ROBUST FREE POWER MANAGEMENT: DELL OPENMANAGE POWER CENTER

Deploying, managing, and controlling power in the data center has become increasingly important for enterprises of all sizes. The growth of the x86 server market in the past 15 years, the need to serve customers and end users with ever more demanding requirements, and the explosion of big data have led to energy and power infrastructure constraints as companies, service providers, government agencies, and other large organizations deal with the balancing act of providing greater levels of service to their end users with a finite amount of incoming power from the grid. The use of blades and other high-density servers compound the problem, as they squeeze more computing power into a smaller physical footprint, which then increases the wattage per square foot required for large data centers.

Studies show that the issue is not going away but rather growing, and that companies should take notice. For instance, a Computer Weekly study showed that power requirements grew globally by 63 percent from 2011 to 2012, and estimates a 17 percent increase anticipated for 2013.[1] A separate study from Gartner shows that energy-related costs are the "fastest rising cost in the data center," and suggests that the problem will continue to burden enterprises unless they can find strategies to lower consumption.[2]

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[1] www.computerweekly.com/news/2240164589/Datacentre-power-demand-grew-63-in-2012-Global-datacentre-census
[2] www.gartner.com/newsroom/id/1442113

A joint study by Microsoft and the University of California, Berkeley found that after servers, the largest contributor to the total operating cost of a data center was the cost of provisioning power.[3] Enterprises are well aware of the impact that data center power usage has on the bottom line, business growth, and even business continuity. In a 2012 survey by Emerson Network Power, 35 percent of respondents pegged power as the primary limiting factor for data center capacity, above cooling and square footage.[4]

There are pressures from multiple angles, including policy directives, grid constraints, and most of all, budget. For example, in the case of a green policy directive, a company may receive orders to lower power consumption by some specific percentage over the next quarter. Other organizations must deal with grid constraints, where plugging in additional devices could overtax their electrical infrastructure. Finally, companies and IT departments have strict budget constraints, and face the extreme challenge of tackling a serious issue with little financial resources. What is a company to do?

Given these realities, what can power-constrained enterprises do?

Improved power management policies and technologies in the data center can help enterprises solve these specific power problems while at the same time improving both capital expenses (CAPEX) and operational expenses (OPEX). For example, enterprises can apply policies that set power consumption limits for servers and then scale that effort to significantly decrease power consumption across the data center, reducing OPEX. In many cases, capping power consumption at the server level will not result in decreased performance, as most enterprise servers use less power than the amount typically allocated to them. Better power management can also reduce CAPEX through better utilization of existing infrastructure through increased server density at the rack or data center level. As each power distribution unit (PDU) kilowatt can represent as much as $10,000 of CAPEX,[5] enterprises are wise to fully use available power capacity rather than build out unnecessarily.

In addition to improving the bottom line, power management policies and technology can help enterprises address business continuity and mission-critical Tier 1 application availability. Enterprises may face situations in which they have no choice to decrease power consumption in the data center, from power shortages or outages to even running into a power ceiling, where no additional devices can be added without removing a device. Business continuity and service-level agreements (SLAs) can also be

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[3] research.microsoft.com/pubs/164427/IGCC2012.pdf
[4] www.emersonnetworkpower.com/documents/en-us/brands/liebert/infographics/documents/half-dc-will-run-out-of-power-or-cooling-before-space.pdf
[5] www.intelcloudbuilders.com/cloud-usage-models/pdf/Intel%20PM%20article%20v2%20Chapter1-5.pdf

threatened by a sudden drop in available energy supply, for example as a result of a brownout or worst-case scenarios such as the decommissioned nuclear power plants in Japan following the March 2011 earthquake. In either case, effective server power management can help enterprises keep running, even extending operating time on a generator by a factor of 1.8.[6]

COST EFFECTIVE POWER MANAGEMENT WITH DELL OMPC

Dell OpenManage Power Center is Dell's answer to this challenge. Administrators can use Dell OpenManage Power Center to set power limits at different levels—data center, room, aisle, rack, or server—and set alert notifications for various events. They can also set different power limits for different times. For example, a server might have a lower power limit in the evenings, when the workload decreases, and a higher limit during the day, when performance demands are greater. Such limits can lead to increased density in data center racks as they make it possible to safely overprovision and add extra servers to a given circuit without fear of overloading that circuit.

In our labs at Principled Technologies, we tested two data center power management tools—Dell OpenManage Power Center version 2.0 and JouleX Energy Manager for Data Centers version 4.2.0. We configured a test bed with Dell OpenManage Power Center version 2.0 managing a group of Dell PowerEdge R720 servers and JouleX Energy Manager for Data Centers, a newly acquired Cisco product, managing an HP ProLiant DL380p Gen8 server. We used JouleX Energy Manager as an example of a tool available for power management that provides comparable feature sets.

While both solutions were effective at capping power, Dell OpenManage Power Center provided a significant cost advantage compared to JouleX and its revolving additional costs—Dell OMPC comes free with iDRAC Enterprise Edition and supports up to 4,000 Dell servers per OMPC instance at additional no cost. In contrast, JouleX Energy Manager for Data Centers has a starting price of $12,500 per 500 kW for the first year, with ongoing maintenance and support costs.[7] That means that with JouleX, organizations would continue to pay high recurring costs for power management over the life of a data center.

In addition, the cost of JouleX is based on the amount of managed device power consumption in kW. This cost structure can be particularly frustrating to managers of a fast-growing server farm. Each time they add a circuit, or even more servers to existing circuits, they must consider the additional costs for the power management product. In

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[6] www.intel.com/content/dam/www/public/us/en/documents/case-studies/data-center-efficiency-xeon-e5-ntt-node-manager-study.pdf
[7] Price accurate as of September 2013.

contrast, Dell OpenManage Power Center provides power management features at no additional cost, which can help companies operate within budget and maintain predictable operational budgets. Dell OpenManage Power Center provides the features you need to handle a wide range of power management tasks in your Dell server farm, and offers the added bonus of being more cost effective.

OMPC DETAILED TEST RESULTS AND SCENARIOS

We configured Dell OpenManage Power Center to communicate with the iDRAC management port on the Dell servers. We then configured JouleX to communicate with the iLO management port on the HP servers for a comparable configuration. JouleX Energy Manager for Data Centers does have the ability to communicate with the operating system to provide additional features; however, for comparison purposes we used both servers' out-of-band management interfaces.

Power capping

Overview

Without power management technologies in place, the power utilization of a server typically increases as its load increases. The ability to designate an upper limit on power consumption—a "power cap"—for a server or group of servers offers a number of advantages and need not negatively affect performance.
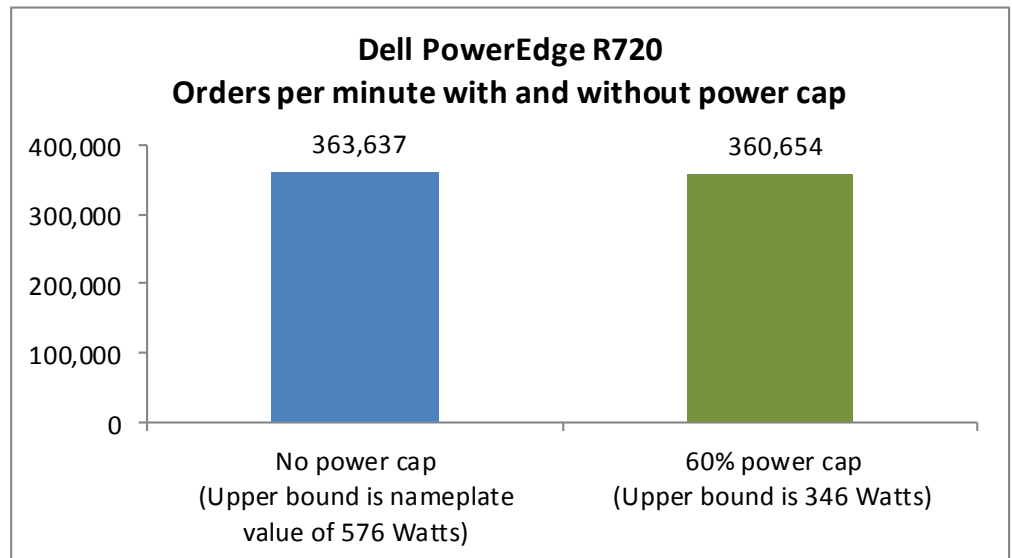
One way to use power capping is by simply assigning a percentage of the nameplate power as a cap. For example, if a server had a nameplate power of 1,200 watts and the administrator set a cap of 50 percent, the server's power usage would never exceed 600 watts. Administrators often use nameplate power for circuit planning, which can cause much of the allocated power to go unused. In the above example, a 50 percent power cap based on the nameplate power would allow you to install two servers and double your circuit/server capacity.

Dell OMPC power capping test results

To show the power capping abilities of Dell OpenManage Power Center, we ran a workload that is common in most data centers – a database application workload simulating e-commerce activity. We ran this workload and used approximately 80 percent CPU capacity to simulate a heavily loaded server. For details about that workload, see Appendix C. We first ran the workload with no power cap and recorded the orders per minute (OPM). Then we applied a 60 percent power cap—that is, 60 percent of the upper bound power. (The Dell server reports an upper bound power reading to OpenManage Power Center, which is the maximum power the hardware configuration could use.)

As Figure 1 shows, the number of orders per minute decreased only 0.8 percent with the power cap in place. In business and end user terms, this shows that you can apply a power cap with little to no performance impact for your end user, and save that allotted power for another device. This is because when the server was uncapped, it did not fully utilize its CPU capacity and did not need all the allotted power. Knowing that your workload can run with a 60 percent power cap with only a minor hit to performance allows you to allocate the unused power to other servers, so that none of your data center power goes to waste.

Figure 1: With a 60 percent power cap in place, the Dell PowerEdge R720 achieved 99.2 percent of the performance as the same server with no power cap.

Dell PowerEdge R720
Orders per minute with and without power cap

No power cap
(Upper bound is nameplate value of 576 Watts): 363,637

60% power cap
(Upper bound is 346 Watts): 360,654

Running a server with a power cap can also yield performance-per-watt advantages. To show this, we used the same OLTP workload as in the above example, but this time used 100 percent processor utilization. We first ran with no power cap and recorded the average power for the run. Then we ran the same workload with power caps incrementally lower than the uncapped power usage. We recorded the OPM and calculated the performance-per-watt. We performed this test on the HP ProLiant DL380p Gen8 as well.

Figure 2 shows the performance-per-watt results at several power cap configurations. While the server performance does decrease as the power cap is applied, the performance per watt increases. This shows the server running more efficiently at lower power levels.

Dell OMPC with Dell PowerEdge R720	Power cap set (W)	Average power utilization (W)	Total OPM	OPM per watt
No power cap	No cap	354	397,790	1,123.7
90% of peak utilization	319	318	367,218	1,154.8
80% of peak utilization	283	283	338,895	1,197.5
70% of peak utilization	248	247	301,393	1,220.2

Figure 2: OLTP workload results and power utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

JouleX power capping with HP DL380p Gen8 test results

To demonstrate the JouleX and HP capabilities of power capping, we repeated this test on the HP ProLiant DL380p Gen8 using JouleX. Note that HP's out-of-band management (iLO) implements power capping in a different manner than Dell's iDRAC, and it is for this reason that the OPM per watt efficiently is lower in Figure 3 below. A Dell server capped via iDRAC will keep the server running very close to the capped wattage, whereas an HP server capped via iLO will maintain a wattage somewhat lower than the applied cap. Because of this design, the HP results in this report are not a direct comparison between OpenManage Power Center and JouleX.

Figure 3 shows the performance-per-watt results at several power cap configurations using the JouleX Energy Manager and HP ProLiant DL380p Gen8 combination.

JouleX Energy Manager with HP ProLiant DL380p Gen8	Power cap set (W)	Average power utilization (W)	Total OPM	OPM per watt
No power cap	No cap	366	375,142	1,025.7
90% of peak utilization	329	294	309,492	1,051.3
80% of peak utilization	293	278	275,017	990.8
70% of peak utilization	256	243	242,874	997.9

Figure 3: OLTP workload results and power utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

Implementing system priority – Dell OMPC

When using power limiting, it is essential that applications across multiple servers get the performance you need. OpenManage Power Center lets you set a dynamic limit and set priorities at the room, aisle, or server rack levels. With a dynamic limit, you specify a priority—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. So what does this mean for the customer or business?

- Management by server groups: Companies can set power policies based on groups of servers at the room, aisle, or rack levels.
- Priority management: Using the priority features, companies can ensure more important systems have the power they need during peak loads. For example, a database server backing your online storefront and fueling your business would be higher priority than an internal file server.
- Ease of use: Administrators can set a total power cap for all these servers and let OpenManage Power Center intelligently distribute the power based on server demand, which means each server gets the power it needs to fulfill its role without wasting energy.

We tested the priority feature by using an e-commerce database workload to apply a constant demand on three Dell PowerEdge R720 servers in a rack. Each server ran at 100 percent CPU utilization and the three servers consumed approximately 1,080 total watts. We set a dynamic limit of 900 watts and gave one server high priority, one medium priority, and one low priority. As Figure 4 shows, total power usage dropped dramatically when we applied the limit approximately 60 seconds into the test period, and the usage of the three servers varied according to their priority, with the high priority server obtaining more power resources around 140 seconds.

We then stopped the workload on the medium-priority server at approximately the 350 second mark and allowed it to focus on background tasks. Once OpenManage Power Center identified available watts for the high- and low-priority servers, they could consume more power up to the dynamic limit, at approximately the 450 second mark.
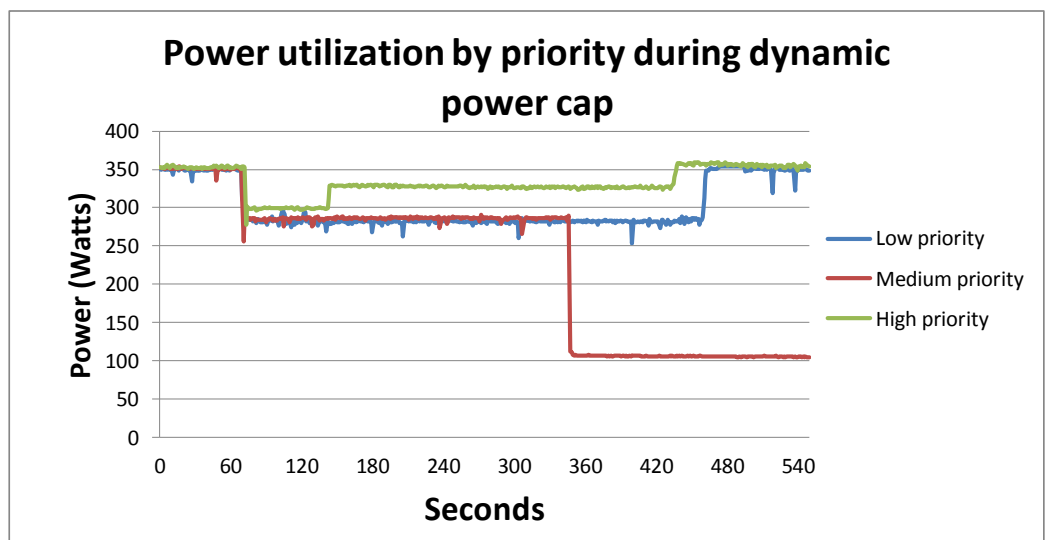
Figure 4: Power utilization of each R720 dynamically adjusting with respect to set server priority and power availability.

JouleX Energy Manager for Data Centers lets you set priorities for policies and components, but the setup is more complex, requires a higher-level engineer, and operates via interaction with the operating system, not out of band. In contrast, Dell OpenManage Power Center offers a free effective priority power capping option with little required configuration.

Reliability during a power outage – Dell OMPC

It is essential that data center servers remain functional and available for users. Both Dell OpenManage Power Center and JouleX Energy Manager for Data Centers include a feature that reduces power following a drop in data center power or cooling or any other emergency.

The Dell OpenManage option is called Emergency Power Reduction (EPR). This feature gives administrators an easy way to put servers into a low power state in the event of an emergency such as partial loss or decrease of available power. In this situation the servers continue to run, but do not overload the circuit breaker. It addresses emergency power issues intelligently, since the server remains functioning during the power event and applications stay up, which is important to end users.

You can initiate EPR by selecting a device or organizational structure (rack, aisle, room, or data center) and clicking a button; power on that device or structure reduces immediately. Because this feature is available at all levels, from the data center down to an individual server, administrators can select with great precision what to slow down.

To test the power reduction feature, we ran an OLTP workload using 100 percent processor utilization on the server while running on battery backup. We first ran the server with no power limits. We then repeated the test after selecting the emergency power reduction option.

As Figure 5 shows, the server ran 220.4 percent longer with the emergency power reduction feature enabled. This could be the difference between keeping your client-facing services up and running or seeing them shut down before finding an alternate source of power.

Figure 5: With the emergency power reduction feature enabled, the Dell PowerEdge R720 lasted more than three times as long as with it disabled.
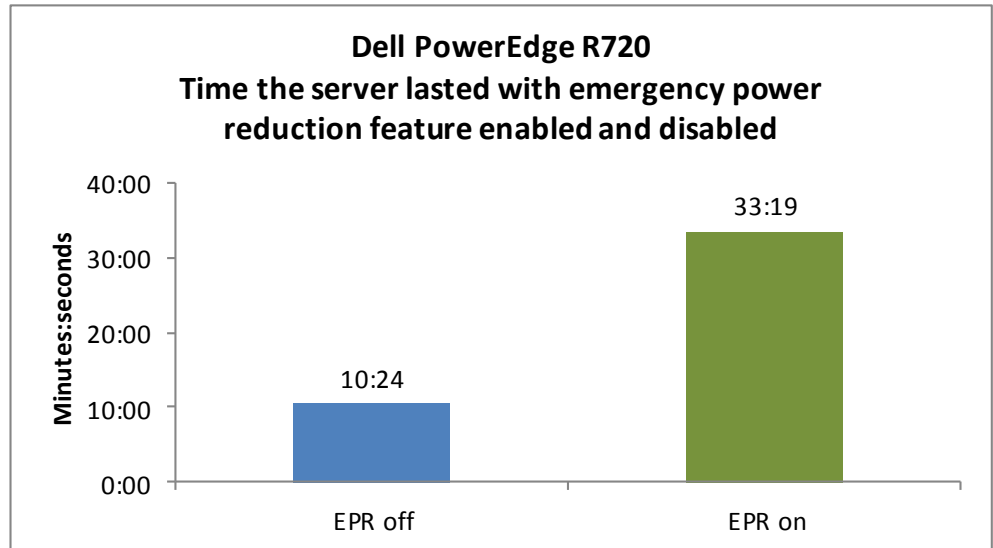
JouleX Energy Manager for Data Centers offers options to reduce power in the event of emergencies, but uses different approaches. One technique is to create a policy that changes the processor to a low performance level. However, this approach requires setup between JouleX and the operating system instead of just the iLO management port. We did not set this feature because we focused our evaluation on the management port communication on both Dell and JouleX configurations. JouleX does let you set up power reduction in the event of an emergency, but this functionality requires a more different and more complex configuration than the dedicated EPR option in OpenManage Power Center, and therefore was not directly comparable.

ABOUT THE PRODUCTS WE TESTED

Dell OpenManage Power Center

With Dell OpenManage Power Center, using Intel Node Manager Technology, IT administrators get a view into various aspects of the data center, including 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, and Dell PowerEdge blade server chassis.

According to Dell, new to Dell OpenManage Power Center 2.0 from version 1 are the following features[8]:

- Improved user interface providing a more intuitive flow with fewer keystrokes

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[8] ftp://ftp.dell.com/Manuals/all-products/esuprt_software/esuprt_ent_sys_mgmt/esuprt_ent_sys_mgmt_opnmng_pwr_centr/dell-opnmang-power-center-v2.0_Release%20Notes12_en-us.pdf

- Dashboard that offers a quick view of power headroom and device usage
- Rack power and space use data
- Power monitoring and capping at the chassis level for the Dell PowerEdge M1000e

IT administrators cannot manage power utilization unless they can collect data related to it. OpenManage Power Center offers a range of features for monitoring your data center power utilization. OpenManage Power Center shows peak, average, and minimum power across the data center, room, aisle, rack, or server. Having such granular knowledge of your power utilization can help you make improvements in many areas, including server density, power savings, and uptime.

To learn more about Dell OpenManage Power Center, visit www.dell.com/us/enterprise/p/dell-openmanage-power-center/pd.

JouleX Energy Manager for Data Centers

JouleX Energy Manager for Data Centers is a tool to monitor and control all aspects of the data center. It offers support for physical and virtual servers as well as other components such as switches, routers, storage devices and other items, but does so at a higher software cost.

For more detailed information on JouleX Energy Manager for Data Centers, visit www.joulex.net/products-0/joulex-energy-manager-for-data-centers/

CONCLUSION

Effective power management is quickly becoming a major concern for data centers of all sizes. Specialized power management software is now available to help meet these needs. We tested two of these power management tools, Dell OpenManage Power Center and JouleX Energy Manager for Data Centers.

Both Dell OpenManage Power Center 2.0 and JouleX Energy Manager address some of the most common critical power tasks for your data center servers. JouleX Energy Manager is a product that includes additional features, but you must pay upfront acquisition costs and incur recurring software maintenance costs for potentially less-common features that just a subset of IT departments may implement. In contrast, Dell OpenManage Power Center, when used in conjunction with iDRAC Enterprise, comes at a very compelling price point – $0.00. This translates to a great value and an immediate return on investment.

APPENDIX A – SERVER CONFIGURATION INFORMATION

Figure 6 provides configuration information for the two servers we tested.

System	Dell PowerEdge R720 (3)	HP ProLiant DL380p Gen8
Power supplies		
Total number	2	2
Vendor and model number	Dell 05NF18	HP HSTNS-PL29
Wattage of each (W)	750	750
Cooling fans		
Total number	6	6
Vendor and model number	AVC DBTC0638B2U	Delta Electronics PFR0612XHE
Dimensions (h x w) of each	2.5" x 2.5"	2.5" x 2.5"
Volts	12	12
Amps	1.2	3.3
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	Default	Default
CPU		
Vendor	Intel®	Intel
Name	Xeon®	Xeon
Model number	E5-2680	E5-2680
Stepping	C1	C1
Socket type	FCLGA2011	FCLGA2011
Core frequency (GHz)	2.70	2.70
Bus frequency (GT/s)	8 GT/s	8 GT/s
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	662530-001
BIOS name and version	Dell 2.0.19	P70
BIOS settings	Default	Default
Memory module(s)		
Total RAM in system (GB)	64 GB	64 GB
Vendor and model number	Hynix® HMT31GR7BFR4A-H9	Samsung® M393B1K70DH0-YH9
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 (3)	HP ProLiant DL380p Gen8
Chip organization	Double-sided	Double-sided
Rank	Dual	Dual
Operating system		
Name	Microsoft® Windows Server® 2012 Datacenter Edition	Microsoft Windows Server 2012 Datacenter Edition
Build number	9200	9200
File system	NTFS	NTFS
Language	English	English
Graphics		
Vendor and model number	Matrox® G200e	Matrox G200e
Driver	16 MB	16 MB
RAID controller		
Vendor and model number	Dell PERC H710p Mini	HP Smart Array P420i
Firmware version	21.1.0-0007	4.68
Driver version	6.801.5.0 (8/9/2013)	3.2.4 (8/21/2013)
Cache size	1024 MB	1024 MB
Hard drive # 1		
Vendor and model number	Hitachi® HUC151414CSS600	HP EH0146FAWJB
Number of disks in system	2	2
Size (GB)	146	146
Buffer size (MB)	64	16
RPM	15k	15k
Type	SAS	SAS
Hard drive # 2		
Vendor and model number	Intel SSDSC2BA20	Intel SSDSC2BA20
Number of disks in system	2	2
Size (GB)	200	200
Type	SSD	SSD
Ethernet adapters		
Vendor and model number	Intel Ethernet 10/1G 4P X540/I350	Broadcom NetExtreme Gigabit
Type	Onboard	Onboard
Driver	14.5.0 (9/26/2013)	16.0.0.17 (9/10/2013)
USB ports		
Number	4 external, 1 internal	4 external
Type	2.0	2.0

Figure 6: System configuration information for the test servers.

APPENDIX B – CONFIGURING POWER-LIMITING SOFTWARE

For Dell testing, we used Dell OpenManage Power Center version 2.0 to control the Dell PowerEdge R720 server. OpenManage communicated with the PowerEdge R720 through the onboard iDRAC 7 Enterprise module, running firmware version 1.46.45. We used the isolated management port for iDRAC communication.

For HP testing, we used JouleX version 4.2.0 to control the HP ProLiant DL380p Gen8. JouleX communicated with the HP ProLiant DL380p Gen8 through the onboard iLO Advanced management module, running firmware version 1.30. We used the isolated management port for iDRAC communication.

Installing Dell OpenManage Power Center

We installed OpenManage in a virtual machine on a Dell PowerEdge R710 running Server 2012 with Hyper-V. We configured the OpenManage Power Center VM with four vCPUs and 16 GB of 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 Create New Policy 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 device page to enable EPR for testing.

Installing JouleX Energy Manager for Data Centers

We installed JouleX in a virtual machine on a Dell PowerEdge R710 running Server 2012 with Hyper-V. We configured the JouleX VM with four vCPUs and 16 GB of memory. We used the default options for the JouleX installation as the installation document outlined.

Setting the power limit for JouleX

1. Click the Devices tab, and click Add.
2. Enter at least an IP address or MAC address and user credentials. For our testing, we entered the IP of the HP iLO Advanced module. Enter a name for the device in the Label field. JouleX will use this field when referring to the device.
3. Click Save Changes & Close.
4. Click the Policy tab.
5. Click Add New Rule.
6. Set a condition (e.g., the name of a device) and an action (e.g., cap power).
7. Click Save Changes.

APPENDIX C – TEST METHODOLOGY

Our test setup was symmetrical between the Dell and HP configurations. On each side, we used three Dell PowerEdge R720s (or one HP ProLiant DL380p Gen8) as our test servers. These servers ran three instances of SQL Server 2012, with two databases per instance, for a total of six databases per server under test (SUT) used in our OLTP workload. We placed the data and log files on solid-state drives to avoid any disk bottlenecking and to stress the processors.

Each SUT had its power run through a power meter (Yokogawa WT210s for all tests except for priority testing, for which we added Extech 380803s). We used generic desktop client machines running Microsoft Windows Server 2003 for our power-meter software.

Each SUT had a dedicated client machine (Dell PowerEdge R720), hosting six virtual machines used as clients for generating the OLTP workload. We used Microsoft Windows Server 2012 Datacenter Edition for all host and guest OS's for the SUTs and client machines.

We used two Microsoft Windows Server 2008 R2 VMs for our JouleX and Dell OpenManage Power Center (OMPC) management services. These were placed on a Dell PowerEdge R720 running Microsoft Windows Server 2012 Datacenter.

We had two subnets in our test setup: One for workload traffic, and one for the out-of-band power management. One onboard NIC from each SUT and client machine was dedicated to the testing network, and the dedicated iDRAC7/iLO NIC from each SUT was used in the management network. We used a Dell PowerConnect 3548 switch to handle all traffic.

Dell IP scheme	Testing network (OLTP workload)	Management network (iDRAC7)
OMPC VM	N/A	192.168.120.1
Client hosts	192.168.220.10/20/30	N/A
Client VMs	192.168.220.11..16/21..26/31..36	N/A
SUT1	192.168.220.1	192.168.120.11
SUT2	192.168.220.2	192.168.120.12
SUT3	192.168.220.3	192.168.120.13

HP IP scheme	Testing network (OLTP workload)	Management network (iDRAC7)
JouleX VM	N/A	192.168.130.1
Client hosts	192.168.230.10/20/30	N/A
Client VMs	192.168.230.11..16/21..26/31..36	N/A
SUT1	192.168.230.1	192.168.130.11

Configuring the BIOS and out-of-band management

On each SUT, we set the BIOS and iDRAC/iLO to the default settings. We then accessed the iDRAC/iLO user interfaces during boot and configured the iDRAC/iLO network settings to connect to our power management VMs.

Installing Microsoft Windows Server 2012 Datacenter Edition and SQL Server 2012

We installed Microsoft Windows Server 2012 Datacenter Edition on the SUTs, client hosts, client VMs and the power management host. Each SUT had a pair of 146GB 15k SAS drives in a RAID1 for hosting the OS. The client hosts had varying configurations of drives to allow space for virtual hard disks.

The SUTs also had two solid-state drives (SSDs) used for SQL Server 2012 data and log files. We created a virtual drive from each, so that each SUT had three virtual drives in total: VD0 (146GB spindle drives in RAID1) for the OS, VD1 (single SSD) for SQL data/logs and VD2 (single SSD) for SQL data/logs.

1. Insert the installation media into the CD/DVD drive and restart the server or VM.
2. Choose the CD/DVD drive as the boot device, and boot to the installation media.
3. Press any key when prompted to boot from DVD.
4. When the installation screen appears, click My language is English.
5. Leave language, time/currency format and input method as default, and click Next.
6. Click Install now.
7. When the Windows Setup window appears, click No thanks when prompted to go online to install updates.
8. Select Windows Server 2012 Datacenter (Server with a GUI), and click Next.
9. Check I accept the license terms, and click Next.
10. Click Custom: Install Windows only (advanced).
11. Press Alt+A to open advanced partition options. Delete any partitions until there is only Drive 0 Unallocated Space, Drive 1 Unallocated Space, and Drive 2 Unallocated Space.
12. Select Drive 0 Unallocated Space, and click Next, at which point Windows will begin installing, and will restart automatically after completing.
13. When the Settings page appears, fill in the Password and Reenter Password fields with the same password.
14. Log in with the previously set up password.

Creating new disks in Windows Server 2012 Standard Edition

1. In the Server Manager window, click Tools, then Computer Management.
2. In the left pane, click Disk Management.
3. On the first unallocated disk (VD1), right-click the disk name and click Online. Right-click the disk name again, and click Initialize Disk. When the Initialize Disk window pops up, select GPT, and click OK.
4. After the disk initializes, right-click the shaded area, and click New Simple Volume.
5. On the New Simple Volume Wizard that pops up, click Next.
6. Select a size (maximum, in our case), and click Next.
7. Assign a drive letter, and click Next.
8. Select Format this volume with the following settings, and leave the default settings. Click Next.
9. Click Finish.
10. Repeat for VD2.

Configuring Windows Update

1. In the left pane of the Server Manager window, click Local Server.
2. In the main frame, next to Windows Update, click Not configured.
3. In the Windows Update window, in the main pane, click Let me choose my settings.

4. Under Important updates, select Never check for updates (not recommended), and then click OK.
5. In the left pane, click Check for updates, and install all available updates.
6. Close the Windows Update window.
7. Repeat these steps to install all available updates.

Configuring Windows Firewall

1. In Server Manager, click Tools→Windows Firewall with Advanced Security.
2. In the Overview section, click Windows Firewall Properties.
3. In the Domain Profile tab, for Firewall state, click Off.
4. In the Private Profile tab, for Firewall state, click Off.
5. In the Public Profile tab, for Firewall state, click Off.
6. Then click OK.
7. Close the Windows Firewall Properties window.

Setting up Remote Desktop

1. In the Local Server tab of the Server Manager window, next to Remote Desktop, click Disabled.
2. In the System Properties window that appears, in the Remote Desktop section, select the Allow remote connections to this computer radio button, and click OK when the warning message appears.
3. Uncheck Allow connections only from computers running Remote Desktop with Network Level Authentication (recommended), and click OK.

Disabling IE Enhanced Security Configuration

1. In the Local Server tab of the Server Manager window, next to IE Enhanced Security Configuration, click On.
2. In the Internet Explorer Enhanced Security Configuration window, select the Off radio buttons for both Administrators and Users, and click OK.

Installing SQL Server 2012

We installed Microsoft SQL Server 2012 on each SUT. We repeated the installation three times in order to install three instances. We named them INSTANCE1, INSTANCE2, INSTANCE3.

1. Insert the installation DVD for SQL Server 2012 into the DVD drive.
2. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2012 DVD, and double-click it.
3. If the installer prompts you with a .NET installation prompt, click Yes to enable the .NET Framework Core role.
4. In the left pane, click Installation.
5. Click New SQL Server stand-alone installation or add features to an existing installation.
6. At the Setup Support Rules screen, wait for the rule check to complete. If there are no failures or relevant warnings, click OK.
7. Enter your product key, and click Next.
8. Click the checkbox to accept the license terms, and click Next.
9. If no failures are displayed after the setup support files are installed, click Next.
10. At the Setup Role screen, choose SQL Server Feature Installation.
11. At the Feature Selection screen, select the features that your organization requires. We chose the following features: Database Engine Services, Full-Text and Semantic Extractions for Search, Client Tools Connectivity,

Client Tools Backwards Compatibility, Management Tools – Basic, and Management Tools – Complete. Click Next.

12. At the Installation Rules screen, click Next after the check completes.
13. At the Instance configuration screen, enter a name for the instance (INSTANCE1) and leave the default directories.
14. At the Disk Space Requirements screen, click Next.
15. At the Server Configuration screen, leave the default users and click Next.
16. At the Database Engine Configuration screen, choose Mixed Mode and enter the system administrator password. Click Add Current User.
17. Click the Data Directories tab, leave the default locations, and click Next. We will later manually place the OLTP database and log files on the SSDs.
18. Click Next.
19. At the Error reporting screen, click Next.
20. At the Installation Configuration Rules screen, check that there are no failures or relevant warnings, and click Next.
21. At the Ready to Install screen, click Install.
22. After installation completes, click Close.
23. Close the installation window.
24. Restart the server.
25. Repeat these steps for INSTANCE2 and INSTANCE3.

Configuring the Dell PowerEdge R710 client machines

We used a Dell PowerEdge R710 for each SUT to host client VMs used in our OLTP testing. We installed Microsoft Windows Server 2012 Datacenter (according to the methodology above) on the host and enabled the Hyper-V role.

Creating a virtual switch

1. Open Server Manager, and click Tools→Hyper-V Manager.
2. In the right pane, click Virtual Switch Manager.
3. Leave External highlighted under type of virtual switch, and click Create Virtual Switch.
4. Enter a name, in our case VMSwitch, and select the NIC connected to the test network from the drop-down menu. Check the Allow management operating system to share this network adapter, and click Apply.
5. When the warning pops up, click Yes.
6. Click OK.

Creating a virtual machine

1. In Hyper-V Manager, click New and select Virtual Machine.
2. Enter a name for the VM and click Next.
3. Enter 4096 for the Startup Memory. Click Next.
4. On the Configure Networking screen, select VMSwitch to use the virtual switch and click Next.
5. On the Connect Virtual Hard Disk screen, select the radio button for Create a virtual hard disk. Enter a name for the VHD and a size of 40 GB. Click Finish.

6. After the VM is created, right-click the VM and click Settings.
7. Click Processor, and increase Number of virtual processors to 2.
8. Click OK.
9. Install Microsoft Windows Server 2012 Datacenter onto the VM using the methodology given above.
10. Repeat this process five more times to create six client VMs.
11. Repeat these steps on each Dell PowerEdge R710 client host.

Configuring the OLTP workload

We used the DVD Store Version 2 (DS2) benchmark to simulate our OLTP workload. DS2 is an open-source application that models an online DVD Store where customers long in, browse movies, and purchase movies. DS2 reports its results in order per minute that the server can handle. For more details about the DS2 tool, see http://www.delltechcenter.com/page/DVD+Store.

We ran DS2 with a 10GB database, using 64 threads and 0 think time per client. We set a warm-up time of 5 minutes to cache the database in memory, and then ran the test for 20 minutes while collecting data.

Data generation overview

We generated the data using the Install.pl script included with DVD Store version 2.1 (DS2), providing the parameters for our 10GB 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 2012. We built the 10GB database in SQL Server 2012, and then performed a full backup, storing the backup file on the C: drive for quick access. We used that backup file to restore to the servers between test runs. We performed the data generation procedure once.

The only modification we made to the schema creation scripts were the specified file sizes for our database. We explicitly 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 10GB 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.

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.

When restoring the database to the SUTs, we restored twice to each instance, for a total six databases per SUT. We arranged each pair of databases to swap data and log directories between drives, as follows:

- INSTANCE1
  - o DS2_1-1: Data on E: and Logs on F:
  - o DS2_1-2: Logs on E: and Data on F:
- INSTANCE2
  - o DS2_2-1: Data on E: and Logs on F:
  - o DS2_2-2: Logs on E: and Data on F:
- INSTANCE3
  - o DS2_3-1: Data on E: and Logs on F:
  - o DS2_3-2: Logs on E: and Data on F:

Running the DVD Store tests

We created a series of batch files, SQL scripts, and shell scripts to automate the complete test cycle. Each complete test cycle consisted of the general steps listed below. For the 80 percent CPU test scenarios, we ran the workload on INSTANCE1 and INSTANCE2 only. For the 100 percent CPU test scenarios, we ran the workload on all three instances.

1. Clean up prior outputs from the server and all client driver systems.
2. Drop all databases from the test servers.
3. Restore all databases on all test servers.
4. Reboot the server and all client systems.
5. Let the test server idle until the power utilization settled.
6. Start the DVD Store driver on all respective clients.

7. We used the following DVD Store parameters for testing the servers in this study:

```
ds2sqlserverdriver.exe --target=<target_IP> --ramp_rate=10 -warmup_time=5 --
run_time=20 --n_threads=64 --db_size=10GB --think_time0 --detailed_view=Y --
database_name=DS2
```

APPENDIX D – MEASURING POWER

Measuring workload power

To record each server's power consumption during the workload test, we used either a Yokogawa WT210 or an Extech Instruments® (www.extech.com) 380803 Power Analyzer/Datalogger. We connected the power cord from the server under test to the power-meter's output load power outlet. We then plugged the power cord from the power-meter's input voltage connection into a 120-volt power outlet.

We used WTViewer 8.11 or 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-meter via an RS-232 cable. We captured power consumption at one-second intervals.

ABOUT PRINCIPLED TECHNOLOGIES

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We provide industry-leading technology assessment and fact-based marketing services. We bring to every assignment extensive experience with and expertise in all aspects of technology testing and analysis, from researching new technologies, to developing new methodologies, to testing with existing and new tools.

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