

SUPPORT MORE VMs WITH A MODERN DELL™ POWEREDGE™ ENVIRONMENT

Dell PowerEdge R930 server powered by Intel® Xeon® processors E7-8860 v4 and Dell Storage SC9000 all-flash array with Microsoft® SQL Server® 2016

AND GET OVER

6X

THE DATABASE PERFORMANCE

with under
1ms response time
and support for
twice as many VMs



versus an HP ProLiant DL580 G7 solution and legacy SAN with Microsoft SQL Server 2005

Is your company still using SQL Server 2005? If so, you likely need to migrate in response to Microsoft's discontinued extended support for that version in April 2016. If your databases are running on older servers, upgrading your hardware at the same time you move to a newer version of SQL Server is a smart move.

In the Principled Technologies datacenter, we found that running SQL Server 2016 in a modern Dell environment—a PowerEdge R930 server, powered by Intel Xeon E7-8860 v4 processors, QLogic® QLE2692 16Gb Fibre Channel (FC) adapter with StorFusion Technology, and Dell SC9000 all-flash storage—achieved more than six times the database work of an older HP ProLiant DL580 G7 server with legacy HDD SAN storage, while delivering a storage response time of less than 1 millisecond.

Being able to consolidate existing work onto fewer servers is essential to making your datacenter more efficient.



DELL MODERN ENVIRONMENT DELIVERS

Moving from large numbers of older servers using HDD storage arrays to fewer, more powerful servers that leverage the advantages of all-flash storage is an excellent way to modernize your datacenter. As you streamline your hardware, your company could realize benefits in many areas. Some possible benefits include less physical space needed, lowered power and cooling expenses, a lightened burden on IT admins who have fewer servers to manage, and the potential for fewer costly software licenses.

For companies migrating their database workloads to SQL Server 2016 and considering new servers to maximize the value of the move, the Dell PowerEdge R930 is an excellent option. SQL Server 2016 features OS-maximum cores and memory as well as in-memory OLTP, meaning that it is well poised to take advantage of the vast resource pools new servers offer. The Dell PowerEdge R930 is a 4U, four-socket server that features Intel Xeon processors E7-8860 v4, provides up to 96 cores and 192 threads, and supports up to 12 TB of DDR4 RAM, making it a perfect candidate to provide large amounts of CPU and memory resources to SQL Server 2016 applications.

The all-flash Dell Storage SC9000 array, geared toward large-scale storage, high-end workloads, and distributed enterprise environments, also helps speed up your SQL Server applications by offering 16Gb Fibre Channel, 12Gb SAS, and hardware redundancy to keep your data moving quickly and safely.

To quantify the benefits a company running SQL Server 2005 workloads on an older server with HDD storage could experience by upgrading to SQL Server 2016 on the modern PowerEdge R930-SC9000 platform, we set up virtual machines in both environments and ran an online transaction processing (OLTP) workload. Figure 1 illustrates our test environment.

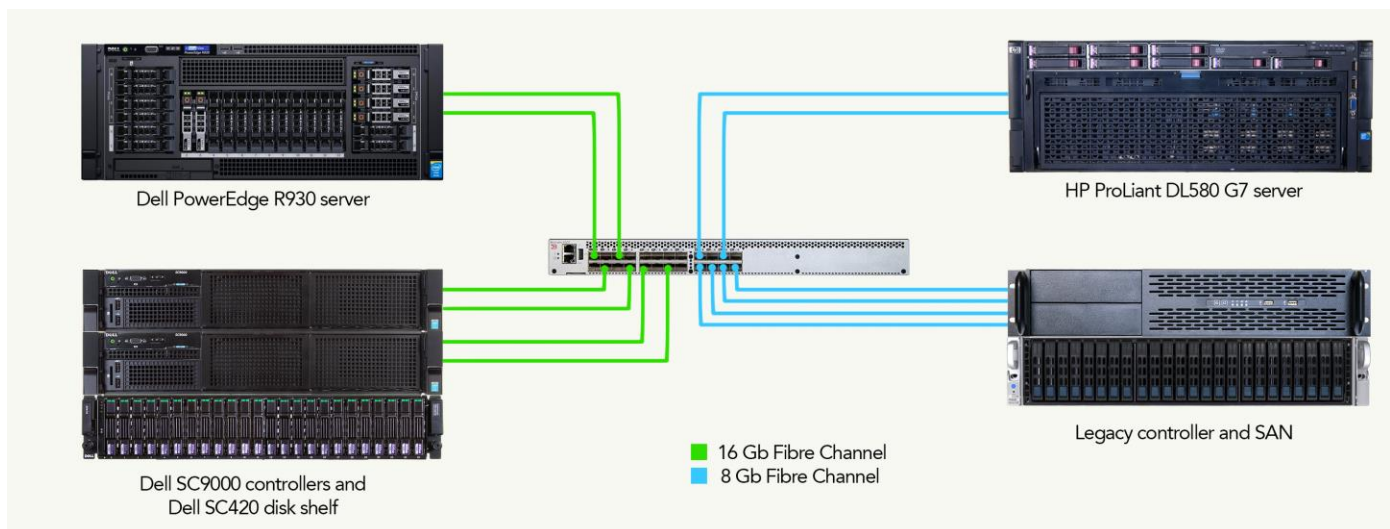


Figure 1: Our testbed.

Our legacy environment, a 2010 HP ProLiant DL580 G7 using HDD-based storage from 2012, ran 12 VMs, each handling an average of 9,159 orders per minute in our test configuration. We configured the modern Dell environment to run 24 VMs, each handling an average of 30,296 orders per minute. That’s twice as many VMs, each doing more than three times the work than the original VMs. As Figure 2 illustrates, that translates to 6.6 times the work that Dell PowerEdge R930 and Dell Storage SC9000 array could accomplish together.

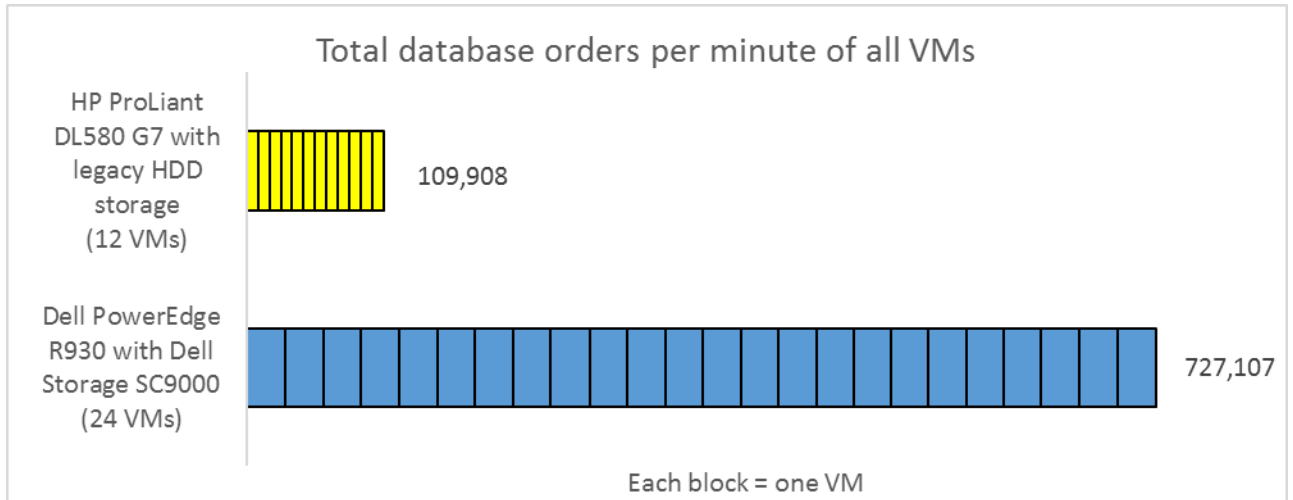


Figure 2: The 24 SQL Server 2016 VMs running on the Dell modern environment performed more than 6 times the work of the 12 SQL Server 2005 VMs running on the legacy environment.

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 R930 and legacy environments, we sized our VMs to utilize the full amount of RAM each server offered. Each legacy VM had four vCPUs, 9,728 MB of RAM, and a 20GB SQL 2005 database. Each of the R930’s VMs had four vCPUs, 9,216 MB of RAM, and a 20GB SQL 2016 database. The Dell PowerEdge R930 environment was able to support 24 VMs and the legacy environment was able to support only 12 in this configuration.

Figure 3 shows the median number of orders per minute that the two solutions were able to process in our testing. As it shows, each of the 24 VMs on the Dell solution achieved more than three times as many orders per minute than each of the 12 legacy VMs did, resulting in an overall difference of greater than six times the output on the Dell solution.

	Dell PowerEdge R930 with Dell Storage SC9000 array (SQL Server 2016)	HP ProLiant DL580 G7 with legacy HDD storage (SQL Server 2005)
VM 1	30,651	9,102
VM 2	30,882	9,125
VM 3	30,290	9,210
VM 4	29,967	9,065
VM 5	31,158	9,208
VM 6	29,366	9,080
VM 7	31,104	9,200
VM 8	29,559	9,215
VM 9	31,509	9,189
VM 10	29,476	9,094
VM 11	31,303	9,243
VM 12	29,804	9,177
VM 13	30,142	
VM 14	29,889	
VM 15	30,344	
VM 16	30,455	
VM 17	29,220	
VM 18	29,409	
VM 19	30,577	
VM 20	29,701	
VM 21	29,930	
VM 22	30,864	
VM 23	30,425	
VM 24	31,082	
Total	727,107	109,908

Figure 3: The 24 SQL Server 2016 VMs running on the Dell modern environment delivered more than 6 times the work of the 12 SQL Server 2005 VMs running on the legacy environment.

One of the most crucial metrics for determining consistent, fast database performance is latency. In our tests, the applications running on the SC9000 storage array were able to support over 700,000 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

As support ends for aging software and applications, such as SQL Server 2005, migrating to a new, updated version is inevitable and necessary. This migration presents a unique opportunity to upgrade the hardware running these applications, too—a real change to your datacenter.

In our test, the modern four-socket Dell PowerEdge R930 powered by Intel Xeon E7-8860 v4 processors working with the powerful Dell Storage SC9000 array and running SQL Server 2016 got over six times the database performance of a legacy solution running SQL Server 2005. The modern PowerEdge solution also delivered a faster response time.

As you move to a more modern, fully featured database software, why not also move to a powerful, modern server hardware solution as well? Consolidating your SQL Server workloads from legacy servers onto Dell PowerEdge R930 servers powered by Intel Xeon E7 v4 processors can let you do more with less, streamline your datacenter, and reduce costs.

APPENDIX A – ABOUT THE COMPONENTS

About the Dell PowerEdge R930

The Dell PowerEdge R930 is a 4U, four-socket server that features the latest from the Intel Xeon processor E7 series. It is a versatile system designed to handle demanding workloads such as large-scale virtualization and massive databases—workloads that are becoming increasingly important for the day-to-day operations of enterprise organizations.

Under the hood, the R930 boasts a bevy of high-class specifications that make it a powerful tool for the modern datacenter. These specifications include:

- 96 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 6 TB for more memory-intensive use cases.
- 24 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 24 HDD/SSD drive bays, and one with 16 HDD/SSD drive bays and 8 PCIe SSD drive bays—allow you to configure the PowerEdge R930 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 R930, visit www.dell.com/us/business/p/poweredge-r930/pd.

About the new Intel Xeon E7 v4 processor family

Intel designed the new Intel Xeon E7 v4 processor family to support demanding enterprise workloads—particularly analytics workloads—by featuring up to 24 cores and 48 threads per socket to offer strong performance and scalability. The Intel Xeon E7 v4 processor family supports up to 24TB DDR4 3DS LRDIMM memory per eight-socket server, which, according to Intel, can provide flexibility and room to grow.

The Intel Xeon E7 v4 processor family supports all the previous reliability, availability, and serviceability features of previous processor releases to support critical workloads. This processor family also includes a new version of Intel® Run Sure Technology with more features, as well as other new security, virtualization, and orchestration features. For more information about the Intel Xeon E7 v4 processor product family, visit www.intel.com.

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

According to Microsoft, “SQL Server 2016 is the biggest leap forward in Microsoft data platform history. Gain real time insights across your transactional and analytical data with a scalable database platform that has everything built in, from unparalleled in-memory performance, new security innovations and high availability, to advanced analytics that make mission-critical applications intelligent.”

Learn more at <https://www.microsoft.com/en-us/server-cloud/products/sql-server/>

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. To download DS2, go to <https://github.com/dvdstore>.

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 R930
General	
Number of processor packages	4
Number of cores per processor	18
Number of hardware threads per core	2
System power management policy	Performance
CPU	
Vendor	Intel
Name	Xeon
Model number	E7-8860 v4
Socket type	FCLGA2011
Core frequency (GHz)	2.20
Bus frequency	3x 9.6 GT/s
L1 cache	32KB + 32KB (per core)
L2 cache	256KB (per core)
L3 cache	45MB
Platform	
Vendor and model number	Dell PowerEdge R930
Motherboard model number	0Y4CNCX19
BIOS version	2.0.1
Integrated LOM	Intel I350-t 4P Gigabit
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 H730P
Firmware version	25.2.2-0004

System	Dell PowerEdge R930
Firmware	
Lifecycle Controller / iDRAC	2.13.13.10
Driver Pack	7.3.2.1

Figure 4: Configuration information for the Dell PowerEdge R930.

System	HP ProLiant DL580 G7
General	
Number of processor packages	4
Number of cores per processor	10
Number of hardware threads per core	2
System power management policy	Performance
CPU	
Vendor	Intel
Name	Xeon
Model number	E7-4870
Socket type	LGA1567
Core frequency (GHz)	2.40
Bus frequency	6.4 GT/s
L1 cache	32KB + 32KB (per core)
L2 cache	256KB (per core)
L3 cache	30MB
Platform	
Vendor and model number	HP ProLiant DL580 G7
Motherboard model number	583367-001
BIOS version	P65
Integrated LOM	HP NC375i 4P Gigabit
Memory module(s)	
Total RAM in system (GB)	128GB
Vendor and model number	Samsung M393B2K70CM0
Type	PC3-8500
Speed (MHz)	1,066
Speed running in the system (MHz)	1,066
Size (GB)	16GB
Number of RAM module(s)	8
Chip organization	Double-sided
Rank	Dual
RAID controller	
Vendor and model number	Smart Array P410i
Firmware version	V6.6.0

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 level	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	1
Number of disks per shelf	24
Type of disk	HDD 15k
Disk capacity	600 GB
Aggregates	1
Disks per aggregate	24
Volumes	3 (OS, data, and logs)
RAID level	Dual Parity

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 June 14, 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 cache and created a single large volume for the VMDKs. On the legacy storage, we created separate volumes for OS, Data, and 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 R930. 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 R930 environment. We installed SQL Server 2005 on the legacy VMs and SQL Server 2016 on the Dell PowerEdge R930 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 in order to fully utilize the host memory.

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 R930 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 R930 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 R930 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 R930 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=32 --db_size=20GB --think_time=0 --detailed_view=Y --warmup_time=15 --
report_rate=1 --csv_output=<drive path>
```

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