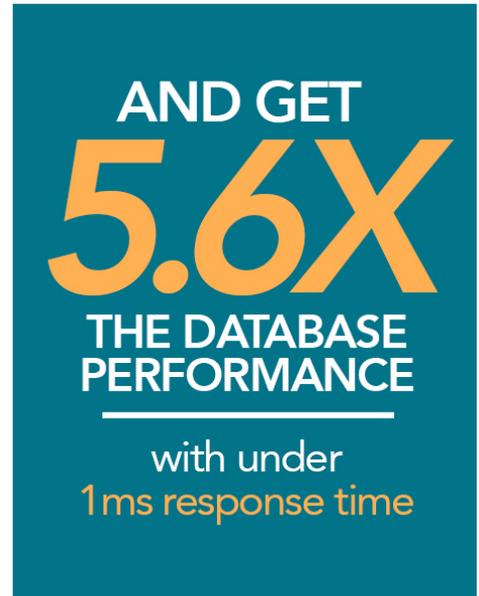


Support twice as many VMs with a modern Dell™ PowerEdge™ environment

Dell PowerEdge R830 server powered by Intel® Xeon® processors E5-4650 v4, Dell Storage SC9000 all-flash array with Microsoft® SQL Server® 2016



versus a Dell PowerEdge R820 solution and legacy SAN with Microsoft SQL Server 2005

In April 2016, Microsoft discontinued extended support for SQL Server 2005, prompting many companies to migrate to a newer version. If your company is planning to migrate from SQL Server 2005 to a newer version, it's a great time to upgrade your hardware to get the most out of the new software.

In the Principled Technologies datacenter, we ran SQL Server 2016 in a modern Dell environment—a PowerEdge R830 server, powered by Intel Xeon E5-4650 v4 processors; QLogic® QLE2692 16Gb Fibre Channel (FC) adapter with StorFusion Technology; and Dell SC9000 all-flash storage. We found that this configuration did more than five times the database work of an older Dell PowerEdge R820 server with legacy HDD SAN storage running SQL Server 2005, while delivering a storage response time of less than 1 millisecond.

When you can use fewer servers to run your SQL Server workloads at equal or higher levels of database performance, you boost your datacenter efficiency, which can translate to savings.



MODERNIZE YOUR DATACENTER WITH NEW DELL SERVERS AND STORAGE

Streamlining your datacenter hardware by replacing older servers using HDD storage arrays with new servers using all-flash storage has the potential to benefit your company many ways. You can use less physical space, see your power and cooling expenses decrease, free up time for IT admins by requiring them to manage fewer servers, and save by paying for fewer software licenses each year.

If your company is migrating your SQL Server 2005 database workloads to SQL Server 2016 and thinking about investing in new servers as well, consider the Dell PowerEdge R830. SQL Server 2016 features OS-maximum cores and memory as well as in-memory OLTP, letting it fully utilize the vast resource pools new servers offer. The Dell PowerEdge R830 is a 2U, four-socket server that features the Intel Xeon processor E5-4600 v4 product family, provides up to 88 cores and 176 threads, and supports up to 3 TB of DDR4 RAM. This means it has large amounts of CPU and memory resources to handle SQL Server 2016 applications in only 2U of rack space.

Dell designed the all-flash Storage SC9000 array with large-scale storage, high-end workloads, and distributed enterprise environments in mind. This array gives your SQL Server applications a boost with 16Gb Fibre Channel, 12Gb SAS, and hardware redundancy—all of which speed and protect the movement of data.

We set out to compare two solutions: (1) SQL Server 2005 workloads on a [2012] Dell PowerEdge R820 with HDD storage and (2) SQL Server 2016 on the modern PowerEdge R830-SC9000 platform. We set up virtual machines in both environments and ran an online transaction processing (OLTP) workload. Figure 1 illustrates our test environment.

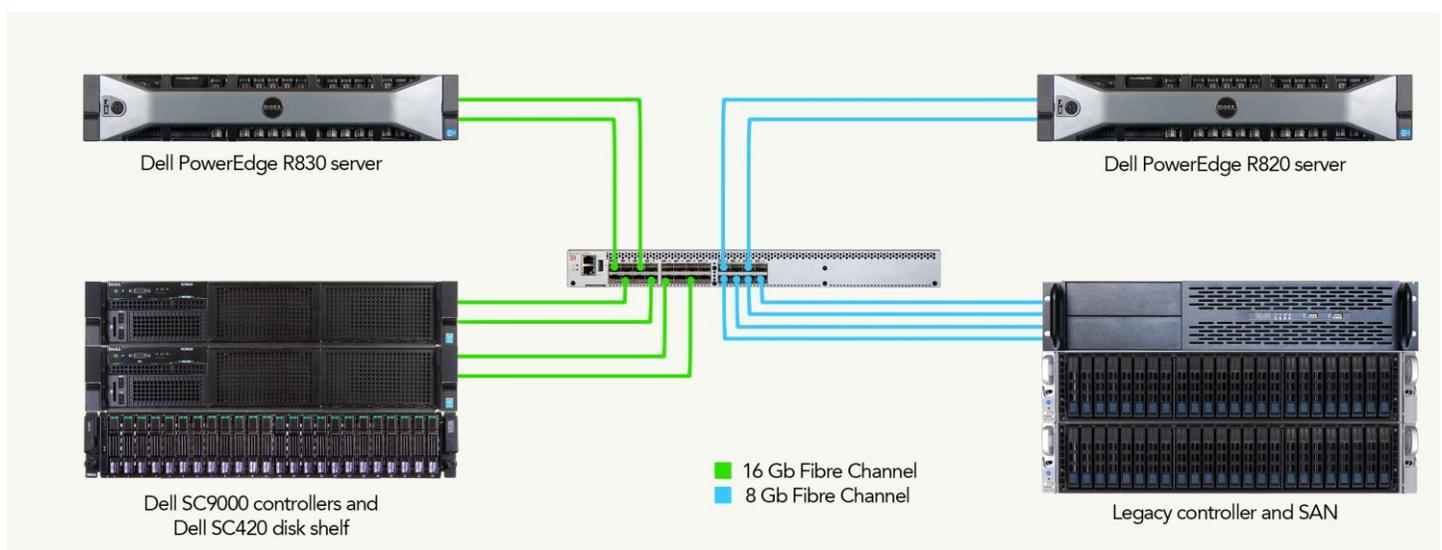


Figure 1: Our testbed.

Our legacy environment, the Dell PowerEdge R820 using HDD-based storage, ran 12 VMs, each handling an average of 10,180.17 orders per minute in our test configuration. We configured the modern Dell environment to run 24 VMs, each handling an average of 28,539.71 orders per minute. That's twice as many VMs, each doing more than twice the work of the original VMs. As Figure 2 illustrates, that translates to over five times the database work that the Dell PowerEdge R830 and Dell Storage SC9000 array could accomplish together.

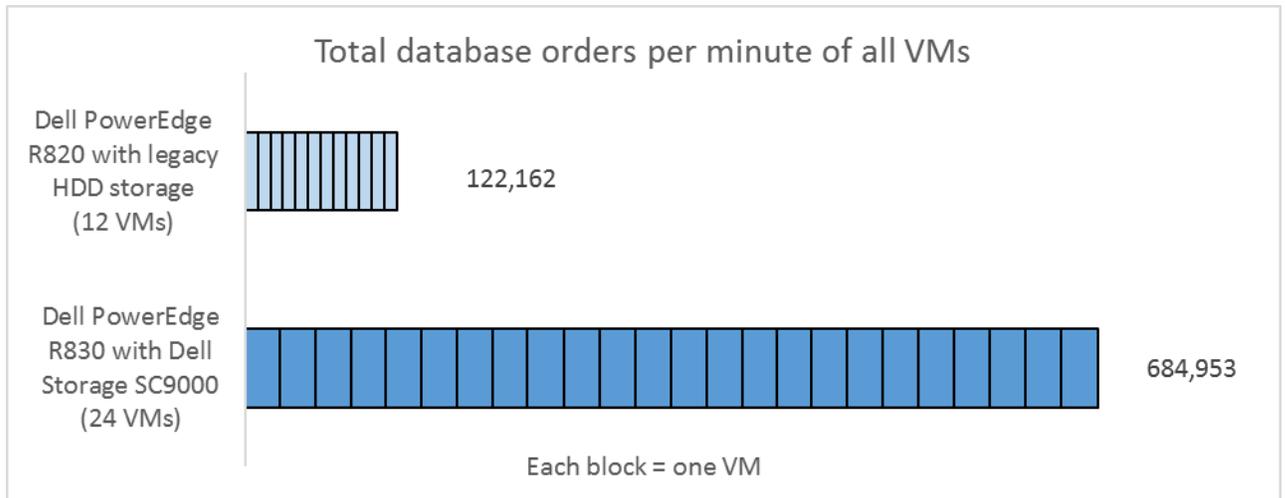


Figure 2: The 24 SQL Server 2016 VMs running on the Dell modern environment performed more than five times the work of the 12 SQL Server 2005 VMs running on the Dell PowerEdge R820 environment.

For more information on components used in our testing, see [Appendix A](#). For detailed hardware configuration information, see [Appendix B](#). For details on our test procedure, see [Appendix C](#).

OUR RESULTS IN DETAIL

On both the Dell PowerEdge R830 and legacy R820 environments, we allocated 8 GB of RAM to the hypervisor and then sized our VMs to utilize the full remaining amount of RAM each server offered. Each VM on the older Dell PowerEdge R820 had four vCPUs, 9,728 MB of RAM, and a 20GB SQL Server 2005 database. Each of the VMs on the new PowerEdge R830 had four vCPUs, 9,216 MB of RAM, and a 20GB SQL Server 2016 database. The Dell PowerEdge R830 environment could support 24 VMs while the legacy environment could support only 12 VMs in this configuration.

Figure 3 shows the median orders per minute that the two solutions were able to process in our testing. Each of the 24 VMs on the Dell PowerEdge R830 solution processed more than twice as many orders per minute than each of the 12 VMs on the legacy R820 did. The Dell PowerEdge R830 solution delivered an overall difference of five times the output.

	Dell PowerEdge R830 with Dell Storage SC9000 array (SQL Server 2016)	Dell PowerEdge R820 with legacy HDD storage (SQL Server 2005)
VM 1	27,470	10,140
VM 2	29,137	10,172
VM 3	28,305	10,119
VM 4	27,920	10,132
VM 5	29,024	10,257
VM 6	28,202	10,294
VM 7	28,353	10,227
VM 8	28,462	10,185
VM 9	28,961	10,161
VM 10	28,987	10,110
VM 11	28,700	10,104
VM 12	29,106	10,261
VM 13	28,203	
VM 14	28,647	
VM 15	27,750	
VM 16	27,671	
VM 17	28,208	
VM 18	29,496	
VM 19	28,287	
VM 20	28,971	
VM 21	28,639	
VM 22	28,270	
VM 23	28,431	
VM 24	29,753	
Total	684,953	122,162

Figure 3: The 24 SQL Server 2016 VMs running on the Dell modern environment delivered over five times the work of the 12 SQL Server 2005 VMs running on the legacy PowerEdge R820 environment.

Latency, or response time, is a critical factor in determining consistent, fast database performance. In our tests, the applications running on the SC9000 all-flash storage array were able to support over 680,000 orders per minute due, in part, to the fast response times at the disk level. According to the esxtop data captured during the run, the device latency on the SC9000 stayed below 1ms for the duration of the run.

VMware guidelines recommend that device latency be less than 20ms for best performance.

CONCLUSION

Nothing lasts forever. When software manufacturers discontinue support for aging programs, as Microsoft has done for SQL Server 2005, businesses using these applications must take the step of migrating to new, updated versions. Coupling this upgrade with an upgrade to the hardware on which the applications run can take performance improvements to an even higher level.

In our testing, the modern four-socket Dell PowerEdge R830 powered by Intel Xeon processors E5-4650 v4 working with the powerful Dell Storage SC9000 array and running SQL Server 2016 delivered over five times the database performance of a legacy PowerEdge R820 solution running SQL Server 2005. The modern PowerEdge solution also delivered a faster response time.

Running modern, fully featured database software on four-year-old servers is possible, but far from optimal. Consolidating your SQL Server workloads from legacy servers onto Dell PowerEdge R830 servers powered by the Intel Xeon processor E5-4600 v4 product family is a way to streamline and modernize your datacenter.

APPENDIX A – ABOUT THE COMPONENTS

About the Dell PowerEdge R830

The Dell PowerEdge R830 is a 2U, four-socket server that features the latest from the Intel® Xeon® processor E5-4600 v4 series. Dell designed the R830 to optimize application performance for dense virtualization or scale out four-socket workloads using resources including the following:

- 48 DIMM slots—The ample number of slots help leverage cost with performance and capacity needs. It accommodates a larger memory footprint which can be configured with smaller-capacity DIMMs for potential cost-efficiency, or can support up to 3 TB for more memory-intensive use cases.
- 16 drive bays, configurable with a mix of SAS/SATA HDDs and SSDs as well as optional NVMe PCIe® SSDs for expanded storage capabilities. Two chassis configurations—one with eight HDD/SSD drive bays, and one with 16 HDD/SSD drive bays—allow you to configure the PowerEdge R830 however your business needs.
- Optional NVMe PCIe SSD drives for data that requires the fastest-available I/O throughput.

To learn more about the Dell PowerEdge R830, visit www.dell.com/us/business/p/poweredge-R830/pd.

About the new Intel Xeon E5 v4 processor family

The latest Intel Xeon processor E5-2600 v4 family contain up to 22 cores at that run at 2.2 GHz – a 20 percent increase compared to previous generations. The Intel Xeon processor E5-2600 v4 family offers features to enhance virtualization, orchestration, and security, including cache monitoring and allocation technologies, memory bandwidth monitoring, and enhanced key security.

To learn more about the Intel Xeon E5 processor product family, read the product brief at <http://www.intel.com/content/dam/www/public/us/en/documents/product-briefs/xeon-e5-brief.pdf>

About the Dell SC9000 storage array

Dell designed the SC9000 as an ideal solution for large-scale storage, high-end workloads, and distributed enterprise environments. According to Dell, this latest flagship array offers all the capabilities of the SC Series line in a fully upgraded, more scalable system leveraging the Dell 13G server platform.

- 16Gb Fibre Channel capability provides a massive network pipe for achieving the throughput needed to take full advantage of the all-flash performance.
- Quick, modular expansion to over 3PB raw SAN and/or NAS storage capacity per array, and the ability to be interconnected with other SC Series arrays in larger federated systems under unified management.
- Superior flash and hybrid performance. Comprehensive SSD integration plus a wide range of HDDs and ultra-dense enclosures provide flexible performance.
- Always available storage with automated cost savings. Ideal for private cloud deployments, the SC Series Live Volume feature now offers seamless disaster recovery with transparent auto-failover to fully synchronized backup volumes on another SC series array.
- Live Volume with auto-failover keeps workloads running continuously during unplanned outages and repairs your high-availability environment automatically when an array comes back online. No extra hardware or software is required.

- Application Protection Manager Suite ensures server-side data integrity in Oracle, VMware and Microsoft database environments. Optional FIPS-certified self-encrypting SSDs and HDDs protect against data theft, loss or unauthorized access.
- Built-in efficiencies include new block-level compression on all-flash arrays and pervasive “thin” methods. Patented auto-tiering leverages the best attributes of diverse drive types to optimize your data throughout its lifecycle.
- Redundant, hot-swappable components make the SC9000 a resilient, easy-to-deploy and highly available solution. Add capacity quickly with any of five supported expansion enclosures. Customize I/O connections to multiprotocol SANs (FC, iSCSI and FCoE) and support file storage from the same pool via the optional FS8600 NAS appliance.

Learn more at www.dell.com/us/business/p/storage-sc9000/pd

About the QLogic QLE269X series of FC adapters

QLogic provides Dell customers with future-ready I/O connectivity. According to QLogic, the QLE269x single- and dual-port 16Gb Fibre Channel host bus adapters (HBAs) boast industry-leading native FC performance with extremely low CPU usage with full hardware offloads, and include the following advanced features:

- Enhanced reliability, diagnostics, and accelerated deployment powered by StorFusion technology
- Up to 1.3 million IOPS to fuel high performance in all-flash arrays and high-density virtualized environments
- Port isolation design that offers deterministic and scalable performance on each port

Learn more at www.qlogic.com/go/dell

About Microsoft SQL Server 2016

SQL Server 2016 delivers performance and security features built-in for mission-critical transactional systems and data warehouses, along with an integrated business intelligence and advanced analytics solution for building data analytics applications. High-performance features are key to ensuring your applications can deliver a smooth transactional experience and also potentially support demanding real-time operational analytics.

You can experience the full features of SQL Server 2016 through the [free developer edition](#). Visit [the SQL Server 2016 webpage](#) to learn more about new features and download the [SQL Server 2016 e-book](#).

About DVD Store Version 2.1

To create our real-world ecommerce workload, we used the DVD Store Version 2.1 benchmarking tool. DS2 models an online DVD store, where customers log in, search for movies, and make purchases. DS2 reports these actions in orders per minute that the system could handle, to show what kind of performance you could expect for your customers. The DS2 workload also performs other actions, such as adding new customers, to exercise the wide range of database functions you would need to run your ecommerce environment.

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

APPENDIX B – SYSTEM CONFIGURATION INFORMATION

Figures 4 and 5 provide detailed configuration information for the test systems. Figures 6 and 7 provide detailed configuration information for the storage array.

System	Dell PowerEdge R830
General	
Number of processor packages	4
Number of cores per processor	14
Number of hardware threads per core	2
System power management policy	Performance
CPU	
Vendor	Intel
Name	Xeon
Model number	E5-4650 v4
Socket type	LGA2011-3
Core frequency (GHz)	2.20
Bus frequency	9.6 GT/s
L1 cache	32KB + 32KB (per core)
L2 cache	256KB (per core)
L3 cache	36MB
Platform	
Vendor and model number	Dell PowerEdge R830
Motherboard model number	0CWF69X02
BIOS version	1.1.0 6/7/2016
Integrated LOM	Intel Ethernet X540-AT2
Memory module(s)	
Total RAM in system (GB)	256
Vendor and model number	Samsung® M393A2K43BB1-CRC
Type	PC4-19200
Speed (MHz)	2,400
Speed running in the system (MHz)	2,400
Size (GB)	16GB
Number of RAM module(s)	16
Chip organization	Double-sided
Rank	Dual
Fibre Channel adapter	
Vendor and model number	QLogic QLE2692 FC Adapter with StorFusion Technology
Number of ports	2
Speed	16G
RAID controller	
Vendor and model number	PERC H730
Firmware version	25.4.0.0015

System	Dell PowerEdge R830
Firmware	
Lifecycle Controller / iDRAC	2.35.35.30
Driver Pack	16.01.08

Figure 4: Configuration information for the Dell PowerEdge R830.

System	Dell PowerEdge R820
General	
Number of processor packages	4
Number of cores per processor	8
Number of hardware threads per core	2
System power management policy	Performance
CPU	
Vendor	Intel
Name	Xeon
Model number	E5-4650
Socket type	LGA2011
Core frequency (GHz)	2.70
Bus frequency	8.0 GT/s
L1 cache	32KB + 32KB (per core)
L2 cache	256KB (per core)
L3 cache	20MB
Platform	
Vendor and model number	Dell PowerEdge R820
Motherboard model number	0X437FX03
BIOS version	2.3.4 1/22/2016
Integrated LOM	Intel Gigabit I350-t
Memory module(s)	
Total RAM in system (GB)	128
Vendor and model number	Hynix HMT31GR7CFR4C
Type	PC3-12800
Speed (MHz)	1,600
Speed running in the system (MHz)	1,600
Size (GB)	8GB
Number of RAM module(s)	16
Chip organization	Double-sided
Rank	Dual
RAID controller	
Vendor and model number	PERC H710
Firmware version	21.3.2-0005

Figure 5: Configuration information for the legacy server.

Storage array	Dell Storage SC9000
Vendor and model number	Dell Storage SC9000
OS version	Storage Center 6.7.5
Connection type	Fibre Channel 16Gb
Number of Fibre Channel cards	1 per controller (2 total)
Fibre Channel card model	QLogic® QLE2662 16G Fibre Channel Adapter
Number of SAS cards	1 per controller (2 total)
SAS card model	SAS9300-8E 12G SAS Dual-Ext Port Adapter
Number of expansion enclosures	1
Expansion enclosure model number	SC420
Number of disks per shelf	24
Type of disk	SSD
Disk capacity	400 GB
Volumes	1
Disks per volume	24
RAID type	RAID 10

Figure 6: Configuration information for the Dell Storage SC9000 storage array.

Storage array	Legacy SAN
Connection type	Fibre Channel 8Gb
Number of Fibre Channel cards	1
Number of SAS cards	1 per controller (2 total)
Number of expansion enclosures	2
Number of disks per shelf	24
Type of disk	HDD 15k
Disk capacity	600 GB
Aggregates	2
Disks per aggregate	24
Volumes	3 (OS, data, and logs)
RAID type	RAID-DP

Figure 7: Configuration information for the legacy storage system.

APPENDIX C – HOW WE TESTED

Note: On May 30, 2016, we finalized the hardware and software configurations we tested. Updates for current and recently released hardware and software appear often, so unavoidably these configurations may not represent the latest versions available when this report appears. For older systems, we chose configurations representative of typical purchases of those systems. We concluded hands-on testing on July 11, 2016.

Installing VMware vSphere onto the servers

Before installing VMware vSphere, we set the System Profile to Performance on both servers. We installed the VMware vSphere 6.0 U2 hypervisor onto the servers' local hard drives, which we placed in a RAID1 pair.

1. Insert the VMware vSphere 6.0 U2 installation media into the optical drive.
2. Boot the server to the VMware vSphere installer.
3. To begin the installation wizard, press F11.
4. As the installation location, select the RAID1 pair.
5. As the keyboard type and language, select US English.
6. Enter the root password for the host.
7. To start the installation, press Enter.
8. When the installation completes, to reboot the host, press Enter.
9. After the host reboots, set the management network IP address.
10. Add the host to vCenter, and enable SSH and ESXi shell.

Configuring the Fibre Channel networking

We used a Brocade 6505 16Gb Fibre Channel top-of-rack switch for the storage network. We left the switch ports at factory settings and created zones for traffic isolation.

Configuring zoning on the Brocade M6505 switch

1. In a web browser, connect to the Brocade M6505 switch, and log in as the admin user.
2. Click Configure→Zone Admin.
3. In the Zone tab, create the following zones:
 - a. All visible physical ports on the SC9000
 - b. All visible virtual ports on the SC9000
 - c. Server Port 1 and all four visible virtual ports
 - i. Repeat Step C for remaining server ports.
4. In the Zone Config tab, click New Zone Config, and give it a name.
5. Add the newly created Zones to the Zone Config.
6. Click Save Config.
7. Click Enable Config.
8. Repeat the zoning process for the legacy server, creating one zone for all Fibre Channel ports associated with the legacy environment.

Configuring the storage

After initial cabling and configuration of the Dell Storage SC9000, we disabled the read and write caches and then created a single large volume, using all 24 disks. On the legacy storage, we created a first RAID aggregate using 24 disks, and within that aggregate, we created a single volume for OS and Data VMDKs. We then created a second RAID aggregate using the remaining 24 disks, and within that aggregate, we created a single volume for Log VMDKs.

Creating a server cluster and connecting the volumes

1. In a web browser, connect to the Storage Center virtual IP address, and log in as the Admin user.
2. Click Storage Management→Servers→Create Server. Select the four HBA WWNs that correspond to the Dell PowerEdge R830. Give the server a name, and click Continue.
3. Click Storage Management→Servers→Create Server Cluster. Click Add Existing Servers to Cluster. Select all servers, and click Continue.
4. Click Storage Management→Volumes→Create Volume. When prompted to specify a size for the volume, select Use All Space.
5. Click Storage Management→Volume→Map volume to server. Select the volume, and click Continue. Select the server cluster, and click Continue.
6. Using VMware vCenter, ensure that the volume is showing as connected to the server. Rebooting the servers and chassis may be necessary to propagate all changes.

Creating the workload virtual machines

We created and cloned out 12 Windows Server 2008 R2 VMs on the legacy environment, and 24 Windows Server 2012 R2 VMs on the Dell PowerEdge R830 environment. We installed SQL Server 2005 on the legacy VMs and SQL Server 2016 on the Dell PowerEdge R830 VMs. All VMs had the same virtual hardware specifications, with the exception of VM memory. The legacy VMs had slightly more memory assigned to each VM to use the host memory fully.

Creating the base VM

1. In VMware vCenter, navigate to Virtual Machines.
2. Click the icon to create a new VM.
3. Leave Create a new virtual machine selected, and click Next.
4. Enter a name for the virtual machine, and click Next.
5. Place the VM on a host with available CPUs, and click Next.
6. Select the Dell Storage SC9000 datastore for the 60GB OS VMDK, and click next.
7. Click Next.
8. Select the guest OS as Windows Server 2012 R2 for the Dell PowerEdge R830 environment, and Windows Server 2008 R2 for the legacy environment, and click Next.
9. In the Customize Hardware section, make the following changes:
 - a. Increase the vCPUs to 4.
 - b. Increase the VM memory to 9,216 MB on the Dell PowerEdge R830 environment, and to 9,728 MB on the legacy environment, in order to fully utilize the host memory.
 - c. Add a 100GB VMDK for SQL data, and select the VMware Paravirtual controller and Thick Provisioned Eager Zeroed.

- d. Add a 20GB VMDK for SQL logs, and select the VMware Paravirtual controller and Thick Provisioned Eager Zeroed. Place the VMDK in the LOGS datastore.
10. Connect the VM to the test network.
11. Click Next.
12. Click Finish.
13. Follow the instructions below to install the guest OS.

Installing Windows Server 2012 R2 onto the Dell PowerEdge R830 VMs

1. Attach the Windows Server 2012 R2 ISO to the virtual machine.
2. Open the VM console, and start the VM.
3. When prompted to boot from DVD, press any key.
4. When the installation screen appears, leave language, time/currency format, and input method as default, and click Next.
5. Click Install now.
6. When the installation prompts you, enter the product key.
7. Select Windows Server 2012 Datacenter Edition (Server with a GUI), and click Next.
8. Check I accept the license terms, and click Next.
9. Click Custom: Install Windows only (advanced).
10. Select Drive 0 Unallocated Space, and click Next. This starts Windows automatically, and Windows will restart automatically after completing.
11. When the Settings page appears, fill in the Password and Reenter Password fields with the same password.
12. Log in with the password you set up previously.

Installing .NET Framework 3.5

1. In the VM, open Server Manager.
2. Click Manage→Add Roles and Features.
3. Select Role-based or feature-based installation, and click Next.
4. Under Server pool, select the local server, and click Next. Click Next.
5. Under Features, select .NET Framework 3.5 Features, and click Next.
6. Click Install.
7. Upon completion, click Close.

Installing SQL Server 2016

1. Attach the installation media ISO for SQL Server 2016 to the VM.
2. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2016 DVD, and double-click it.
3. In the left pane, click Installation.
4. Click New SQL Server stand-alone installation or add features to an existing installation.
5. To accept the license terms, click the checkbox, and click Next.
6. Click Use Microsoft Update to check for updates, and click Next.

7. To install the setup support files, click Install.
8. If there are no failures displayed, click Next.
9. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
10. 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.
11. Click Next.
12. At the Instance configuration screen, leave the default selection of default instance, and click Next.
13. At the Database Engine Configuration screen, select the authentication method you prefer. For our testing purposes, we selected Mixed Mode.
14. Enter and confirm a password for the system administrator account.
15. Click Add Current user. This may take several seconds.
16. Click Next.
17. At the Error and usage reporting screen, click Next.
18. At the Installation Configuration Rules screen, check that there are no failures or relevant warnings, and click Next.
19. At the Ready to Install screen, click Install.
20. Close the installation window.

Installing Windows Server 2008 R2 Standard Edition on the legacy VMs

1. Attach the installation media ISO to the VM.
2. Open the VM console, and boot to the DVD.
3. At the Language Selection Screen, click Next.
4. Click Install Now.
5. Select Windows Server 2008 R2 Standard (Full Installation), and click Next.
6. Click the I accept the license terms check box, and click Next.
7. Click Custom.
8. Click Drive options (advanced).
9. Delete all partitions, if they exist.
10. Click New.
11. Click Apply.
12. Click Next.
13. At the User's password must be changed before logging on warning screen, click OK.
14. As the new password in both fields, type Password1. To continue, click the arrow.
15. At the Your password has been changed screen, click OK.

Installing SQL Server 2005

1. Attach the installation media ISO to the VM.
2. Inside the VM, if AutoPlay does not begin the installation, navigate to the SQL Server 2005 DVD, and double-click Autorun.

3. If prompted with a .NET installation prompt, to enable the .NET Framework Core role, click Yes.
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 2005 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. 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.

Enabling Lock pages in memory

1. Inside the VM, click Start, type `gpedit.msc`, and press Enter.
2. In the Local Group Policy Editor, expand Computer Configuration→Windows Settings→Security Settings→Local Policies.
3. Select User Rights Assignment, and in the right pane, scroll down to Lock pages in memory.
4. Right-click Lock pages in memory, and click Properties.
5. Click Add User or Group, and add your SQL user account.
6. Click OK.
7. Repeat steps 1-6 for the legacy base VM.

Configuring the DVD Store 2 benchmark

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 20GB database size and the Microsoft SQL Server 2016 platform. 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 2005. We built the 20GB database in SQL Server 2005, then performed a full backup,

storing the backup file on the C: drive for quick access. We used that backup file to restore the server between test runs. In the SQL Server 2005 database build, we did not include the WITH(FORCESEEK) clause in the BROWSE_BY_ACTOR and BROWSE_BY_TITLE stored procedures, as the feature did not exist in SQL Server 2005. When we restored the backups for use in SQL Server 2016, we added those clauses back to the stored procedures.

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. Apart from this file size modification, we created and loaded the database schema according to the DVD Store documentation. Specifically, we followed the steps below:

1. Generate the data and create the database and file structure using database creation scripts in the DS2 download. Make size modifications specific to 20GB database and the appropriate changes to drive letters.
2. Transfer the files from the Linux data generation system to a Windows system running SQL Server 2005.
3. Create database tables, stored procedures, and objects using the provided DVD Store scripts.
4. Set the database recovery model to bulk-logged to prevent excess logging.
5. Load the data you generated into the database. For data loading, use the import wizard in SQL Server Management Studio. Where necessary, retain options from the original scripts, such as Enable Identity Insert.
6. Create indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
7. Update statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
8. On the SQL Server instance, create a ds2user SQL Server login using the following Transact-SQL (T-SQL) 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. Set the database recovery model back to full.
10. Create the necessary full text index using SQL Server Management Studio.
11. Create a database user and mapped this user to the SQL Server login.
12. Perform a full backup of the database. Note: This backup allowed us to restore the databases to a pristine state relatively quickly between tests.
13. We used the backup created in Step 12 in the legacy environment, as SQL Server 2005 does not support FORCESEEK. To enable FORCESEEK on the database used in the Dell PowerEdge R830 environment, we restored the backup from Step 12 in a SQL Server 2016 instance. We then edited the stored procedures

BROWSE_BY_ACTOR and BROWSE_BY_TITLE to use FORCESEEK. We then made a new backup of the database in SQL Server 2016.

Figure 8 shows our initial file size modifications.

Logical name	Filegroup	Initial size (MB)
Database files		
primary	PRIMARY	4
cust1	DS_CUST_FG	8,500
cust2	DS_CUST_FG	8,500
ind1	DS_IND_FG	5,120
ind2	DS_IND_FG	5,120
ds_misc	DS_MISC_FG	500
orders1	DS_ORDERS	4,015
orders2	DS_ORDERS	4,015
Log files		
ds_log	Not applicable	16,384

Figure 8: Our initial file size modifications.

Configuring the database workload client

For our testing, we used a virtual client for the Microsoft SQL Server client. To create this client, we installed Windows Server 2008 R2, assigned a static IP address, and installed .NET 3.5.

Running the DVD Store tests

We created a series of batch files, SQL scripts, and shell scripts to automate the complete test cycle. DVD Store outputs an orders-per-minute metric, which is a running average calculated through the test. In this report, we report the last OPM that each client/target pair reported.

Each complete test cycle consisted of general steps:

1. Clean up prior outputs from the target system and the client driver system.
2. Drop the database from the target.
3. Restore the database on the target.
4. Shut down the target.
5. Reboot the host and client system.
6. Wait for a ping response from the server under test and the client system.
7. Let the test server idle for 10 minutes.
8. Start the DVD Store driver on the client.

We used the following DVD Store parameters for testing:

```
ds2sqlserverdriver.exe --target=<target_IP> --ramp_rate=10 --run_time=30 --
n_threads=24 --db_size=20GB --think_time=0 --detailed_view=Y --warmup_time=15 --
report_rate=1 --csv_output=<drive path>
```

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