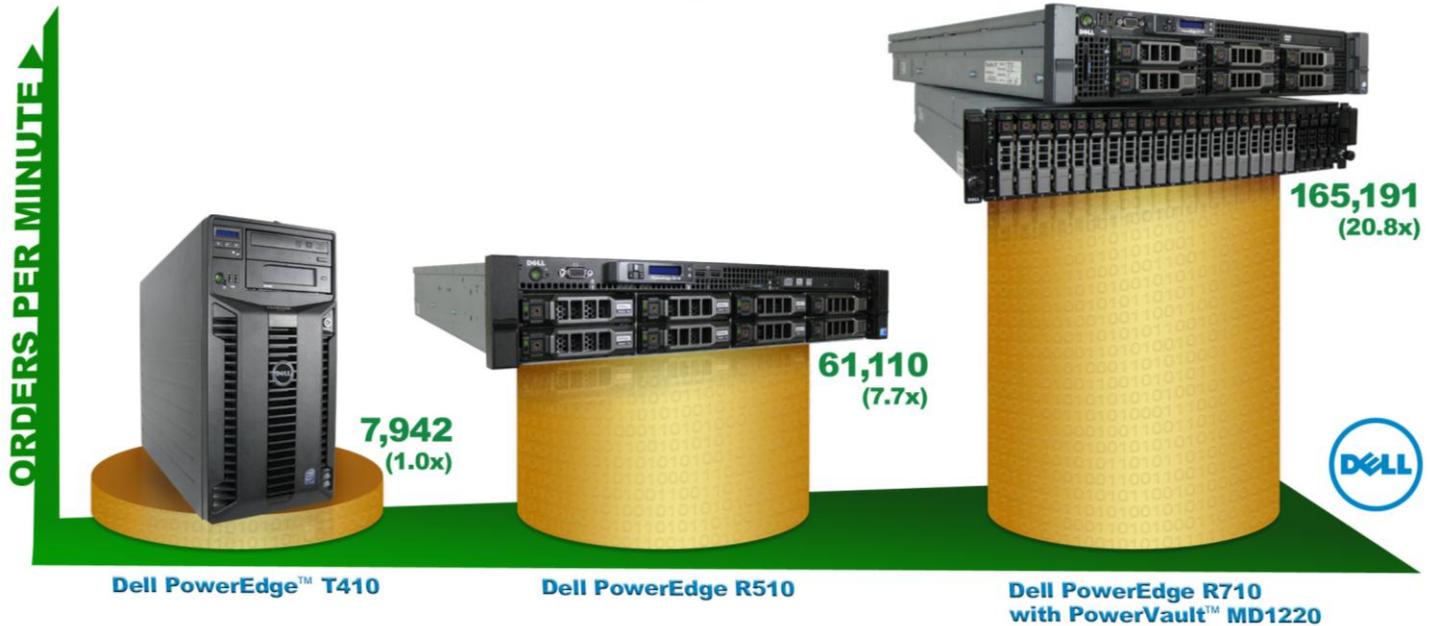


Dell™ database server solutions handled growing business needs



OUR FINDINGS

As companies' sizes and functions vary, so do their database server needs. One means of evaluating a database server is recording the number of orders per minute it can support. In Principled Technologies' tests in our labs, the Dell PowerEdge T410 achieved over 7,900 orders per minute, an amount comparable to an entry-level database server for a typical small business. The Dell PowerEdge R510 achieved over 61,000 orders per minute, or 7.7 times the performance of the Dell PowerEdge T410, and would support a more demanding small-to-medium business database workload. The Dell PowerEdge R710 with the Dell PowerVault MD1220 external storage array achieved over 165,000 orders per

minute, or 20.8 times the performance of the Dell PowerEdge T410, and would support a complex small-to-medium business database workload.

OUR PROCESS

We used the open-source DVD Store Version 2 benchmark to provide a workload representative of many real-world database applications. With it, we measured the database performance of the Dell PowerEdge T410, Dell PowerEdge R510, and the Dell PowerEdge R710, each of which was running Microsoft® Windows Server® 2008 R2 Standard Edition with Microsoft SQL Server® 2008 R2 Standard Edition.



PROJECT OVERVIEW

The purpose of this report is to demonstrate how Dell servers can meet the needs of businesses database no matter the size or demand. Selecting a server that can handle the number of orders you will incur is crucial, as this performance affects the number of users your server can support. We tested the following servers to gauge how many order per minute each could handle:

- Dell PowerEdge T410
- Dell PowerEdge R510
- Dell PowerEdge R710

Note that the actual number of orders or transactions servers can handle in a particular company's environment is highly dependent on both the hardware and the complexity of the specific database application. Our analysis can, however, give end-users a relative indication of how much database load each server can bear.

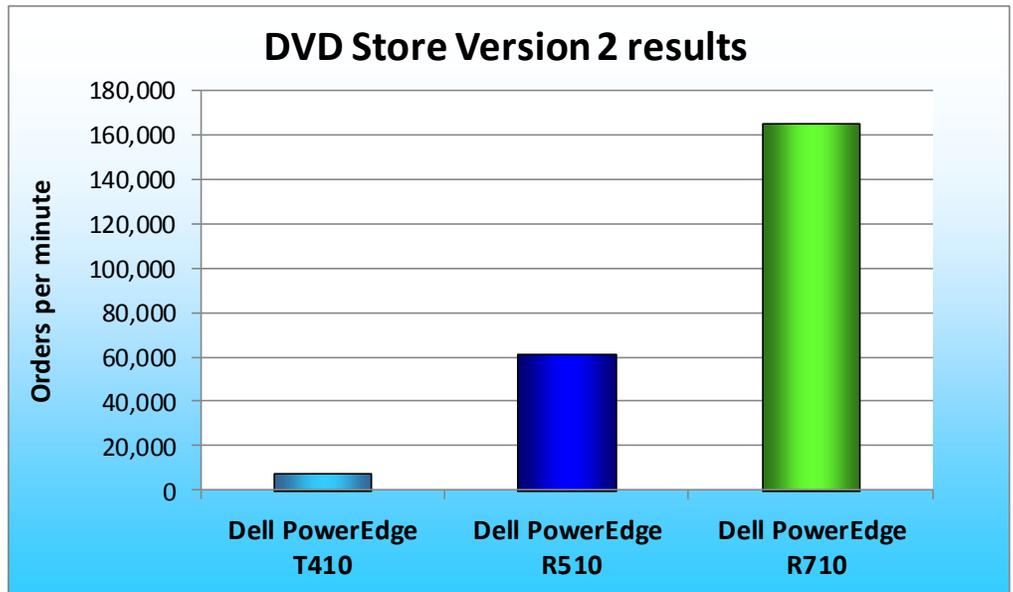


Figure 1: DVD Store Version 2 performance results, in orders per minute, for the test servers.

As Figure 1 shows, the Dell PowerEdge T410 server achieved 7,942 orders per minute, the Dell PowerEdge R510 achieved 61,110 orders per minute, and the Dell PowerEdge R710 achieved 165,191 orders per minute.

More details on our findings are in the What we found section.

WHAT WE TESTED

To build the workload, we used DVD Store Version 2 (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 put heavy loads on these components. We used the included driver program to stress the database component. The servers under test ran varying numbers of SQL Server 2008 R2 Standard instances to show performance scaling. The Dell PowerEdge T410 ran 1 instance, the Dell PowerEdge R510 ran 2 instances, and the Dell PowerEdge R710 ran 4 instances. We configured each SQL Server 2008 R2 Standard instance on the servers with a 5GB database. Each instance of DS2 had 32 threads to simulate a heavily loaded environment; the load-generating client machines ran with no think time, processing requests as quickly as the servers could handle them.

The main DS2 metric is orders per minute (OPM), which the driver program calculates and reports via the Windows Performance Monitor utility on the client machines. We used the output from the driver program to record OPM, and we report the last OPM score the benchmark reported.

When DS2 is executing, simulated customers log in; browse movies by actor, title, or category; and purchase movies. Each DS2 order consists of a customer login, a number of searches for movies, and a purchase. Each search is by either title, actor, or category. The title and actor searches use full-text search. The other customer actions, including adding new customers, 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 the included driver application 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 section in the How we tested section of this report.

The DS2 driver application creates an OPM performance counter on the client. While the DVD Store client application outputs OPM at 10-second intervals visually, we chose to collect this OPM metric via a performance monitor counter on each client at 1-second intervals. We ran this workload on the servers for 30 minutes.

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

SYSTEM COMPARISON

Figure 2 shows a side-by-side comparison of the key hardware differences among the test servers.

Appendix A presents detailed system information.

Hardware specifications	Dell PowerEdge T410	Dell PowerEdge R510	Dell PowerEdge R710
CPU	Intel Xeon E5620	Intel Xeon E5640	Intel Xeon X5670
CPU speed (GHz)	2.40	2.67	2.93
Number of processor packages	2	2	2
Number of cores per processor package	4	4	6
Number of hardware threads per core	2	2	2
Memory type	8GB (4x2GB), 1,333MHz, 2R UDIMMs	12GB (6x2GB), 1,333MHz, 2R UDIMMs	24GB (6x4GB), 1,333MHz, 2R RDIMMs
Total memory (GB)	8	12	24
Storage controller	Dell PERC 6/i	Dell PERC 6/i	Dell PERC H700 (internal) /PERC H800 (external)
Hard disks	4 x 160GB SATA	6 x 300GB SAS	2 x 147GB SAS, 2 x 50GB SSD (internal)/ 20 x 146GB SAS (external)

Figure 2: Key hardware differences between the test servers.

WHAT WE FOUND

Figure 3 shows the OPM results for the Dell PowerEdge T410 server, the Dell PowerEdge R510 server, and the Dell PowerEdge R710 server. We ran a differing number of SQL Server 2008 R2 Standard instances on each server based on their capabilities. The results show the OPM recorded by each test client and the total OPM for each server. We ran each DS2 test three times, and report the median runs for the servers.

OPM	Dell PowerEdge T410	Dell PowerEdge R510	Dell PowerEdge R710
Client 1	7,942	30,760	42,642
Client 2		30,350	41,910
Client 3			40,561
Client 4			40,078
Total OPM	7,942	61,110	165,191

Figure 3: Median OPM results for the test servers. Higher numbers are better.

HOW WE TESTED

Setting up the servers

Prior to OS installation, we set up a two disks RAID 1 configuration for the OS on all systems. We installed a fresh copy of Windows Server 2008 R2 Standard Edition on each server.

Installing Windows Server 2008 R2 Standard Edition on the hosts

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 Standard (Full Installation), and click Next.
5. Click the I accept the license terms check box, and click Next.
6. Click Custom.
7. Click Drive options (advanced).
8. Delete all partitions, if they exist.
9. Click New.
10. Click Apply.
11. Click Next.
12. At the User's password must be changed before logging on warning screen, click OK.
13. Type Password1 as the new password in both fields, and click the arrow to continue.
14. At the Your password has been changed screen, click OK.

Disabling Windows Firewall with Advanced Security

1. Open Server Manager.
2. In the left hand pane, expand Configuration.
3. Click Windows Firewall with Advanced Security.
4. In the middle pane, click Windows Firewall Properties.
5. Under the Domain Profile tab, change the Firewall state to Off.
6. Under the Private Profile tab, change the Firewall state to Off.
7. Under the Public Profile tab, change the Firewall state to Off.
8. Click OK.

Enabling Remote Desktop

1. Click Start, and right click on Computer.
2. Select Properties.
3. In the far left hand column click Remote settings.
4. Click the radio button beside Allow connections from computers running any version of Remote Desktop.
5. When the caution screen pops up, Click OK.
6. Click OK in the System Properties window.

Disabling Automatic Updates

1. Click Start→All Programs→Windows Update.
2. In the far left column, click Change settings.
3. From the pull-down menu, select Never check for updates.

4. Click OK.

Setting up network configuration on the server

1. Click Start→Control Panel→Network and Internet→Network Connections, and double-click the Local Area Connection assigned to client/server network traffic.
2. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
3. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
4. Enter a valid static IP address, subnet mask, and default gateway.
5. Click OK, and click Close to exit.

Installing system updates in Windows Server 2008 R2

We installed the following updates on each server using the Windows Update feature:

- Update for Internet Explorer 8 for Windows Server 2008 R2 x64 Edition (KB2398632)
- Update for Windows Server 2008 R2 x64 Edition (KB976422)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2008 R2 x64 Edition (KB980195)
- Security Update for Windows Server 2008 R2 x64 Edition (KB2347290)
- Update for Windows Server 2008 R2 x64 Edition (KB977074)
- Security Update for Windows Server 2008 R2 x64 Edition (KB979309)
- Update for Internet Explorer 8 Compatibility View List for Windows Server 2008 R2 x64 Edition (KB982664)
- Security Update for Windows Server 2008 R2 x64 Edition (KB972270)
- Security Update for Windows Server 2008 R2 x64 Edition (KB980232)
- Update for Windows Server 2008 R2 x64 Edition (KB976662)
- Security Update for Windows Server 2008 R2 x64 Edition (KB974571)
- Security Update for Windows Server 2008 R2 x64 Edition (KB979482)
- Update for Best Practices Analyzer for Application Server for Windows Server 2008 R2 x64 Edition (KB981392)
- Update for Best Practices Analyzer for File Services for Windows Server 2008 R2 x64 Edition (KB981111)
- Update for Windows Server 2008 R2 x64 Edition (KB2272691)
- Security Update for .NET Framework 3.5.1 on Windows 7 and Windows Server 2008 R2 for x64-based Systems (KB983590)
- Security Update for Windows Server 2008 R2 x64 Edition (KB975560)
- Microsoft .NET Framework 3.5 SP1 Security Update for Windows 7 and Windows Server 2008 R2 for x64-based Systems (KB979916)
- Security Update for Windows Server 2008 R2 x64 Edition (KB2160329)
- Security Update for Windows Server 2008 R2 x64 Edition (KB2032276)
- Update for Best Practices Analyzer for HYPER-V for Windows Server 2008 R2 x64 Edition (KB977238)

- Security Update for Windows Server 2008 R2 x64 Edition (KB2079403)
- Cumulative Security Update for Internet Explorer 8 for Windows Server 2008 R2 x64 Edition (KB2183461)
- Security Update for Windows Server 2008 R2 x64 Edition (KB978886)
- Security Update for Windows Server 2008 R2 x64 Edition (KB981852)
- Microsoft .NET Framework 3.5 SP1 Update for Windows 7 and Windows Server 2008 R2 for x64-based Systems (KB982526)
- Update for Windows Server 2008 R2 x64 Edition (KB981793)
- Update for Best Practices Analyzer for DHCP Server for Windows Server 2008 R2 x64 Edition (KB977236)
- Security Update for Windows Server 2008 R2 x64 Edition (KB980218)
- Windows Malicious Software Removal Tool x64 - September 2010 (KB890830)
- Update for Windows Server 2008 R2 x64 Edition (KB982110)
- Update for Best Practices Analyzer for Network Policy and Access Services for Windows Server 2008 R2 x64 Edition (NPAS) (KB977239)
- Update for Windows Server 2008 R2 x64 Edition (KB974431)
- Update for Windows Server 2008 R2 x64 Edition (KB980846)
- Update for Windows Server 2008 R2 x64 Edition (KB974332)
- Security Update for Windows Server 2008 R2 x64 Edition (KB978542)
- Update for Windows Server 2008 R2 x64 Edition (KB978637)
- Security Update for Windows Server 2008 R2 x64 Edition (KB2286198)
- Security Update for Windows Server 2008 R2 x64 Edition (KB978601)
- Update for Best Practices Analyzer for Windows Server Update Services for Windows Server 2008 R2 x64 Edition (KB981390)
- Update for Rights Management Services Client for Windows Server 2008 R2 x64 Edition (KB979099)
- Update for Best Practices Analyzer for Active Directory Rights Management Services for Windows Server 2008 R2 x64 Edition (KB981391)
- Security Update for Windows Server 2008 R2 x64 Edition (KB982799)
- Security Update for Windows Server 2008 R2 x64 Edition (KB981332)
- Security Update for Windows Server 2008 R2 x64 Edition (KB980436)
- Update for Windows Server 2008 R2 x64 Edition (KB980408)
- Security Update for Windows Server 2008 R2 x64 Edition (KB975467)
- Security Update for Windows Server 2008 R2 x64 Edition (KB982214)

Installing SQL Server 2008 R2 Standard Edition on the server

1. Insert the installation DVD for SQL Server 2008 R2 Standard Edition into the DVD drive.
2. If AutoPlay does not begin the installation, navigate to the SQL Server 2008 R2 Standard Edition DVD, and double-click.

3. If prompted with a .NET installation prompt, click Yes 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, choose the service account, fill in a password if necessary, 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.

Database and Log Volume Setup

For the Dell PowerEdge T410 and the Dell PowerEdge R510, we created two volumes: two disks in a RAID 1 for the OS and the SQL log files, two disks in a RAID 1 on the Dell PowerEdge T410, and four disks in a RAID 10 on the Dell PowerEdge R510 for the SQL database files. For the Dell PowerEdge R710, we configured two drives in a RAID 1 for the OS and two SSD drives in a RAID 1 for the SQL log files. For the SQL database files, we used a Dell PowerVault MD1220 external SAS storage tray with 20 drives split into two RAID 10 virtual disks using 10 physical disks per virtual disk. We attached the external storage to the Dell PowerEdge R710 using a PERC H800 external SAS controller and two external SAS cables.

Installing and configuring the database clients

For the DS2 scripts, we used a number of clients to simulate a number of users putting a load on the server. For our clients, we created a folder we called C:\ClientShare to store workload scripts, and shared this folder for access from our controller machine. We installed the .NET 3.5 framework on each client, as the DS2 test executable requires at least .NET2.0. We created a performance counter log on each client machine to

track the number of orders per minute each database instance returns. We followed this process for each installation:

1. Install Microsoft Windows Server 2003 R2 Enterprise x86 Edition 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 log on.
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 framework, and copy the DVD Store client executable into the C:\ClientShare folder.
9. Assign a valid IP address and subnet mask to each client's NIC.

Setting up DVD Store

Data generation overview

We built the database schema using the scripts in the DS2 distribution package, though we made a few minor modifications. The DS2 stress tool provides options to generate 10MB, 1GB, or 100GB datasets. To get the tool to generate the 5 GB of user data we used in this test, we had to make a few straightforward changes to the source code and to the DVD Store application's scripts. Note: We created our test data on a Linux system to take advantage of the larger RAND MAX.

Editing the ds2_create_orders.c module

The module ds2_create_orders.c defines constants that define the maximum values for the customer ID and the product ID. The constants for the 5GB database size did not exist. We added the constants for this size.

On the command line for the ds2_create_orders.c module, we specified the size. The available options were S (small), M (medium), and L (large). We added the case V for the 5GB database. In the switch statement that sets the values for the variables max_cust_id and max_prod_id, we added cases that assigned them the proper values for the 5GB database size.

We recompiled the ds2_create_orders.c module on Linux, following the instructions in the header comments. We used the following command line:

```
gcc -o ds2_create_orders ds2_create_orders.c -lm
```

Editing the ds2_create_cust.c module

We had to make the same changes to the ds2_create_cust.c module that we made to the ds2_create_orders.c module. On the command line for the ds2_create_cust.c module, we specified the size.

The available options were S (small), M (medium), and L (large). We added the case V for the 5GB database. In the switch statement that sets the values for the variables `max_cust_id` and `max_prod_id`, we added cases that assigned them the proper values for the 5GB database size.

We recompiled the `ds2_create_cust.c` module on Linux, following the instructions in the header comments. We used the following command line:

```
gcc -o ds2_create_cust ds2_create_cust.c -lm
```

Generating the data for the 5GB database

We used shell scripts to run all four of the executables that generate the data. The distribution did not include shell scripts for the 5GB size. We wrote shell scripts based on the `ds2_create_cust_large.sh` and `ds2_create_orders_large.sh` scripts. The `ds2_create_prod` and `ds2_create_inv` executables did not ship with associated shell scripts, so we created shell scripts using the instructions in the readme files. We ran the shell scripts in the following order to generate the data for the 5GB database:

1. `ds2_create_orders_5gb.sh`
2. `ds2_create_inv_5gb.sh`
3. `ds2_create_prod_5gb.sh`
4. `ds2_create_cust_5gb.sh`

We waited until the processes finished before we moved onto the next step.

Creating the database

We modified the database creation SQL Server scripts in the DVD Store distribution package to build the database schema, which includes the file structure, tables, indices, stored procedures, triggers, and so on. We built a master copy of the 5GB database version for SQL Server 2008 R2 and then used that master copy to restore our test database to the server between each test run. We stored the backup file on the C: drive of the Dell PowerEdge T410 and the Dell PowerEdge R510 for quick access. On the Dell PowerEdge R710, we stored the backup file with the SQL log files on a separate volume.

We followed these steps to create the database:

1. We created the database and file structure using database creation scripts in the DS2 download. We made size modifications specific to our 5GB database and the appropriate changes to drive letters.
2. We created database tables, stored procedures, and objects.
3. We set the database recovery model to bulk-logged to prevent excess logging.
4. We loaded the data we generated into the database.
5. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.

6. We updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
7. On each SQL Server 2008 R2 instance, we created a ds2user SQL Server login using the following Transact SQL (TSQL) script:

```
USE [master]
GO
CREATE LOGIN [ds2user] WITH PASSWORD=N'',
DEFAULT_DATABASE=[master],
DEFAULT_LANGUAGE=[us_english],
CHECK_EXPIRATION=OFF,
CHECK_POLICY=OFF
GO
```

8. We set the database recovery model back to full.
9. We made the following changes in the build scripts:
 - Because we varied the size of the datasets, we sized the files in our scripts to reflect the database size and the number of files per filegroup. We allowed for approximately 40 percent free space in our database files to ensure that filegrowth activity did not occur during the testing.
 - We followed Microsoft's recommendation of having 0.25 to 1 file per filegroup per core. We used eight files per filegroup on all servers.
 - We did not use the DBCC PINTABLE command for the CATEGORIES and PRODUCTS tables, both because Microsoft recommends against this practice and because the commands do nothing in SQL Server 2008 R2.
 - We created a SQL Server login we called ds2user and mapped a database user to this login. We made each such user a member of the db_owner fixed database role.
 - Using the DVD Store scripts as a reference, we created the full-text catalog and index on the PRODUCTS table manually in SQL Server Management Studio.

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.

Editing the workload script - ds2xdriver.cs module

To use the 5GB database we created earlier, we had to change the following constants:

- In the routine Controller(), we changed the string sizes. We added the V option for the 5GB database size. DS2 uses the sizes string to interpret the db_size_str option.
- In the class Controller, we changed the arrays MAX_CUSTOMER and MAX_PRODUCT. To each, we added values specifying the bounds for the customer and product IDs. The Controller() routine uses these arrays.
- We added a command-line parameter for the database name:

```
-database_name
```

Editing the workload script - ds2sqlserverfns.cs module

We changed the connection string to increase the number of available connections, to not use the default system administrator (sa) account, and to include a parameter for the database name. We raised the available connections limit from the default of 100 to 200 to allow room for experimentation. We created a user account we called ds2User and used that account.

The ds2connect routine in the ds2sqlserverfns.cs module defines sConnectionString. We used the following string; the changes we made appear in bold:

```
string sConnectionString = "User ID=ds2User;Initial  
Catalog="+dbname+";Max Pool Size=200;Connection Timeout=120;Data  
Source=" + Controller.target;
```

Recompiling the ds2sqlserverdriver.exe executable

We recompiled the ds2xdriver.cs and ds2sqlserverfns.cs module in Windows by following the instructions in the header comments. Because the DS2 instructions were for compiling from the command line, we used the following steps:

1. Open a command prompt.
2. Use the cd command to change to the directory containing our sources.
3. Run the batch file C:\Program Files\Microsoft Visual Studio 9.0\Common7\Tools\vsvars32.bat. This sets up the environment variables for us.
4. Execute the following command:

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

Testing procedure

To perform the test, we used a series of batch files. We stored batch files on each client, either under the C:\ServerShare folder or the C:\ClientShare folder, and we used the PsExec utility to coordinate the test procedures amongst the client machine, server machine, and controller. We use simple file sharing or secure FTP to copy files from machine to machine as we needed. To minimize OPM variance across runs, we added the --warmup_time parameter to each DS2 batch file on the clients and set the warmup time to 5 minutes.

The testing procedure consisted of the following steps:

1. Drop the database on each instance.
2. Restore the database on each instance.
3. Restart the MSSQLSERVER service.
4. Wait 10 minutes for any background tasks to complete.

5. Start Performance Monitor.
6. Start the workload for one SQL instance with a 5GB database when testing the Dell PowerEdge T410, two SQL instances with 5GB databases when testing the Dell PowerEdge R510, and four SQL instances with 5GB databases when testing the Dell PowerEdge R710.
7. When the workload finishes after 35 minutes, stop Performance Monitor.
8. Record the OPM results from each output file on the clients.
9. Record CPU utilization from the Performance Monitor output file.

APPENDIX A – SERVER CONFIGURATION INFORMATION

Figure 4 provides detailed configuration information about the test servers.

System	Dell PowerEdge T410	Dell PowerEdge R510	Dell PowerEdge R710
Power supplies			
Total number	2	2	1
Vendor and model number	Dell AA25730L	Dell L1100A-S0	Dell A570P-00
Wattage of each (W)	580	1100	570
Cooling fans			
Total number	1	5	5
Vendor and model number	Sunon PSD1212PMB1-A	Delta Electronics Inc. PFC0612DE	San Ace 60 9GV0612P1M041
Dimensions (h x w) of each	5-3/4" x 5-3/4"	2-1/2" x 2-3/8"	2-3/8" x 2-1/2"
Volts	12	12	12
Amps	1.7	1.7	1.5
General			
Number of processor packages	2	2	2
Number of cores per processor	4	4	6
Number of hardware threads per core	2	2	2
System power management policy	Balanced	Balanced	Balanced
CPU			
Vendor	Intel	Intel	Intel
Name	Xeon	Xeon	Xeon
Model number	E5620	E5640	X5670
Stepping	B1	B1	B1
Socket type	LGA 1366	LGA 1366	LGA 1366
Core frequency (GHz)	2.40	2.67	2.93
Bus frequency (GT/s)	5.86	5.86	6.40
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	1 MB (4 x 256 KB)	1 MB (4 x 256 KB)	1.5 MB (6 x 256 KB)
L3 cache (MB)	12	12	12

System	Dell PowerEdge T410	Dell PowerEdge R510	Dell PowerEdge R710
Platform			
Vendor and model number	Dell PowerEdge T410	Dell PowerEdge R510	Dell PowerEdge R710
Motherboard model number	Dell Inc. 0M638F	Dell Inc. 0W844P	Dell Inc. 0M233H
Motherboard chipset	Intel 5500	Intel 5500	Intel 5520
BIOS name and version	Dell Inc. 1.4.8 (09/08/2010)	Dell Inc. 1.4.0 (09/03/2010)	Dell Inc. 2.1.15 (09/02/2010)
BIOS settings	Default	Default	Default
Memory module(s)			
Total RAM in system (GB)	8	12	24
Vendor and model number	Hynix HMT125U7BFR8C-H9	Hynix HMT125U7BFR8C-H9	Micron MT36JSZF51272PY-1G4D1AB
Type	PC3-10600E	PC3-10600E	PC3-10600R
Speed (MHz)	1,333	1,333	1,333
Speed running in the system (MHz)	1,066	1,066	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	7-7-7-20	7-7-7-20	9-9-9-24
Size (GB)	2	2	4
Number of RAM module(s)	4 x 2 GB	6 x 2 GB	6 x 4 GB
Chip organization	Double-sided	Double-sided	Double-sided
Rank	Dual	Dual	Dual
Hard disk			
Vendor and model number	Western Digital WD1600AAJS	Dell ST3300657SS	Hitachi Ultrastar HUS153014VLS300
Number of disks in system	4	6	2
Size (GB)	160	300	147
Buffer size (MB)	8	16	16
RPM	7,200	15,000	15,000
Type	SATA 3 Gb/s	SAS 6 Gb/s	SAS 3 Gb/s
Hard disk 2			
Vendor and model number	N/A	N/A	Dell MCB4E50G5MXP-OVB
Number of disks in system	N/A	N/A	2

System	Dell PowerEdge T410	Dell PowerEdge R510	Dell PowerEdge R710
Size (GB)	N/A	N/A	50
Buffer size (MB)	N/A	N/A	N/A
RPM	N/A	N/A	N/A
Type	N/A	N/A	SSD SATA
Disk Controller			
Vendor and model	Dell PERC 6/i	Dell PERC 6/i	Dell PERC H700
Controller cache	256 MB	256 MB	512 MB
Controller driver	LSI 4.5.0.64 (02/06/2009)	LSI 4.5.0.64 (02/06/2009)	Dell 4.23.0.64 (11/16/2009)
Controller firmware	6.2.0-0013	6.2.0-0013	12.0.1-0091
RAID configuration	RAID 1	RAID 1/ RAID 10	RAID 1
Disk Controller 2			
Vendor and model	N/A	N/A	Dell PERC H800
Controller cache	N/A	N/A	512 MB
Controller driver	N/A	N/A	Dell 4.23.0.64 (11/16/2009)
Controller firmware	N/A	N/A	12.0.1-0083
RAID configuration	N/A	N/A	RAID 10
Operating system			
Name	Windows Server 2008 R2 Standard Edition	Windows Server 2008 R2 Standard Edition	Windows Server 2008 R2 Standard Edition
Build number	7600	7600	7600
Service pack	N/A	N/A	N/A
File system	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English
Graphics			
Vendor and model number	Matrox® G200eW	Matrox G200eW	Matrox G200eW
Graphics memory (MB)	8	8	8
Driver	Matrox Graphics Inc. 1.1.3.0 (07/27/2009)	Matrox Graphics Inc. 1.1.3.0 (07/27/2009)	Matrox Graphics Inc. 1.1.3.0 (07/27/2009)
Ethernet			
Vendor and model number	Broadcom® BCM5716C NetXtreme® II GigE	Broadcom BCM5716C NetXtreme II GigE	Broadcom BCM5709C NetXtreme GigE
Type	Integrated	Integrated	Integrated
Driver	Broadcom 5.2.14.0 (12/17/2009)	Broadcom 5.2.14.0 (12/17/2009)	Broadcom 5.2.14.0 (12/17/2009)

System	Dell PowerEdge T410	Dell PowerEdge R510	Dell PowerEdge R710
Optical drive(s)			
Vendor and model number	TSSTcorp TS-H653F	PLDS DVD+RW DS-8A3S	TSSTcorp TS-L333A
Type	DVD+RW	DVD+RW	DVD-ROM
USB ports			
Number	6	4	4
Type	2.0	2.0	2.0

Figure 4: Configuration information for the test servers.

APPENDIX B - TEST STORAGE INFORMATION

Figure 5 provides detailed configuration information about the external storage system we used with the Dell PowerEdge R710 server.

Storage	Dell PowerEdge R710 external storage
Vendor and model	Dell PowerVault MD1220
Connection type	SAS SFF 8088
Connectivity mode	Unified mode (redundant path)
Total number of drives	20
Hard drive	
Vendor and model number	Dell ST9146852SS
Size (GB)	146
RPM	15K
Type	SAS 6 Gb/s

Figure 5: Detailed configuration information for the external storage system for the Dell PowerEdge R710.

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Principled Technologies, Inc.
1007 Slater Road, Suite 300
Durham, NC, 27703
www.principledtechnologies.com

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