

## LENOVO® THINKSERVER® SMART GRID TECHNOLOGY



When it comes to your data center, new energy-efficient servers and advanced server management technologies can dramatically reduce operational expenses, including the cost of power to run and cool your servers. We tested Lenovo ThinkServer Smart Grid Technology, based on Intel® Node Manager, on a Lenovo ThinkServer RD630 server, with the goal of understanding how it handles power management and affects performance and power usage in the data center.

We found that Lenovo ThinkServer Smart Grid Technology, available for Lenovo rack servers with Intel Node Manager, enables you to plan, observe, and manage your server infrastructure to increase server density, ensure server uptime, reduce power and cooling needs, and reduce operational expenses.

Lenovo ThinkServer Smart Grid Technology provides a wide range of power-management capabilities that can easily enable these benefits, as our testing demonstrated. In our processor-intensive tests, we saw that we could add power capping to force the server into a more power-efficient state. In our I/O-intensive tests, we were able to cut power by 20 percent and still maintain the same overall performance.

Furthermore, additional features of ThinkServer Smart Grid allowed us to view processor and memory utilization, offered multiple reports for recent activity that we could export to Microsoft® Excel® for offline viewing, and gave us an emergency power option that we could quickly initiate to scale power utilization down drastically and keep servers operational longer in the event of a critical power situation.



## HOW POWER CAPPING CAN HELP YOU

New server management technologies, coupled with new servers with power-saving technologies, can save businesses money through power capping, the ability to set maximum levels of power usage for particular servers or groups of servers at particular times. In processor-intensive workloads, you can use less power and yield greater performance per watt by forcing the CPU into a more power-efficient state. In I/O-intensive workloads, where you have unused processor cycles, you can increase server rack density, recouping unused power capacity without significantly affecting overall performance. When you can know that a given server will not exceed a certain level of power usage, you can allocate the total amount of power you have available to your data center without worrying about overloading your circuits during times of heavy server load. These power management technologies can offer new levels of flexibility in how you allocate power amongst servers and how you lay out your data center. This can increase server density, reduce power and cooling needs, ensure server uptime, and reduce TCO.

## THE LENOVO APPROACH TO POWER MANAGEMENT

Lenovo ThinkServer Smart Grid Technology lets the latest servers, including the Lenovo ThinkServer RD630, offer customers a new view into data center power usage. ThinkServer Smart Grid Technology is a power management application that uses industry-standard protocols to read power usage information from Lenovo ThinkServer servers and then distribute power limits to them, all through a single easy-to-use interface.

To learn more about Lenovo ThinkServer Smart Grid Technology, visit [http://support.lenovo.com/en\\_US/downloads/detail.page?DocID=DS029844](http://support.lenovo.com/en_US/downloads/detail.page?DocID=DS029844).

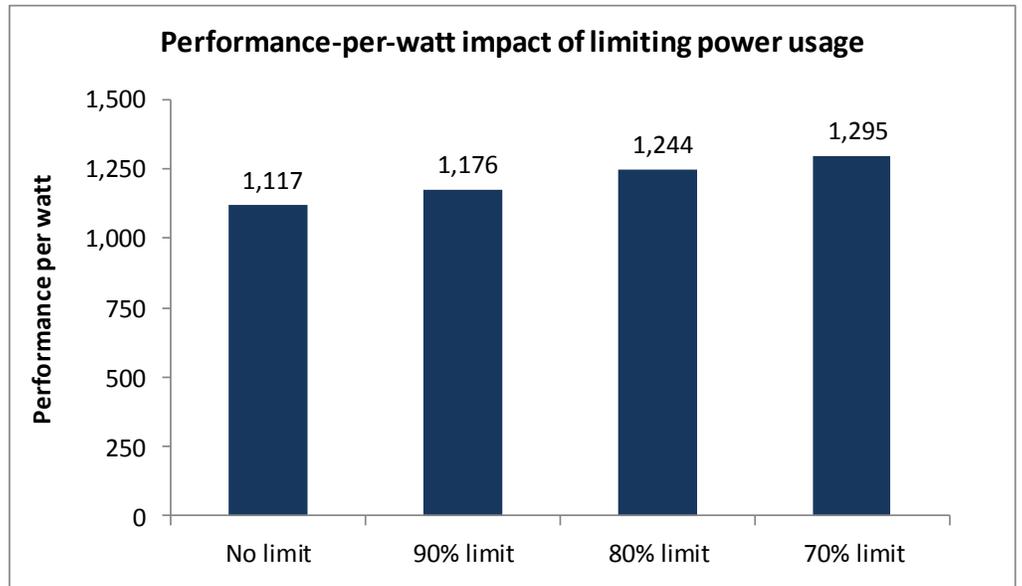
## POWER CAPPING IN ACTION

To evaluate the capabilities and advantages of power capping with Lenovo ThinkServer Smart Grid Technology managing a Lenovo ThinkServer RD630 server, we first ran a heavy OLTP database workload using nearly 100 percent processor utilization on the server. We used STEC Mach16 MLC SSD drives to maximize storage subsystem IOPS and prevent an I/O bottleneck. We capped the power at 90%, 80% and 70% of the peak power and recorded the performance per watt at each level in order to see where we achieved the best power/performance ratio.

As Figure 1 and Figure 2 show, Smart Grid enabled us to lower the power available to the server, which lowered the overall database performance. That said, performance per watt increased as we lowered the power, as the processor moved into a more power-efficient state. This increased efficiency has far-reaching ramifications for reducing power and cooling issues in the data center. One practical application of this

capability would be a nighttime database reporting job where time-to-finish is not a major concern. You could cut power and force the system to operate at a higher efficiency as you are not worried that the job will take slightly longer to complete.

Figure 1: Setting power limits increased performance per watt on the Lenovo ThinkServer RD630.



To test this scenario, we used DVD Store 2.1, which reports performance in orders per minute (OPM), running four Microsoft SQL Server 2008 R2 instances with one 10GB databases in each instance. To find the maximum performance per watt, we ran each system as close to 100 percent processor utilization as possible. Figure 2 shows the results from our test.

Lenovo ThinkServer RD630	Total OPM	CPU %	Power set point (W)	Power utilization (W)		Perf/watt
				Peak	No activity	
No power limit	451,335	92.3	No limit	404	129	1,117
90% power limit	414,864	92.4	364	353	129	1,176
80% power limit	391,279	93.8	323	315	130	1,244
70% power limit	356,968	94.0	283	276	126	1,295

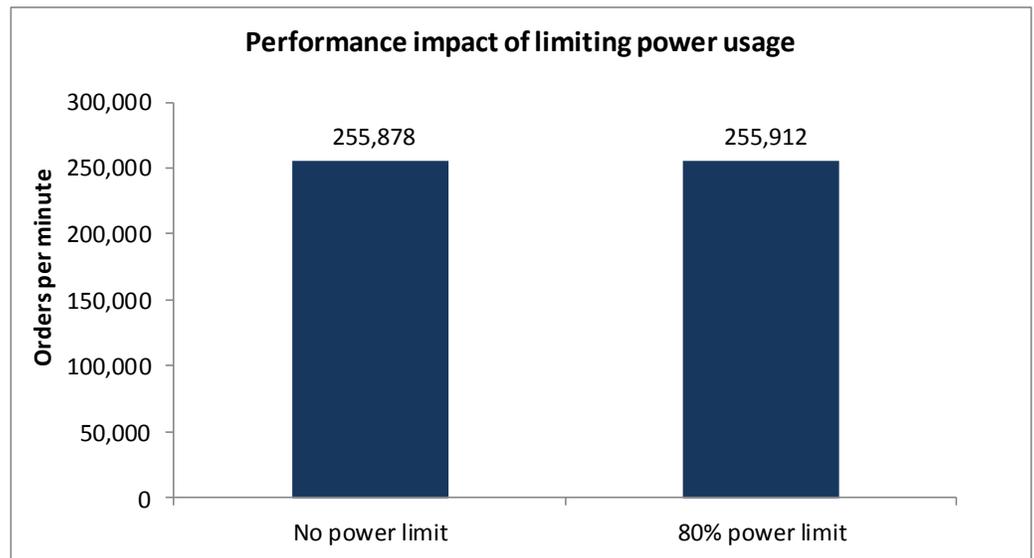
Figure 2: Database workload results with high processor utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

In addition to showing the capabilities of power capping and evaluating the improvements in server efficiency, we also looked at the performance impact of applying a power limit on a real-world database workload with heavy I/O (where the limiting feature in the system is I/O and not processor). The point of this testing is to show that if you are running an I/O-intensive workload, where the processor is not capable of reaching its maximum level due to bottlenecks elsewhere in the system, there is unused power capacity available. This power capacity is the difference between

what your server could use and what your server is actually using. Smart Grid allows you recover that unused power capacity by capping the maximum server power allotment.

As Figure 3 shows, when we reduced available server power by 20 percent, there was no reduction in performance as the additional processor performance is not required in this I/O-heavy workload. Because most servers do not run at 100 percent processor utilization, you can apply a similar power cap and match real power allocation to real power needs, saving power, data center circuit capacity, and money. In a real-world scenario, this would allow you to increase server rack density, and even recoup the unused power capacity.

Figure 3: Setting an 80 percent power limit on the Lenovo ThinkServer RD630 did not change performance.



To test this scenario, we used the same database workload as the efficiency test above but adjusted the configuration to simulate an I/O-intensive load and maintain 65 percent processor utilization. We used a power cap of 323 watts, a number higher than the amount of power required for the server under test when delivering 255,000 OPM. As long as the power cap was above the amount the server required, the server maintained the same performance. This shows that we were able to regain some of our allotted power capacity for the server, which we could then use for other purposes.

Figure 4 shows the results from our testing.

Lenovo ThinkServer RD630	Total OPM	CPU %	Power set point (W)	Power utilization (W)		Perf/watt
				Peak	No activity	
I/O-intensive workload with no power limit	255,878	65.5	No limit	302	126	847
I/O-intensive workload with 65% power limit	255,912	66.4	323	300	127	853

Figure 4: Database workload results in an I/O intensive workload. Higher OPM and performance/watt are better. Lower power utilization is better.

# KEY FEATURES OF LENOVO THINKSERVER SMART GRID

Lenovo ThinkServer Smart Grid Technology offers several other key features to manage power polices, extend operational time in the event of a power outage, implement server priorities, monitor server performance and provide alerts during a critical event. We explain these features in the section below.

## Defining power caps with management policy

Lenovo ThinkServer Smart Grid Technology offers power capping through management policies. Power usage can be set in one-hour increments and by days of the week. Figure 5 shows a 283-watt power policy we used for testing. This policy caps power at 283 watts 24 hours a day seven days a week.

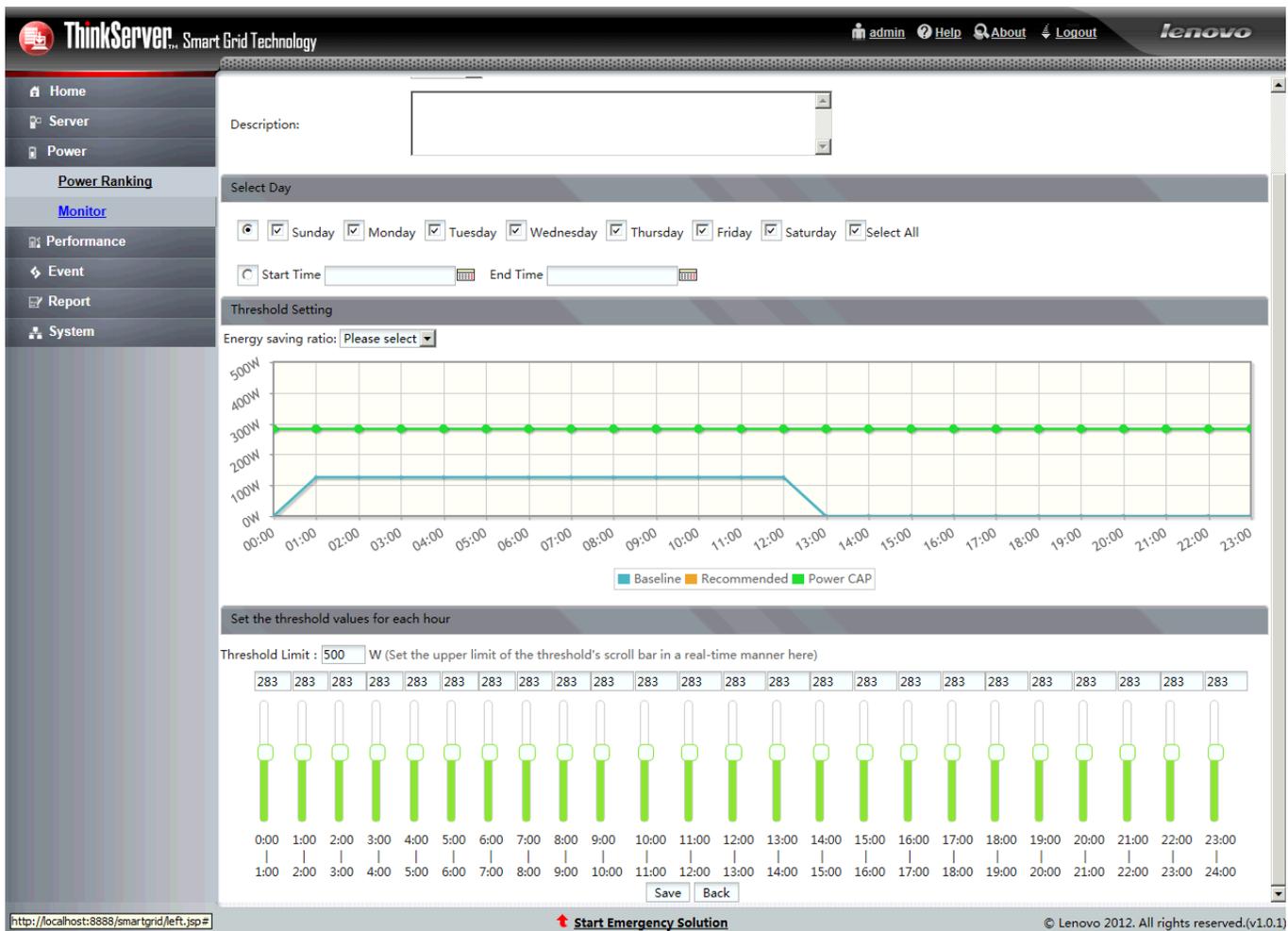


Figure 5: The Lenovo ThinkServer Smart Grid Technology 283 watt power policy.

When you add a server to ThinkServer Smart Grid Technology management console it is placed into a learning stage, which is set to one week by default, but can be set to any amount of time. At the end of the learning stage, a default policy is created

that reflects actual power consumption. Applying this default policy restricts power for best savings without affecting performance.

In addition to the default policies, you can add a customized, database, or Web server policy. The customized policy allows you to specify the power cap, the time of day and days of the week you would like to restrict power.

The database and Web server policies can adjust power based on the response time for server request. To configure these policies, you enter your database or Web server information and give a response time in milliseconds that you want the server to maintain. Smart Grid adjusts power based on that response time. When the response time is less than the value you set in the policy then it will adjust the power downwards. The power will increase if the response time goes up and needs more performance.

### **Maintaining business continuity - Reliability during power outage**

One capability a data center server must offer is maximum availability. Lenovo ThinkServer Smart Grid Technology helps by offering a feature called Emergency Solution, which reduces server power draw on a group of servers in the event of an emergency such as drop in data center power or cooling capacity. Although the server is not performing at peak output, you get the benefits of protecting critical workloads or extending the server uptime when running on a UPS source or putting less demand on a backup generator. All this and your end-users can keep working.

The administrator can initiate Emergency Solution by simply clicking a button in the management console. Figure 6 shows the Emergency Solution option and how to enable it. At the bottom of the ThinkServer Smart Grid Technology management screen is a Start Emergency Solution link. Clicking this link opens the Emergency window, where you can select the group on which you want to enable the Emergency Solution. To disable the Emergency Solution, you follow the same procedures, but uncheck the group to disable it.

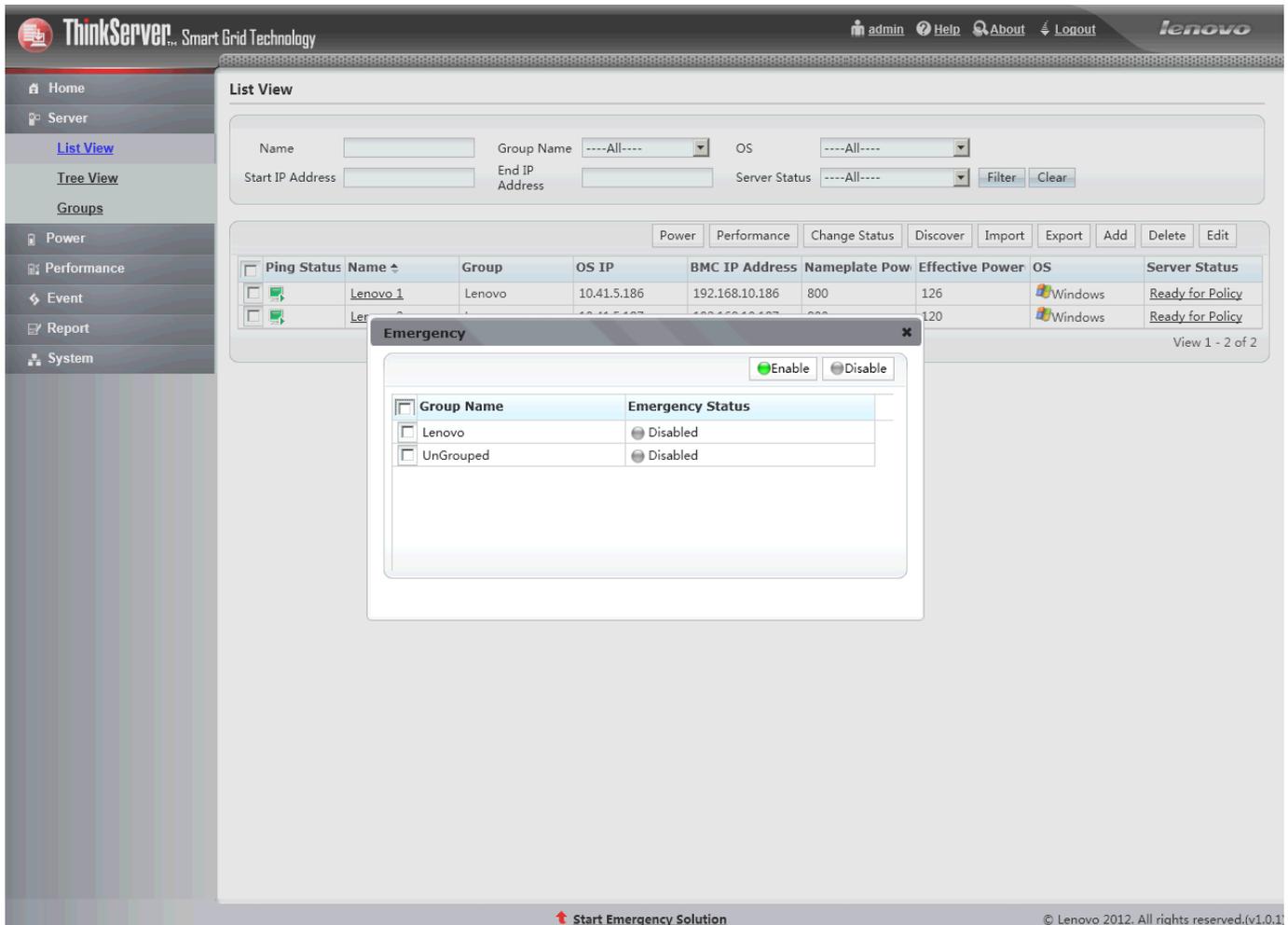


Figure 6: The Lenovo ThinkServer Smart Grid Technology Emergency Solution option.

## Protecting critical workloads - Implementing server priority

Another important feature offered by ThinkServer Smart Grid Technology is server prioritization, which gives administrators the ability to intelligently and automatically parcel out more of the available power to the most important servers in a group first, and then to give less power to other servers. When applying a dynamic cap, you can specify a priority of high, medium, or low for each server or group based on its performance and power needs.

To test this feature, we used a heavy database workload to apply a constant nearly 100 percent processor load on two servers in a group. The two Lenovo ThinkServer RD630 servers consumed approximately 550 watts. We set a dynamic cap of 450 watts to the group and gave each server a different priority—one high and one low.

As Figure 7 shows, with the cap applied, both servers used less power, and utilization varied according to their priority. Power dropped precipitously when the cap was applied. We then stopped the workload on the high-priority server. The power

dropped on the high-priority server while the low-priority server stayed constant. We then started the workload again on the high-priority server and the power came back up as before. This illustrates the ability to implement a total power cap for the group, saving power on lower-priority servers, and dynamically maintaining availability for higher-priority servers.

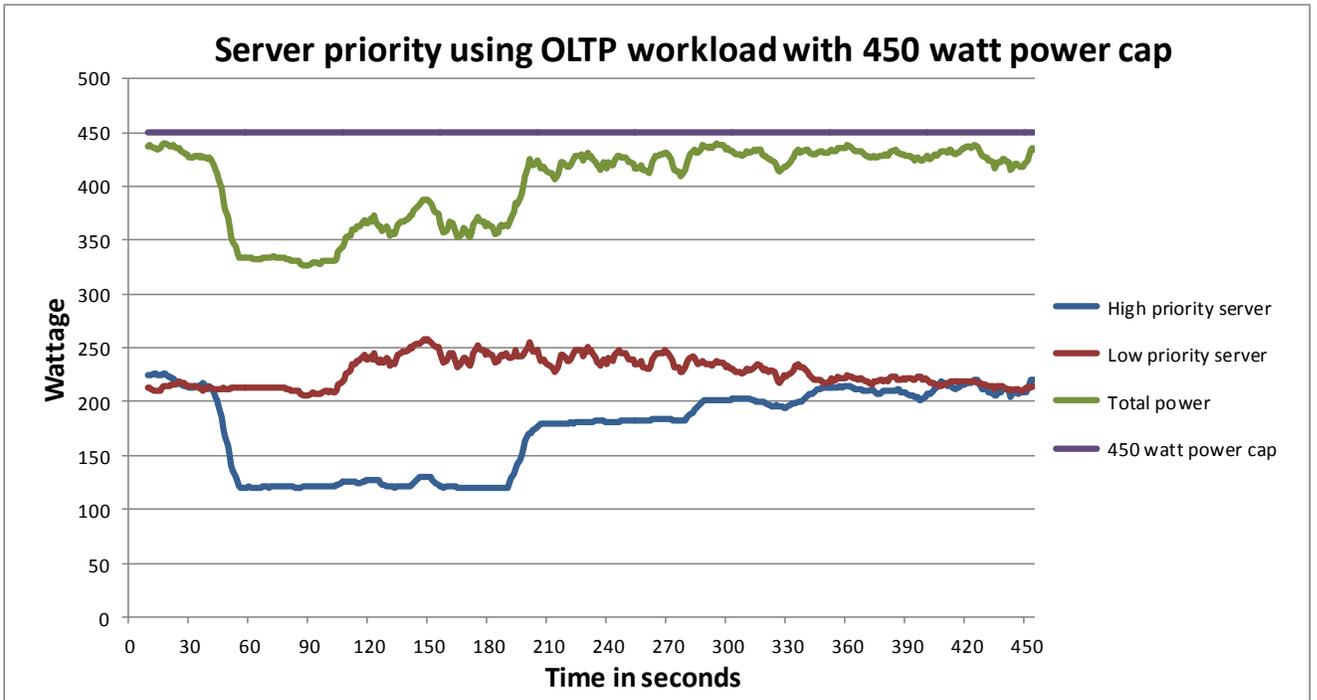


Figure 7: Power utilization using a dynamic power cap with high-and low-priority settings on two identical Lenovo ThinkServer RD630 servers.

### Monitoring processor and memory utilization

Administrators must always keep an eye on the performance of the various servers in their data centers. A server in high demand can show high processor or memory utilization. It is important that high-demand servers stay online and available for all users. ThinkServer Smart Grid Technology offers a feature to monitor CPU and memory utilization from the main console.

Figure 8 shows the CPU and memory monitor console. This feature gives administrators more information to help understand when the servers are under the greatest load and when they are relatively idle. This shows the administrator where they can cut power without affecting performance and hindering user load. For example, a server using less processor and memory during off hours could have a power cap applied and still keep up with user demand.

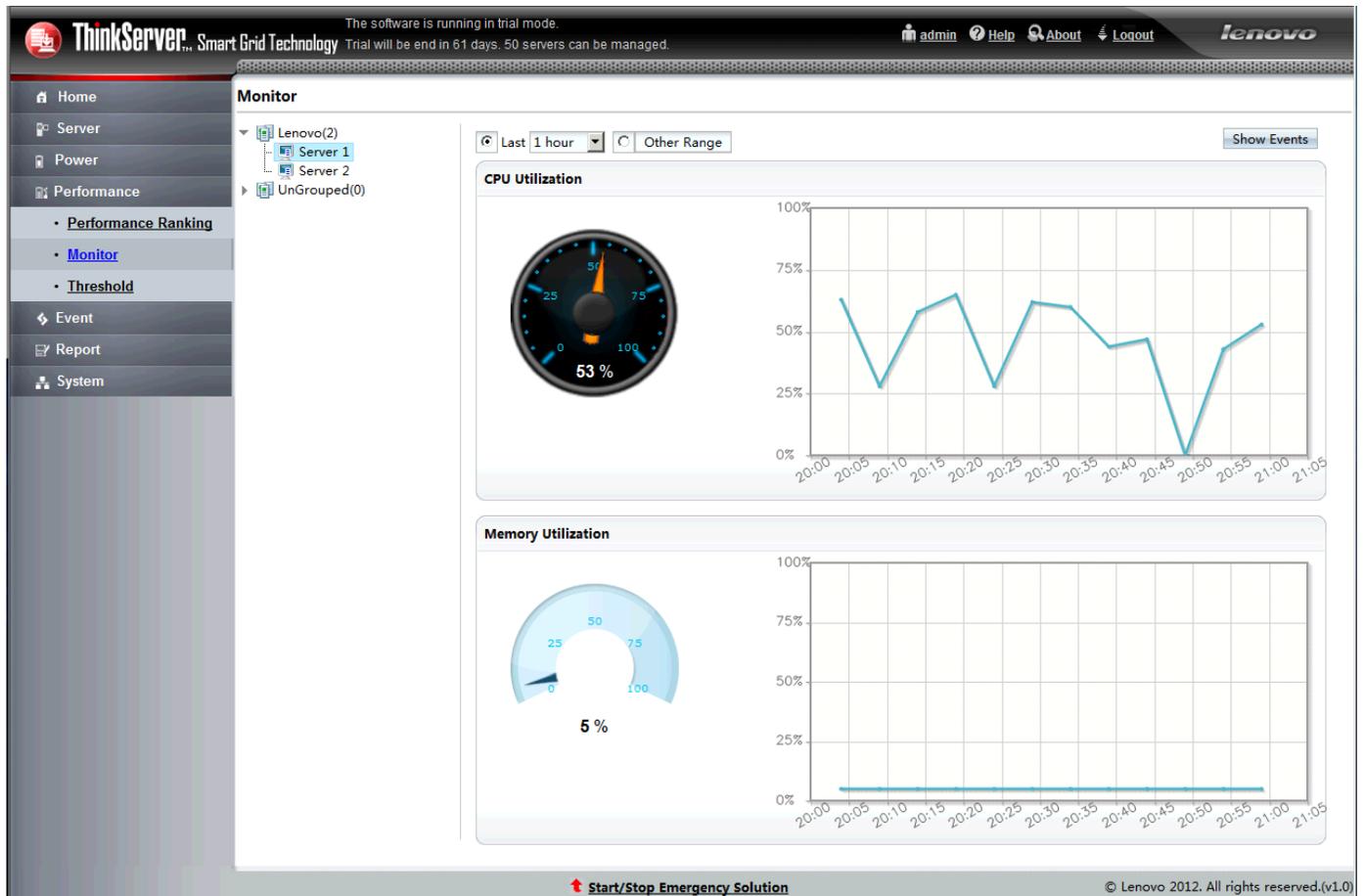


Figure 8: The Lenovo ThinkServer Smart Grid Technology Monitor console.

## Email alerts

Administrators must stay informed of what is going on in the data center. ThinkServer Smart Grid Technology offers the option of sending email alerts to a list when things go wrong. ThinkServer Smart Grid Technology offers alerts of the following event types:

- DCM - shows an internal error in the application
- Threshold - gives warning events due to a set threshold being reached.
- Probe - shows cannot connect to node manager
- Optimization - shows that a server violated a power policy

The events show one of the following severities: information, warning, or error. Figure 9 shows the Mail Alerts console, which gives the administrator one more way to stay informed about what is happening in the data center.

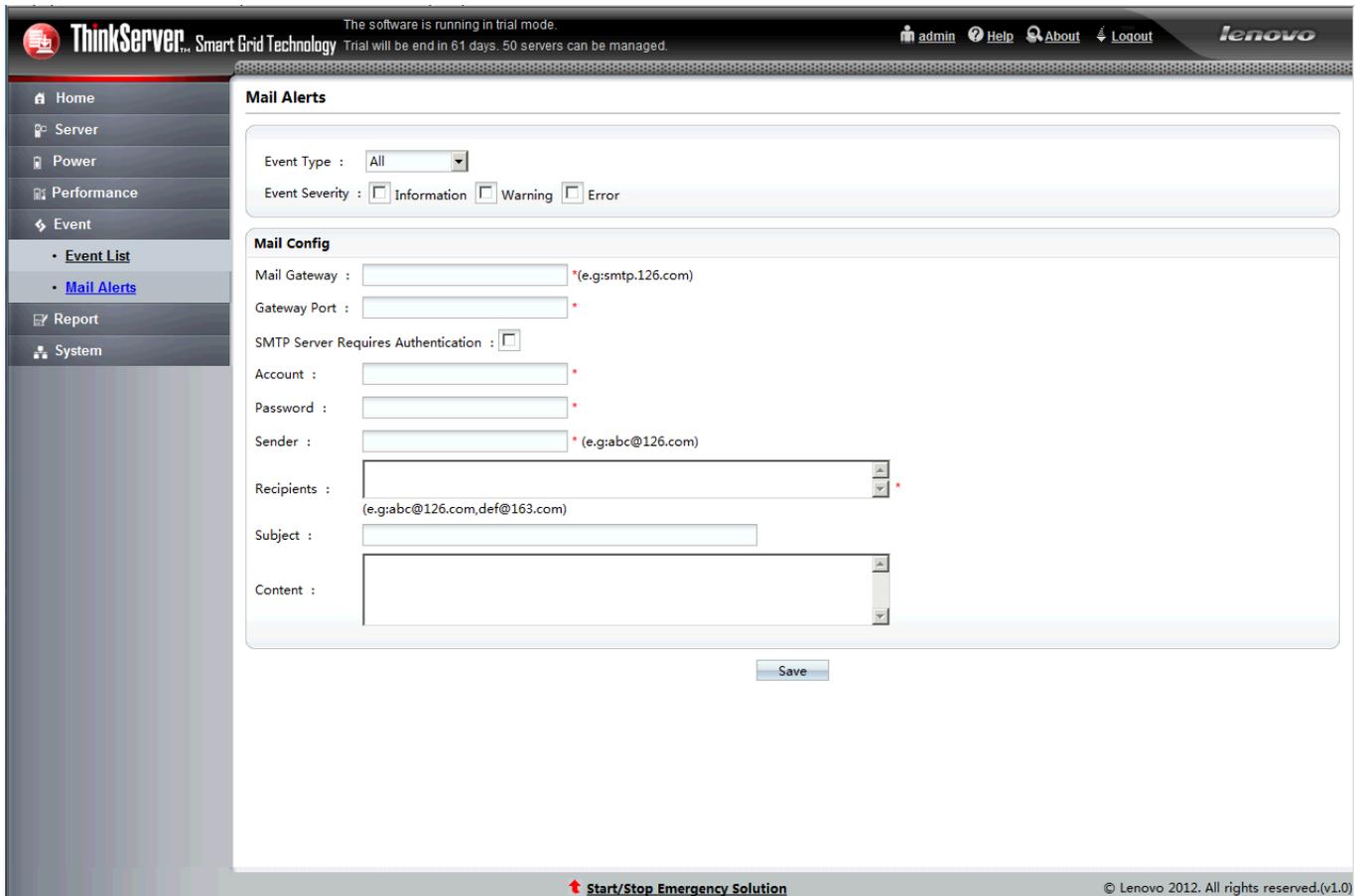


Figure 9: The Lenovo ThinkServer Smart Grid Technology Mail Alerts console.

## Data center reports

Administrators need a way of looking at logs and reports to monitor systems in the data center. ThinkServer Smart Grid Technology offers the following report options:

- Power Trends of Day
- Power Trends of Period
- Server's Consumption
- Group's Consumption
- All Consumption
- Policy Running Status

Figure 10 shows the management screen with the different type of available reports. All of the report options give data with charts and the ability to export the data to an .xls file. This gives the administrators flexibility to view these reports within the console or export them to Excel for offline evaluation.

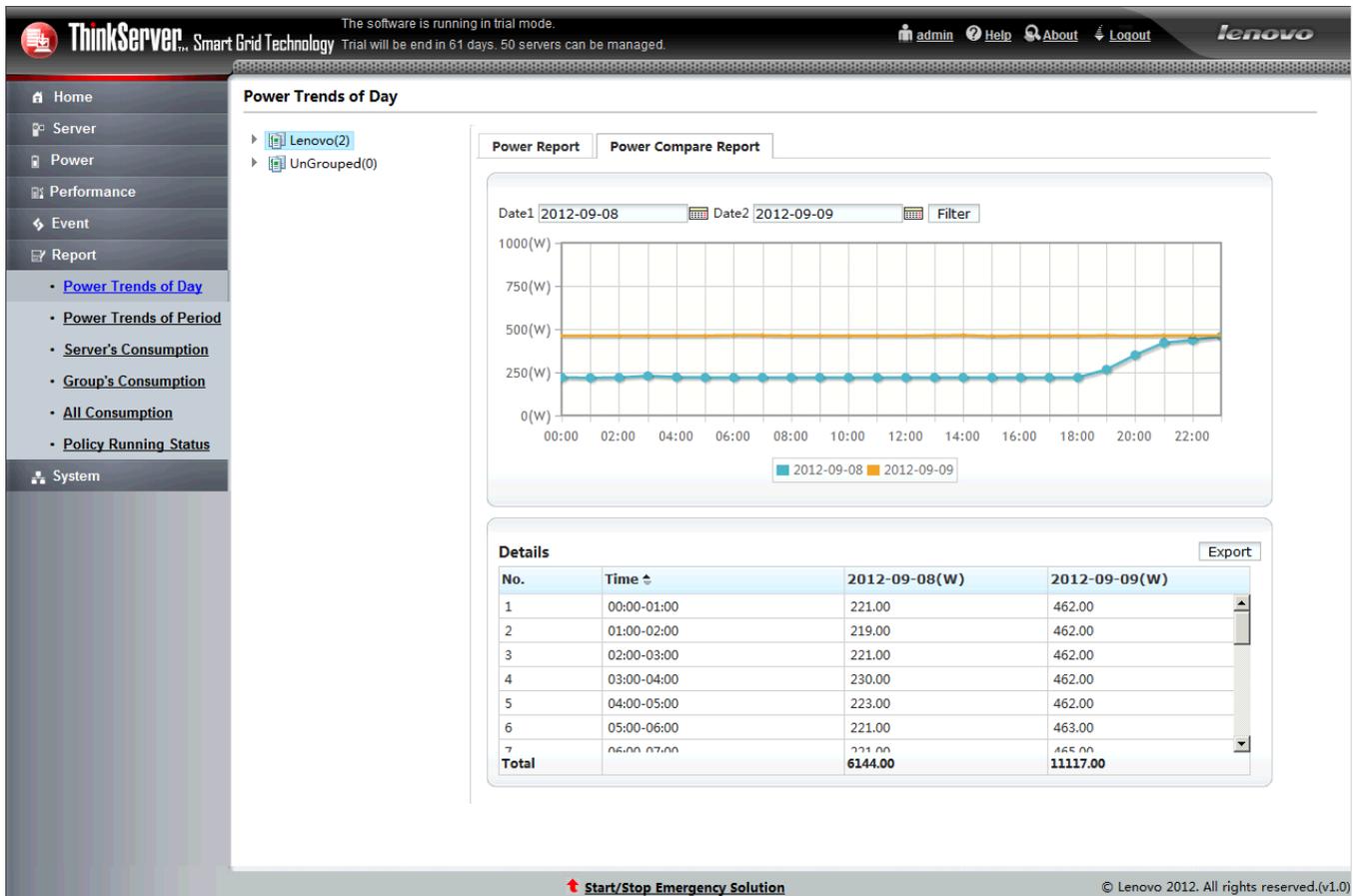


Figure 10: The Lenovo ThinkServer Smart Grid Technology Power Trends of the Day screen.

## TOTAL COST OF OWNERSHIP

A major part of the data center budget goes to power and cooling server and other equipment. Using ThinkServer Smart Grid Technology and Lenovo rack servers, capping capabilities can help reduce these expenses by implementing power capping to reduce server power and cooling needs.

As we showed in Figures 1 and 2 of this report, when running a processor-intensive OLTP workload, using power capping to lower power increases server efficiency. Increasing server efficiency has a direct effect on energy costs. Figure 11 summarizes the performance-per-watt results of a 70 percent power cap and the associated energy costs.

Lenovo ThinkServer RD630	Power utilization (W)	Power efficiency (Perf/watt)	KWh	Energy cost per year (at \$.1017 per KWh)
No power limit	404	1,117	3,541.46	\$360.17
70% power limit	276	1,295	2,419.42	\$246.05
Savings	128	178	1,122.05	\$114.11
Percentage savings	32%	16%	32%	32%

Figure 11: Database workload results with high processor utilization. Higher OPM and performance/watt are better. Lower power utilization and energy cost are better.

Using a 70 percent power cap increased performance per watt by 16 percent and delivered the same total OPM with 32 percent fewer watts. Using current power rates where 100W of power costs roughly \$90 a year, we see a 32 percent savings in energy costs when comparing the 70 percent power cap to no power cap. That translates to energy cost savings of \$114.11 over a one-year period.

This type of savings cascades into savings throughout the power and cooling infrastructure as well. A typical power infrastructure includes UPSs, PDUs, rack distribution units, backup generators, and other equipment to distribute power and provide emergency backup. The cooling infrastructure includes CRACs and CRAHs, chillers, humidifiers, rack cooling, and other equipment to dissipate the heat servers and other equipment generate. All of these require power and proper infrastructure sizing to operate.

While all power is recorded in watts, when sizing the individual power circuits, the capacity is expressed in Amps while cooling capacity is frequently sized in BTU/hr.

- **Amps (A).** The formula relating watts and amps is watts = amps \* volts, or  $W=A*V$ .
- **BTUs per hour.** Estimate BTUs/hour by multiplying watts by 3.41.

### Practical example – circuit sizing

Lenovo ThinkServer RD630	Amps at 208 Volts	Number servers supported by a 30A circuit
No power limit	2.04	14.72
70% power limit	1.46	20.53
Savings	0.58	5.81
Percentage savings	28%	39%

Figure 12: Circuit sizing example.

As Figure 12 shows, using a 70 percent power cap allows a 28 percent savings in amps. This allows for a 39 percent increase in server capacity, or a full five extra servers on a 30A 208V circuit. Extending these savings into other infrastructure components results in a much more efficient infrastructure for additional savings throughout the data center budget.

Another expense that increases the capital budget is the server racks themselves. Server racks require power supplies, switches, and even rack-based cooling. Some estimates set data center space costs at \$500 or more per square foot. A typical

server rack can require 14 or more square feet, including surrounding clearances, which puts space costs alone at \$7,000 or higher per rack.

Using Lenovo ThinkServer Smart Grid Technology to implement power capping can allow for many infrastructure savings. These savings include the following:

- A lower up front cost, or capital expenditure (CAPEX)
- Savings on expansion capacity if your data center is at or nearing maximum capacity due to getting more servers into your same space
- Energy saving costs. Typically, each watt of server power typically requires another watt or more to power the cooling and power infrastructure.
- Requiring fewer server racks and rack-based components as well as less required datacenter square footage.

## **Trim underutilized infrastructure by sizing with power caps and save on CAPEX and OPEX**

Over-configured power components hurt your CAPEX budget. Some traditional methods suggest sizing based off the server nameplate power. These methods can lead to improperly sized power capacity that goes unused, increasing both upfront and operational cost.

Using our test servers as an example, the Lenovo ThinkServer RD630 server has a nameplate power of 800 watts. However, our 100 percent workload testing with no power cap used an average of 404 watts. In this instance, using the nameplate estimate would create an infrastructure almost double the capacity you need to run our tested workload without a power cap. With an underutilized infrastructure, you pay more for underutilized circuits, cooling and equipment. Because the Lenovo ThinkServer Smart Grid Technology holds maximum power consumption near any applied power cap, we can use the power cap rather than the much higher nameplate power to size the infrastructure and save on cost.

## **Balance power during power events**

It is important to consider how your data center can respond to an unplanned power or thermal event. Using a power management program like Lenovo ThinkServer Smart Grid Technology allows emergency power features. These features allow the data center administrator to implement an emergency power cap that keeps the servers up and operating—at a lower performance level—while requiring less power to do so. This can reduce end-user downtime and lead to significant operational savings.

## CONCLUSION

Using Lenovo ThinkServer Smart Grid Technology with Intel Node Manager Technology allows you to plan, observe, and manage your power utilization on Lenovo servers. In processor-intensive workloads, you can lower power and achieve increased performance per watt for maximum efficiency. In IO-intensive workloads, where unused processor utilization exists, you can increase server density per rack (per unit power) and recoup unused power without significantly affecting overall performance. These and the other features of Lenovo ThinkServer Smart Grid Technology offer new flexible and powerful ways for administrators to manage data center power usage and control costs.

## APPENDIX A – SERVER CONFIGURATION INFORMATION

Figure 13 provides configuration information for the server we tested.

System	Lenovo ThinkServer RD630
<b>Power supplies</b>	
Total number	2
Vendor and model number	Delta DPS-800RB A
Wattage of each (W)	800
<b>Cooling fans</b>	
Total number	6
Vendor and model number	AVC 2B06038B12G
Dimensions (h x w) of each	2.5" X 2.5 "
Volts	12
Amps	2.20
<b>General</b>	
Number of processor packages	2
Number of cores per processor	8
Number of hardware threads per core	2
System power management policy	Balanced
<b>CPU</b>	
Vendor	Intel
Name	Xeon®
Model number	E5-2680
Stepping	C1
Socket type	LGA2011
Core frequency (GHz)	2.70
Bus frequency (GT/s)	8.0
L1 cache	32 KB + 32 KB (per core)
L2 cache	256 KB (per core)
L3 cache	20
<b>Platform</b>	
Vendor and model number	Lenovo ThinkServer RD630
Motherboard model number	PBT-SX52600
BIOS name and version	Lenovo 1.00 5/9/2012
BIOS settings	Default
<b>Memory module(s)</b>	
Total RAM in system (GB)	64
Vendor and model number	Samsung M393B1K70DH0-CH9
Type	PC3-10600R
Speed (MHz)	1,333
Speed running in the system (MHz)	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-24
Size (GB)	8
Number of RAM modules	8
Chip organization	Dual sided

<b>System</b>	<b>Lenovo ThinkServer RD630</b>
Rank	Dual
<b>Operating system</b>	
Name	Microsoft Windows Server® 2008 R2
Build number	7601
File system	NTFS
Language	English
<b>RAID controller</b>	
Vendor and model number	LSI® MegaRAID™ SAS 9260-8i
Driver version	LSI 4.5.0.64
Cache size	512 MB
<b>Hard drive # 1</b>	
Vendor and model number	Lenovo 67Y2621
Number of disks in system	2
Size (GB)	600
Buffer size (MB)	32
RPM	10,000
Type	SAS
<b>Hard drive # 2</b>	
Vendor and model number	STEC M16ISD2-200UCP
Number of disks in system	3
Size (GB)	200
Buffer size (MB)	N/A
RPM	N/A
Type	SATA SSD
<b>Ethernet adapters</b>	
Vendor and model number	Intel I350 Gigabit Network Adapter
Type	Integrated
Driver	Intel 11.14.43.0
<b>Optical drive(s)</b>	
Vendor and model number	DS8D4SH
Type	DVD-ROM
<b>USB ports</b>	
Number	6
Type	USB 2.0

Figure 13: Detailed configuration information for the server we tested.

## APPENDIX B – DATABASE WORKLOAD

We used a Lenovo ThinkServer RD630 as the system under test. We configured it with two 600GB SAS drives in a RAID 1 for the Windows Server 2008 R2 operating system and installed three SSD drives for all database traffic.

The steps below show how we configured the two Lenovo ThinkServer RD630 server for testing.

### Installing Windows Server 2008 R2 Enterprise Edition

We installed a fresh copy of Windows Server 2008 R2 Enterprise Edition on both servers. We used the same network setup steps and ran Windows updates on both.

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 2012

We used the following steps to install four instances of SQL Server 2012 on the Lenovo ThinkServer RD630.

1. Insert the installation DVD.
2. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2012 DVD, and double-click.
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. Select the Specify a free edition and select Evaluation from the drop-down menu. 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 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, choose a named instance, specify an instance name, and click Next.
14. At the Disk Space Requirements screen, click Next.
15. At the Server Configuration screen, choose system accounts, such as NT Service\MSSQLSERVER, for SQL Server services. Click Next.
16. At the next error-checking screen, click Next.
17. At the Database Engine Configuration screen, select Mixed Mode.
18. Enter and confirm a password for the system administrator account.
19. Click Add Current user. This may take several seconds.
20. Click Next.
21. At the Error-and usage-reporting screen, click Next.
22. At the Installation Configuration Rules screen, check that there are no failures or relevant warnings, and click Next.
23. At the Ready to Install screen, click Install.
24. After installation completes, click Close.
25. Repeat steps 5-24 to install second SQL Server instance using MSSQLSERVER2 as the instance name. Continue this process for SQL Server instance three and four.
26. Close the installation window.

### Setting up the storage on the server

We used the steps below to configure the three SSD drives. We configured the drives in the RAID controller properties prior to following these steps. We configured the drives into drive volumes. One two-disk RAID 0 and one single disk.

1. In the taskbar, click the Server Manager icon.
2. In the left pane, expand Storage, and click Disk Management.
3. Right-click the first volume, and choose Initialize Disk.
4. In the right pane, right-click the volume, and choose New Simple Volume...
5. At the welcome window, click Next.
6. At the Specify Volume Size window, leave the default selection, and click Next.
7. At the Assign Drive Letter or Path window, choose a drive letter, and click Next.
8. At the Format Partition window, choose NTFS and 64K allocation unit size, and click Next.
9. At the Completing the New Simple Volume Wizard window, click Finish.
10. Repeat steps 3 - 9 for the additional volume.

## Installing and configuring the database clients

For the DS2 scripts, we used a dual-socket server with two Intel Xeon E5-2680 2.7GHz processors and 64GB of system memory as clients to simulate a number of users putting a load on the server. We installed Windows Server 2008 R2 Enterprise Edition on the server as outlined in the steps above. We installed the .NET 4.0 framework on the server as the DS2 test executable requires. After the installation, we created four folders on the server with a DS2 executable in each. We opened four command prompts and running one of the four executable in each command prompt window.

## Creating scripts on the database clients

To simplify testing, we created batch files named test.bat in all four folders to start the DVD Store executable with the correct parameters. We put the batch files in a folder on the clients in the following directory: c:\clientshare1 - c:\clientshare4. The batch files contained the following text:

Note: we changed the folder path and client output file name for each of the four executable. Client share 2 - 4 had the server instance after the IP address. For example, clientshare2 target was 192.168.30.186\MSSQLSERVER2

```
c:\Lenovo_1\clientshare1\ds2sqlserverdriver.exe --target=192.168.30.186 --ramp_rate=10 --run_time=10 --n_threads=32 --db_size=10GB --think_time=0 --detailed_view=Y --warmup_time=5 --pct_newcustomers=20 >NUL
2>c:\Lenovo_1\clientshare1\client1.csv
```

## 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 10GB database size and the database platform on which we ran - Microsoft SQL Server 2012. 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 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, we created and loaded the database schema 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.
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 14 shows our initial file size modifications.

Logical name	Filegroup	Initial size (MB)
<b>Database files</b>		
primary	PRIMARY	4
cust1	DS_CUST_FG	5,632
cust2	DS_CUST_FG	5,632
ind1	DS_IND_FG	2,560
ind2	DS_IND_FG	2,560
ds_misc	DS_MISC_FG	2,560
orders1	DS_ORDERS	2,560
orders2	DS_ORDERS	2,560
<b>Log files</b>		
ds_log	Not Applicable	17,719

Figure 14: Our initial file size modifications.

## APPENDIX C – MEASURING POWER

### Measuring workload power

To record each server's power consumption during the workload test, we used an Extech Instruments® ([www.extech.com](http://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.

## ABOUT PRINCIPLED TECHNOLOGIES



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