed within 1 percent of the power cap.

Figure 7: Example of sub-second response time when cap is applied.



Thermal balancing

One advantage of Dell PowerEdge R720 servers is their ability to run at higher temperatures to save on data center cooling cost. For testing, we ran the Dell PowerEdge R720 server at two different room temperatures: 72 degrees Fahrenheit and 104 degrees Fahrenheit. Figure 8 shows the results. Raising the temperature by 32 degrees increased power by only 8.5 percent. While increasing power may appear to be a disadvantage, the potential savings on cooling could far outweigh the increase. According to Dell, their servers are rated to operate at up to 113 degrees Fahrenheit, allowing data centers to save substantially on cooling costs.¹ For most datacenter managers, the best approach will be to examine temperature and usage patterns in order 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.

Room temperature	Total OPM	CPU %	Power utilization		Perf/watt	Temperature	
			Peak	No activity		Inlet	Outlet
72° F	463,625	98.3	363.3	112.0	1,276.1	72.2	87.3
104° F	460,033	98.3	394.2	117.3	1,167.0	103.3	119.1

Figure 8: Dell PowerEdge R720 DVD Store results with CPU and power utilization at two different operating temperatures. Higher OPM and performance/watt are better. Lower power utilization is better.

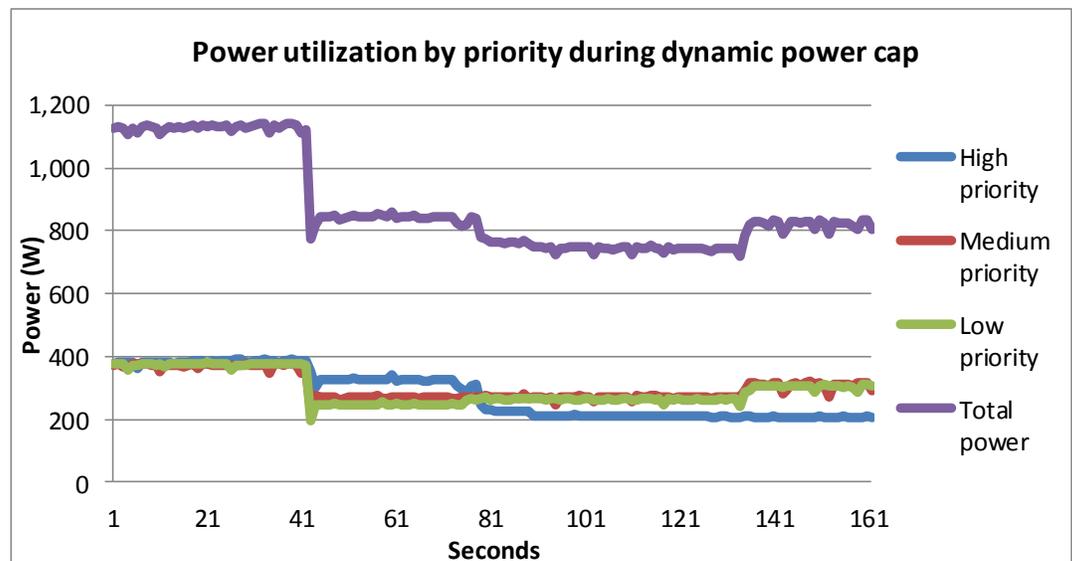
¹ <http://en.community.dell.com/dell-blogs/direct2dell/b/direct2dell/archive/2012/03/06/12-things-you-need-to-know-about-dell-poweredge-12th-generation-servers-and-solutions-part-iii.aspx>

Implementing server priority

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

To test this feature, we used the SPECjbb2005 benchmark to apply a constant workload on three servers in a rack. We ran each server at 100 percent CPU utilization. With all three servers running, they were drawing around 1,150 watts. We set a dynamic cap of 850 watts and gave each server a different priority—one high, one medium, and one low. As Figure 9 shows, with the cap applied, all three servers dropped in power utilization and utilization varied according to their priority. As the graph shows, the power dropped precipitously when the cap was applied. We then stopped the workload on the high-priority server. Once OpenManage Power Center identified available watts for the medium- and low-priority servers, they were allowed to consume more power up to the cap of 850 watts. This illustrates the ability to implement a total power cap for the group, saving power on lower-priority servers, and maintaining availability for higher-priority servers.

Figure 9: Power utilization using a dynamic power cap with high, medium, and low priority settings on three identical servers.



CONCLUSION

As data centers grow, their power utilization continues to increase. The rising cost of power makes it essential to manage your data center as effectively as possible.

Dell latest servers with iDRAC7 Enterprise, Intel Node Manager Technology, and Dell OpenManage Power Center offer a completely new way to see datacenter power usage. Dell OpenManage Power Center allows managers to collect, observe, and optimize power utilization to increase uptime, improve server density, and make better power-usage decisions.

APPENDIX A – SERVER AND STORAGE CONFIGURATION INFORMATION

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

System	Dell PowerEdge R720	Dell PowerEdge R710
Power supplies		
Total number	2	2
Vendor and model number	Dell D750E-S1	Dell N870-S0
Wattage of each (W)	750	870
Cooling fans		
Total number	6	5
Vendor and model number	AVC® DBTC0638B2V	Sanyo® 9GV0612P1M041
Dimensions (h x w) of each	2.5" x 2.5"	2.5" x 2.5"
Volts	12	12
Amps	1.2	1.5
General		
Number of processor packages	2	2
Number of cores per processor	8	6
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	X5670
Stepping	C1	B1
Socket type	LGA2011	FCLGA1366
Core frequency (GHz)	2.70	2.93
Bus frequency (GT/s)	8.0	6.4
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	12 MB
Platform		
Vendor and model number	Dell PowerEdge R720	Dell PowerEdge R710
Motherboard model number	00W9X3	0N0H4P
BIOS name and version	Dell 0.3.38	Dell 6.1.0
BIOS settings	Default	Default
Memory module(s)		
Total RAM in system (GB)	64	96
Vendor and model number	Hynix HMT31GR7BFR4A-H9	Samsung M393B1K70BH1-CH9
Type	PC3-10600R	PC3-10600R
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	9-9-9-24
Size (GB)	8	8
Number of RAM module(s)	8	12

System	Dell PowerEdge R720	Dell PowerEdge R710
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 G200e
Graphics memory (MB)	8	8
Driver	Matrox 2.4.1.0	Microsoft 6.1.7600.16385
RAID controller		
Vendor and model number	PERC H710P Mini	PERC 6/i
Firmware version	3.130.05-1311	1.22.32-1371
Driver version	Dell 5.1.90.64	LSI 1.28.3.52
Cache size	1 GB	256 MB
Hard drive # 1		
Vendor and model number	Seagate ST9300605SS	Seagate ST973402SS
Number of disks in system	2	2
Size (GB)	300	73
Buffer size (MB)	64	16
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	Broadcom® NetXtreme® II GigE 5709C Quad-Port Ethernet
Type	Integrated	Integrated
Driver	Intel 11.14.42.0	Microsoft 4.8.4.1
Optical drive(s)		
Vendor and model number	TEAC DV-28SW	TEAC DV-28SV
Type	DVD-ROM	DVD-ROM
USB ports		
Number	4 external, 1 internal	4 external, 1 internal
Type	2.0	2.0

Figure 10: System configuration information for the test servers.

APPENDIX B – 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 ran two Microsoft SQL Server® 2008 R2 instances, with two 6GB databases per instance for the real-world testing. The Dell PowerEdge R720 and R710 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 in the detailed test methodology in Appendix D.

We used eight client machines with one client going to each of the eight databases. On 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 Dell PowerEdge R710 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 as of 1/31/2012 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-hand 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. Select SQL Server Services in the left pane.
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 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 20GB 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 20GB 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 20GB database and the appropriate changes to drive letters.
2. We transferred the files from our Linux data generation system to a Windows system running SQL Server.
3. We created database tables, stored procedures, and objects using the provided DVD Store scripts.
4. We set the database recovery model to bulk-logged to prevent excess logging.
5. 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.
6. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
7. We updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
8. 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
```
9. We set the database recovery model back to full.
10. We created the necessary full text index using SQL Server Management Studio.
11. We created a database user and mapped this user to the SQL Server login.

12. 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	3
cust1	DS_CUST_FG	2,168
cust2	DS_CUST_FG	2,168
cust3	DS_CUST_FG	2,168
cust4	DS_CUST_FG	2,168
cust5	DS_CUST_FG	2,168
cust6	DS_CUST_FG	2,168
cust7	DS_CUST_FG	2,168
cust8	DS_CUST_FG	2,168
ind1	DS_IND_FG	1,280
ind2	DS_IND_FG	1,280
ind3	DS_IND_FG	1,280
ind4	DS_IND_FG	1,280
ind5	DS_IND_FG	1,280
ind6	DS_IND_FG	1,280
ind7	DS_IND_FG	1,280
ind8	DS_IND_FG	1,280
ds_misc1	DS_MISC_FG	256
ds_misc2	DS_MISC_FG	256
ds_misc3	DS_MISC_FG	256
ds_misc4	DS_MISC_FG	256
ds_misc5	DS_MISC_FG	256
ds_misc6	DS_MISC_FG	256
ds_misc7	DS_MISC_FG	256
ds_misc8	DS_MISC_FG	256
orders1	DS_ORDERS	1,536
orders2	DS_ORDERS	1,536
orders3	DS_ORDERS	1,536
orders4	DS_ORDERS	1,536
orders5	DS_ORDERS	1,536
orders6	DS_ORDERS	1,536
orders7	DS_ORDERS	1,536
orders8	DS_ORDERS	1,536
Log files		
ds_log	Not Applicable	20,480

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 the Dell PowerEdge 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 C – 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 did modify the SPECjbb.props file to change the number of JVM instances to 2. This change allows a server to run 2 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 %PROFFILE% -id %I% >
multi.%I%
@echo off
IF %I% == %JVM% GOTO END
GOTO LOOP
:END
```

APPENDIX D – 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 1-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 cap 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.

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