Support the user experience

14,049 online transactions per second

Draw insights from information

- Process **48 separate 300GB** database query sets in **46 minutes**
- **48,391 IOPS** and **4,857 MB/s throughput**

Use data center space efficiently

with a cluster that can handle **8 VMs** doing heavy OLAP analytics or **12 VMs** processing robust OLTP requests

Give your business the benefits of online transaction processing and data analytics with less hassle and delay

Dell EMC Ready Solutions for Microsoft SQL is a streamlined solution for your database applications

For many companies, database applications are the backbone of business. E-commerce relies on online transaction processing, and informed decision-making requires analyzing the rich troves of data your business collects. For such critical operations, a robust solution is a must.

Dell EMC™ Ready Solutions for Microsoft® SQL is a solution that comes pre-configured to meet these business needs. At Principled Technologies, we set up Dell EMC Ready Solutions for Microsoft SQL that included four Dell EMC PowerEdge™ R740xd servers in a Microsoft Storage Spaces Direct (S2D) cluster environment running SQL Server® 2017. We put this solution through its paces, first running an online transactional processing (OLTP) workload and then performing online analytical processing (OLAP) data warehouse queries.

On both database applications, the Dell EMC Ready Solutions for Microsoft SQL achieved levels of performance that could serve a company with growing database requirements well—either by delivering a strong user experience or by providing valuable data analysis.

Juan is a hypothetical character, but the decision he faces is real. At Principled Technologies, we tested the performance of the Dell EMC Ready Solutions for Microsoft SQL (see the science addendum to this report for all of the details). Read on to see how it could handle your company's performance requirements.

Juan wonders, "Should we buy a preconfigured solution or assemble our own?"

Juan manages IT at a mid-sized lumber wholesaler. Most of his efforts focus on keeping the ordering system running optimally. The last thing a salesperson working with a customer on a large order should encounter is an error or delay.

Last month, Juan attended an industry conference where almost every session mentioned data analysis and how it can fuel business decisions. He realized his company had been lagging in this area and came back enthusiastic about catching up. The server they've been using to run their website—and the storage it uses—has been keeping up with demand, but just barely. Adding an analytics workload will tax the server further, so it's definitely time to invest in a new solution.

Back when he was putting together the current server setup, Juan did a lot of research. All the components had to work together and the solution had to meet their needs for performance and storage capacity. He did a pretty good job, but he spent weeks figuring out what to order. Once the gear arrived, he discovered a few details he'd overlooked. Working those out took even more time.

Now, he doesn't have the luxury of time. He's leaning toward Dell EMC Ready Solutions for Microsoft SQL, a preconfigured solution that includes all the hardware and software necessary for the company's database applications. Its certified components and validated building blocks would greatly simplify the ordering process and reduce the chance of incompatibilities or missing elements. Juan would fine-tune the package, but he wouldn't have to design, configure, and validate the hardware himself. Before he can make the decision, he needs to know what level of performance the solution supports.

Dell EMC Ready Solutions for Microsoft SQL

To get the best SQL Server performance, you need the right architectural design and sizing. According to Dell EMC, "Ready Solutions for Microsoft SQL is designed for superior performance, significant cost savings and future-ready scalability."[1] The Dell EMC Ready Solutions for Microsoft SQL is available in a variety of sizes to accommodate your needs.

Dell EMC PowerEdge R740xd

The 14th generation Dell EMC PowerEdge R740xd offers strong database performance with a variety of storage configuration options. It can support up to 24 NVMe drives (we tested with four SSDs and eight HDDs per server) and is powered by Intel® Xeon® Scalable processors.[2]

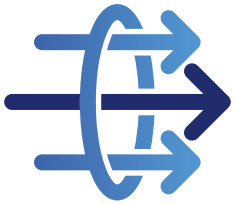
Microsoft SQL Server 2017

According to Microsoft, SQL Server 2017 Standard helps users "find rich programming capabilities, security innovations, and fast performance for mid-tier applications and data marts" with features such as end-to-end database security, enhanced in-memory performance, basic reporting and analytics, and hybrid scenarios.[3]

Help the sales team respond to customers in real time

Juan's most important customers are the sales team, and their most important customers are the retailers and contractors who purchase the company's lumber. When a salesperson is on the phone with a buyer from a major account, she relies on the company ordering system to quote up-to-the-minute prices and delivery estimates. Having to ask a busy buyer to wait while the system responds would be embarrassing, and Juan would hear about it.

The business need:	How Dell EMC Ready Solutions for Microsoft SQL meets that need:	What this means for Juan and his company:
Strong online **transaction** processing performance.	In our testing, a cluster handled **14,049 online transactions** per second.	The OLTP performance of the Dell EMC Ready Solution for Microsoft SQL will help keep the sales team t the top of their game.



Analyze data to improve business decisions

The company's upper-level leadership team is made up of sharp people who know the lumber business inside and out. Over the years, Juan has seen them make solid decisions based on this knowledge and on their instincts. But after learning how other companies are analyzing their data—such as sales and customer information—to better see trends and gain insight into what is and isn't working, he suspects they could do even better. He's made a presentation to the team, and they're eager to pursue an analytics solution. Now he needs to put something in place quickly!

The business need:	How Dell EMC Ready Solutions for Microsoft SQL meets that need:	What this means for Juan and his company:
Strong online **analytical** processing performance.	In our testing, a cluster processed **48 separate 300GB** data warehouse query sets in **46 minutes**. The solution also delivered **48,391 IOPS** and **4,857 MB/s throughput** on a data analysis workload.	The OLAP performance of the Dell EMC Ready Solution for Microsoft SQL will help management make better business decisions based on data.

Boost the bottom line by using datacenter space efficiently

Meeting the online transaction demands of the sales team is Juan's highest priority, and now that the leadership group understands the value of a data analytics solution, supporting that solution will be a strong second priority. Datacenter space is limited, though, and fitting everything in will be a challenge.

The business need:

A database server-and-storage solution that packs a great deal of compute power into a small package.

How Dell EMC Ready Solutions for Microsoft SQL meets that need:

In our testing, a cluster could handle either **8 VMs** doing heavy OLAP analytics or **12 VMs** processing robust OLTP requests.

What this means for Juan and his company:

With two clusters in a single rack, he can devote 12 VMs dedicated to the ordering system and other OLTP applications and 8 VMs to run the heavy-hitting analytical databases. Maintaining two similar clusters in one small space will help keep operational expenses down as well.

Conclusion

Our hands-on testing shows that the Dell EMC Ready Solutions for Microsoft SQL can handle both robust OLTP transaction applications and heavy OLAP analysis workloads. In our OLTP scenario, this server and hardware combination supported 12 VMs processing a total of 14,049 online transactions per second. In our data analysis scenario, it supported eight VMs processing 48 separate large-block 300GB database query sets in 46 minutes and delivered 48,391 IOPS with 4,857 MB/s throughput.

These results demonstrate what the Dell EMC Ready Solutions for Microsoft SQL has to offer data center managers like Juan: the storage density and compute power necessary to give users the service they demand and to support better-informed decision-making. It also lets them start reaping these business benefits quickly by eliminating the time and worries of designing, configuring, and testing hardware themselves.

1 Ready Solutions for Microsoft SQL, accessed June 1, 2018, http://www.dell.com/en-us/work/learn/software-platforms-sql-server

2 Dell EMC, "Dell EMC R740xd spec sheet," accessed May 8, 2018, http://i.dell.com/sites/doccontent/shared-content/data-sheets/en/Documents/poweredge-r740xd-spec-sheet.pdf

3 Microsoft SQL Server datasheet, accessed May 8, 2018, https://www.microsoft.com/en-us/sql-server/sql-server-2017-editions

Disclaimer:

The content on the following pages includes appendices and methodologies from our hands-on work.

We will publish this content as a separate document linked to the report.

We must receive your approval on both the report and this document before taking them public simultaneously.

The science behind the report:

Give your business the benefits of online transaction processing and data analytics without delay

This document describes what we tested, how we tested, and what we found. To learn how these facts translate into real-world benefits, read the report "Give your business the benefits of online transaction processing and data analytics without delay."

On March 19, 2018, 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 May 21, 2018.

Our test approach

We ran the Benchmark Factory TPC-E-like workload to measure the transactional database performance of the Dell EMC™ Ready Solutions for Microsoft® SQL, and the HammerDB TPC-H-like workload to measure the analytical database performance. We sized both workloads and determined the maximum number of VMs for each test to fit the working set into the cache tier according to Microsoft recommendations. In addition to generating load on the storage, the OLTP workload is CPU intensive. During this phase of testing, each node in the cluster averaged 69 percent CPU utilization, showing a good level of resource saturation for a sustainable workload. Because the OLAP workload is less CPU intensive, but still disk intensive, we allocated plenty of RAM to each VM to help with the load. Each node utilized nearly 60 percent of the RAM in addition to having heavy disk throughput, showing a good, balanced use of resources. While your databases and workloads will vary in size, intensity, and number from those in our tests, we have shown the kind of performance customers can expect from the solution in these two areas under a reasonable load.

Our results

The table below presents our OLAP findings in detail.

Complete query set (min)

	User 1	User 2	User 3	User 4	User 5	User 6	Max query length
VM01	42.72	43.45	42.35	43.65	41.48	40.95	43.65
VM02	44.65	44.30	44.43	43.50	43.78	44.52	44.65
VM03	36.87	34.27	38.68	38.45	35.20	34.18	38.68
VM04	44.08	45.83	46.68	46.55	45.85	46.50	46.68
VM05	43.03	42.90	43.03	41.08	41.80	42.97	43.03
VM06	38.70	41.47	38.72	41.50	38.92	39.35	41.50
VM07	43.08	41.70	42.17	42.42	43.23	43.57	43.57
VM08	41.62	43.22	42.97	38.60	42.20	40.98	43.22

Cluster storage volume performance

	Reads/sec	Writes/sec	Total IOPS	MB read/s	MB write/s	Total MB/s	Average RAM used/node (GB)
Cluster	44,060.60	4,331.03	48,391.63	4,665.79	191.85	4,857.64	108.84

The table below presents our OLTP findings in detail.

Benchmark Factory statistics

System under test	Transactions per second	CPU %	System under test	Transactions per second	CPU %
Node1			**Node2**		
VM01	1,027.18	69.80	**VM04**	1,027.07	69.40
VM02	1,447.67		**VM05**	1,445.61	
VM03	1,024.23		**VM06**	1,040.74	
Node3			**Node4**		
VM07	1,035.64	69.60	**VM10**	1,024.16	68.74
VM08	1,441.30		**VM11**	1,457.13	
VM09	1,042.53		**VM12**	1,036.23	
Summary					
Total transactions per second					14,049.49
Average transactions per second per VM					1,170.79

The tables below present our TPC-E findings in detail.

TPC-E-like Benchmark Factory results

VM	TPS	Response time (ms)	Transaction time (ms)
Node 1			
VM01	1,027.18	12	47
VM02	1,447.67	9	34
VM03	1,024.23	11	48
Node 2			
VM04	1,027.07	12	48
VM05	1,445.61	9	34
VM06	1,040.74	11	47
Node 3			
VM07	1,035.64	11	47
VM08	1,441.30	9	34
VM09	1,042.53	11	47
Node 4			
VM10	1,024.16	11	48
VM11	1,457.13	9	33
VM12	1,036.23	11	47
Summary			
Total	**14,049.49**		
Average	**1,170.79**	**10.5**	**42.83**

TPC-E-like full-cluster perfmon statistics

	Disk Read/s	Disk Write/s	MB/s Read	MB/s Write	Disk Read Lat (ms)	Disk Write Lat (ms)	Avg. Block Size Read (KB)	Avg. Block Size Write (KB)	RAM used (GB) (avg./ node)	CPU% (avg./ node)
Total	46,531.35	14,247.55	786.69	126.57						
Average	11,632.84	3,561.89	196.67	31.64	0.45	1.32	15.53	9.60	90.58	68.96

The tables below present our TPC-H findings in detail.

TPC-H-like HammerDB results (min)

	User 1	User 2	User 3	User 4	User 5	User 6	Max query length
VM01	42.72	43.45	42.35	43.65	41.48	40.95	43.65
VM02	44.65	44.30	44.43	43.50	43.78	44.52	44.65
VM03	36.87	34.27	38.68	38.45	35.20	34.18	38.68
VM04	44.08	45.83	46.68	46.55	45.85	46.50	46.68
VM05	43.03	42.90	43.03	41.08	41.80	42.97	43.03
VM06	38.70	41.47	38.72	41.50	38.92	39.35	41.50
VM07	43.08	41.70	42.17	42.42	43.23	43.57	43.57
VM08	41.62	43.22	42.97	38.60	42.20	40.98	43.22

TPC-H-like full-cluster perfmon statistics summary

	Disk Read/s	Disk Write/s	MB/s Read	MB/s Write	Disk Read Lat (ms)	Disk Write Lat (ms)	Avg. Block Size Read (KB)	Avg. Block Size Write (KB)	RAM used (GB) (avg./ node)	CPU% (avg./ node)
Total	44,060.60	4,331.03	4,729.93	256.41						
Average	11,015.15	1,082.76	1,182.48	64.10	27.81	19.99	61.28	55.94	108.84	21.43

System configuration information

The table below presents detailed information on the systems we tested.

Server configuration information	Dell EMC™ PowerEdge™ R740xd
BIOS name and version	Dell 1.3.7
Non-default BIOS settings	N/A
Operating system name and version/build number	Windows Server® 2016
Date of last OS updates/patches applied	3/14/2018
Power management policy	Custom
Processor	
Number of processors	2
Vendor and model	Intel® Xeon® Gold 6130
Core count (per processor)	16
Core frequency (GHz)	2.10
Stepping	4
Memory module(s)	
Total memory in system (GB)	192
Number of memory modules	12
Vendor and model	Hynix® HMA82GR7AFR8N-VK
Size (GB)	16
Type	PC4-2666
Speed (MHz)	2666
Speed running in the server (MHz)	2666
Storage controller	
Vendor and model	Dell HBA330 Mini
Cache size (GB)	N/A
Firmware version	13.17.03.05
Driver version	N/A
Local storage 1	
Number of drives	2
Drive vendor and model	Intel SSDSCKJB240G7R
Drive size (GB)	240
Drive information (speed, interface, type)	m.2 SSD
Local storage 2	
Number of drives	4
Drive vendor and model	Toshiba THNSF8800CCSE

Server configuration information	Dell EMC™ PowerEdge™ R740xd
Drive size (GB)	800
Drive information (speed, interface, type)	6 Gb/s, SATA, SSD
Local storage 3	
Number of drives	8
Drive vendor and model	Toshiba MG04ACA4
Drive size (GB)	4,096
Drive information (speed, interface, type)	6 Gb/s, 7.2K SATA, HDD
Network adapter	
Vendor and model	Mellanox® ConnectX-4 LX 25GbE SFP
Number and type of ports	2 x 25GbE
Driver version	14.20.18.22
Cooling fans	
Vendor and model	Delta PFR0612DHE-C
Number of cooling fans	6
Power supplies	
Vendor and model	Dell 05RHVVA00
Number of power supplies	2
Wattage of each (W)	750

How we tested

Configuring the out-of-band management switch

We used a 1GbE Dell EMC Networking S3048 switch for our out-of-band (OOB) management of the Microsoft® Storage Spaces Direct (S2D) cluster. We configured four ports with the appropriate VLAN for our S2D iDRAC connections. We also configured one port for our AD & S2D management VMs, and another port to connect our OOB switch to the TOR switch. For details on our switch configuration, see the Switch configurations section.

Configuring the top-of-rack switch

We used a Dell EMC Networking S5048 25GbE switch for our cluster networking traffic. We placed all cluster-facing ports into hybrid mode, enabled datacenter bridging (DCB), and enabled priority flow control on all ports. For details on our switch configuration, see the Switch configurations section.

Configuring the infrastructure VM

We used Windows Server 2016 VM as our Active Directory and DNS server. On this VM, we added the Active Directory Domain Service and the DNS Server roles, and created a new domain for our test cluster.

Configuring the cluster nodes

We used four Dell EMC PowerEdge R740xd servers for our test cluster. We configured the iDRAC and BIOS on each server to match the pre-deployment checklist provided by Dell in the Ready Node deployment guide. We first installed Windows Server 2016 Datacenter Edition onto a 240GB virtual disk, consisting of two m.2 SSDs in a RAID 1 pair and separate from the drives designated for cluster storage. We then created a SET switch, configured the network adapters with IP addresses, and joined each server to the domain. Finally, we ran the network and storage commands to enable RDMA and Storage Spaces Direct. We chose the manual deployment method, and performed the following steps for each server:

Installing Windows Server 2016

1. Boot the server to the Windows Server 2016 installation media. We used the BMC console virtual media to mount the ISO image and install remotely.
2. At the prompt, to boot from the CD/DVD location, press any key.
3. Click Next.
4. Click Install Now.
5. Select Windows Server 2016 Datacenter Edition (Desktop Experience), and click Next.
6. Check I accept the license terms, and click Next.
7. Select the 240GB OS drive, and click Next.
8. After installation, enter a password for Administrator, and click Finish.

Installing server roles and features

1. To install the required roles and features for Storage Spaces Direct, open a PowerShell window as the domain administrator, and run the following command:

```
Install-WindowsFeature -Name "Data-Center-Bridging","Failover-Clustering","Hyper-V","RSAT-Clustering-PowerShell","Hyper-V-PowerShell"
```

Changing the host name

1. In the open PowerShell window, run the following command to change the hostname, and restart the server.

```
Rename-Computer -NewName S2D-Node01 -Restart
```

Configuring the VM switch and adapters

1. As the domain administrator, open a PowerShell window, and run the following commands to create and configure the VM switch and adapters:

```
New-VMSwitch -Name S2DSwitch -AllowManagementOS 0 -NetAdapterName 'SLOT 4 PORT 1','SLOT 4 PORT 2' -MinimumBandwidthMOde Weight -Verbose
```

```
Add-VMNetworkAdapter -ManagementOS -Name 'Management' -SwitchName S2DSwitch -Passthru | Set-
VMNetworkAdapterVLan -Access -VlanID 101 -Verbose

Add-VMNetworkAdapter -ManagementOS -Name 'Storage1' -SwitchName S2DSwitch -Passthru | Set-
VMNetworkAdapterVLan -Access -VlanID 102 -Verbose


Add-VMNetworkAdapter -ManagementOS -Name 'Storage2' -SwitchName S2DSwitch -Passthru | Set-
VMNetworkAdapterVLan -Access -VlanID 103 -Verbose

New-NetIPAddress -InterfaceAlias 'vEthernet (Management)' -IPAddress 192.168.100.1 -PrefixLength 24
-AddressFamily IPv4 -Verbose

Set-DNsClientServerAddress -InterfaceAlias 'vEthernet (Management)' -ServerAddresses 192.168.100.10

New-NetIPAddress -InterfaceAlias 'vEthernet (Storage1)' -IPAddress 192.168.101.1 -PrefixLength 24
-AddressFamily IPv4 -Verbose

New-NetIPAddress -InterfaceAlias 'vEthernet (Storage2)' -IPAddress 192.168.102.1 -PrefixLength 24
-AddressFamily IPv4 -Verbose
```

Joining the AD domain

1. As the domain administrator, open a PowerShell window, and run the following command to join the active directory domain:

```
$credential = Get-Credential
Add-Computer -DomainName test.local -Credential $credential -Restart
```

Configuring the network adapters for RDMA

1. As the domain administrator, open a PowerShell window.
2. To enable RDMA on the virtual adapters, run the following command:

```
Enable-NetAdapterRDMA -Name 'vEthernet (Storage1)', 'vEthernet (Storage2)'
```

3. To map the virtual adapters to the physical ports, run the following commands:

```
Set-VMNetworkAdapterTeamMapping -VMNetworkAdapterName "Storage1" -ManagementOS
-PhysicalNetAdapterName "SLOT 4 PORT 1"
Set-VMNetworkAdapterTeamMapping -VMNetworkAdapterName "Storage2" -ManagementOS
-PhysicalNetAdapterName "SLOT 4 PORT 2"
```

4. To enable RDMA for Live Migration Traffic, run the following command:

```
Set-VMHost -VirtualMachineMigrationPerformanceOption SMB
```

5. To set a network QoS policy, run the following commands:

```
New-NetQosPolicy -Name 'SMB' -NetDirectPortMatchCondition 445 -PriorityValue8021Action 3

New-NetQosTrafficClass -Name 'SMB' -Priority 3 -BandwidthPercentage 50 -Algorithm ETS

Enable-NetQosFlowControl -Priority 3

Disable-NetQosFlowControl -Priority 0,1,2,4,5,6,7

Enable-NetAdapterQos -InterfaceAlias 'SLOT 4 PORT 1','SLOT 4 PORT 2'

Set-NetQosDcbxSetting -Willing $false

Set-NetAdapterAdvancedProperty -Name 'SLOT 4 PORT 1' -DisplayName 'Dcbxmode' -DisplayValue 'Host in
charge'

Set-NetAdapterAdvancedProperty -Name 'SLOT 4 PORT 2' -DisplayName 'Dcbxmode' -DisplayValue 'Host in
charge'
```

Running the cluster validation tool

1. As the domain administrator, open a PowerShell window.
2. To validate the cluster configuration, run the following command:

```
Test-Cluster -Node S2D-Node01, S2D-Node02, S2D-Node03, S2D-Node04 -Include 'Storage Spaces Direct',
'Inventory', 'Network', 'System Configuration'
```

3. Open the cluster validation report, and ensure no failures have taken place. Verify that any warnings in the report are negligible, or correct the warnings before deployment.

Deploying the S2D cluster

1. As the domain administrator, open a PowerShell window.
2. To create a new Storage Spaces Direct cluster without storage (we will add storage later) , run the following command:

```
New-Cluster -Name S2DSystem -Node S2D-Node01, S2D-Node02, S2D-Node03, S2D-Node04 -StaticAddress
192.168.100.6 -NoStorage -IgnoreNetwork 192.168.101.0/24, 192.168.102.0/24 -Verbose
```

Enabling the S2D cluster

1. As the domain administrator, open a PowerShell window, and run the following command:

```
Enable-ClusterS2D -Verbose
```

Removing the host management network from Live Migration

1. As the domain administrator, open a PowerShell window, and run the following commands:

```
$clusterResourceType = Get-ClusterResourceType -Name 'Virtual Machine'

$hostNetworkID = Get-ClusterNetwork | Where-Object { $_.Address -eq '192.168.100.0' } | Select
-ExpandProperty ID

Set-ClusterParameter -InputObject $clusterResourceType -Name MigrationExcludeNetworks -Value
$hostNetworkID
```

Updating Hardware timeout for Spaces port

1. As the domain administrator, open a PowerShell window, and run the following commands:

```
Set-ItemProperty -Path HKLM:\SYSTEM\CURRENTCONTROLSET\SERVICES\spaceport\Parameters -Name HwTimeout
-Value 0x00002710 -Verbose

Restart-Computer -Force
```

Performing firmware, driver, and OS updates

1. To see what driver and firmware versions you have, as the domain administrator, open a PowerShell window, and run the following commands:

```
Get-PnpDevice | Select-Object Name, @{l='DriverVersion' ;e={(Get-PnpDeviceProperty -InstanceID
$_.InstanceID -KeyName 'DEVPKEY_Device_DriverVersion').Data}} -Unique
```

2. Go to support.dell.com and download the latest drivers and firmware (make sure that they're at least the minimum supported in the matrix: http://en.community.dell.com/techcenter/extras/m/white_papers/20444545).
3. Open Failover Cluster Manager.
4. Right-click the S2D Cluster.
5. Select More Actions→Shutdown Cluster…
6. Install all drivers and firmware that you downloaded.
7. Run Windows Update and reboot after the updates have completed.
8. Repeat steps 3–7 until you have installed all Windows updates.

Creating the volumes

1. As the domain administrator, open a PowerShell window.
2. Run the following command to create a 3TB OS and backup volume:

```
New-Volume -FriendlyName "Node01-OS" -FileSystem CSVFS_ReFS -StoragePoolFriendlyName "*S2D*" -Size
3TB -ResiliencySettingName Mirror
```

3. Run the following command to create a 3TB data volume:

```
New-Volume -FriendlyName "Node01-Data" -FileSystem CSVFS_ReFS -StoragePoolFriendlyName "*S2D*" -Size
3TB -ResiliencySettingName Mirror
```

4. Run the following command to create a 500GB log volume:

```
New-Volume -FriendlyName "Node01-Log" -FileSystem CSVFS_ReFS -StoragePoolFriendlyName "*S2D*" -Size
500GB -ResiliencySettingName Mirror
```

Creating the VMs

1. On one of the cluster nodes, open Hyper-V Manager and click New→Virtual Machine.
2. Click Next.
3. Type the name of the virtual machine into the Name field.

4. Change the storage location of the VM to the OS volume on the local node, and click Next.
5. Select Generation 2, and click Next.
6. Set the startup memory to 49,152 MB, and click Next.
7. Select the SET switch you created earlier, and click Next.
8. Select Attach a virtual hard disk later, and click Next.
9. Click Finish.
10. Right-click the virtual machine, and click Settings.
11. Click Add New Hardware, select SCSI Controller, and click OK.
12. Repeat step 11 two more times for a total of four SCSI Controllers.
13. Select the first SCSI Controller in the left-hand menu, click the Hard Drive selection in the right-hand menu, and click Add.
14. Select the new Hard Drive in the left-hand menu, and click New in the right-hand menu under Virtual hard disk.
15. Click Next.
16. Select Fixed Size, and click Next.
17. Name the Virtual Hard Disk and change the storage location to the OS volume on the local node.
18. Click Next.
19. Set the size to 40GB, and click Next.
20. Click Finish.
21. Repeat steps 13 through 20 on the second SCSI controller. Change the size of the Virtual Hard Disk to 420GB, and the storage location to the data volume on the local node.
22. Repeat steps 13 through 20 on the third SCSI controller. Change the size of the Virtual Hard Disk to 75GB, and the storage location to the log volume on the local node.
23. Repeat Steps 13 through 20 on the fourth SCSI controller. Change the size of the Virtual Hard Disk to 295GB, and the storage location to the OS volume on the local node.
24. Set the number of virtual processors to 16.
25. Change the automatic stop action to Shut Down.
26. Select the first SCSI controller in the left-hand menu, click the DVD Drive selection, and click Add.
27. Select ISO Image File, and click Browse...
28. Enter the location of the Windows Server 2016 installation media, and click Open.
29. Select Firmware in the left-hand menu, and change the boot order to the DVD drive.
30. Click Apply.
31. Click OK.
32. Power on the VM.
33. At the prompt, press any key to boot from the CD/DVD location.
34. Click Next.
35. Click Install Now.
36. Select Windows Server 2016 Datacenter Edition, and click Next.
37. Check I accept the license terms, and click Next.
38. Select the OS VHD, and click Next.
39. After installation, enter a password for Administrator, and click Finish.
40. Run Windows Updates and reboot when prompted.

Installing SQL Server 2017

1. Attach the installation media ISO for SQL Server 2017 to the VM.
2. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2017 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 no failures display, 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, and Client Tools Backwards Compatibility.
11. Click Next.
12. At the Instance Configuration screen, leave the instance default selection, 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 the Data Directories tab.
17. Change the database directory, the database log directory, and the backup directory storage locations to the data, log, and backup volumes.
18. Click the TempDB tab.
19. Change the number of files to 8.
20. Change the initial file size to 1,024 MB.
21. Change the Data Directory to the data volume.
22. Change the intial size of the log to 1,024 MB.
23. Change the Log Directory to the log volume.
24. Click Next.
25. At the Error and usage reporting screen, click Next.
26. At the Installation Configuration Rules screen, verify the absence of failures or relevant warnings, and click Next.
27. At the Ready to Install screen, click Install.
28. When SQL Server 2017 has finished installing, go to the Installation tab in the Installation Center, and click Install SQL Server Management Tools.
29. In the browser that pops up, click Download SQL Server Management Studio 17.X.
30. To open the installer , click on the download.
31. Click Run.
32. Click Install.
33. When the installation has completed, close the installation window.

Expanding TempDB & TempLog files

1. Open SQL Server Management Studio.
2. Expand Databases→System Databases
3. Right-click tempdb, and choose Properties.
4. Click Files, and enter a new Initial Size (MB) for both files. The size required will depend on the scale of your TPC-H database. We set to each tempdb file to 6 GB and templog to 20 GB to ensure more than enough space.
5. When the files have finished expanding, click OK.

Enabling Lock pages in memory

1. Click Start, and type gpedit.msc, and hit Enter.
2. In the Local Group Policy Editor, expand Computer Configuration→Windows Settings→Security Settings→Local Policies
3. Select User Rights Assignment.
4. In the right pane, scroll down to Lock pages in memory.
5. Right-click Lock pages in memory, and click Properties.
6. Click Add User or Group, and add your SQL user account `(NT SERVICE\MSSQLSERVER)`.
7. Click OK.

Creating a database

1. Open SQL Server Management Studio.
2. Right-click Databases→New Database.
3. Name the database. We named ours tpch.
4. To add seven more database files for a total of eight, click Add.
5. Name the database files, and click OK.

Installing HammerDB

1. Download the latest version of HammerDB from www.hammerdb.com/download.html
2. Double-click the .exe file, choose English, and click OK.
3. Click Yes.
4. Click Next.
5. Choose a destination location, and click Next.
6. Click Next.
7. Click Finish.

Populating the database

1. Open HammerDB, and click Options→Benchmark.
2. Choose MSSQL Server and TPC-H.
3. Expand SQL Server→TPC-H→Schema Build.
4. Double-click Options.
5. Choose 300 scale, and the number of virtual users corresponding to the number of CPU cores.
6. Check the Clustered Columnstore box.
7. Click OK.
8. Double-click Build. This build could take several hours.

Backing up the database

1. Open SQL Server Management Studio.
2. Right-click the TPC-H database, and click Tasks→Back up…
3. Choose a location to store the backup, and click OK.

Cloning the VMs

1. Shut down the gold VM.
2. Copy and paste the OS VHD file seven times. Place two of each VHD on the OS volume of each node. Repeat this process with the data, log, and backup VHDs, putting them on their respective volume on each node.

Running the test

After cloning the VMs, we joined each VM to the AD domain. We then ran the power test on each VM without refreshes to prime S2D and SQL for the throughput run. Since we wanted to show how much throughput we could get out of our S2D Ready Nodes, we ran through the queries at least once to get them all loaded into the cache. You can find the configurations we used for the power test and throughput test in HammerDB configurations. For our throughput run, we completed the following steps:

1. On each VM, open SQL Server Manager, and run the following query:

```
alter database tpch
set allow_snapshot_isolation on

alter database tpch
set read_committed_snapshot on
```

2. Close SQL Server Manager, and open HammerDB.
3. Select Options→Benchmark.
4. Choose MSSQL Server and TPC-H.
5. Expand SQL Server→TPC-H→Mode.
6. Double-click Options, and select Master Mode for the first VM.
7. Record the ID and hostname of the Master VM.
8. Repeat step 5 for the remaining VMs.
9. On each of the remaining VMs, double-click options, and select Slave Mode, filling in the ID and hostname fields with the ID and hostname of the Master VM.
10. Click OK.
11. On the Master VM, expand SQL Server→TPC-H→Schema Build
12. Double-click Options, and set the scale to 300. Click OK.
13. Expand Driver Script, and double-click Options.
14. Set MAXDOP to 8, and check the box for Refresh Function and Refresh Verbose.
15. Click OK.
16. Double-click Load.
17. Click the Master Distribution button to distribute the driver script to the seven slave VMs.
18. Expand Virtual User, and double-click Options.
19. Choose 7 Virtual Users, and check the boxes for Show Output, Log Output to Temp, and Use Unique Log Name.
20. Click OK.
21. Double-click Create users.
22. Start Perfmon to capture CPU, RAM, and disk counters on each VM and node in the cluster.
23. On the Master VM, click Start to begin the run.
24. When the run finishes, stop Perfmon.
25. Save the HammerDB results text file and the Perfmon output.
26. Open SQL Manager, delete the TPCH database, and create a new one by restoring from the backup file.
27. Repeat the test two more times, and take the median run.

Switch configurations

OOB S3048 switch

```
! Version 9.11(2.1)
! Last configuration change at Tue Feb 27 23:59:57 2018 by admin
! Startup-config last updated at Sat Mar 10 02:49:36 2018 by admin
!
boot system stack-unit 1 primary system://A
boot system stack-unit 1 secondary system://B
!
hostname OOB-S3048
!
protocol lldp
 advertise dot1-tlv port-protocol-vlan-id port-vlan-id
 advertise dot3-tlv max-frame-size
 advertise management-tlv management-address system-capabilities system-description system-name
 advertise interface-port-desc
!
redundancy auto-synchronize full
!
enable password level 15 7 b125455cf679b208977c4f7f88315f9a4bfb576bb4df134f
!
username admin password 7 297a4f435cb9010182895c1658f993e7
!
stack-unit 1 provision S3048-ON
!
interface GigabitEthernet 1/1
 description Node01:BMC
 no ip address
 switchport
 spanning-tree 0 portfast
 no shutdown
!
interface GigabitEthernet 1/2
 description Node02:BMC
 no ip address
 switchport
 spanning-tree 0 portfast
 no shutdown
!
interface GigabitEthernet 1/3
 description Node03:BMC
 no ip address
 switchport
 spanning-tree 0 portfast
 no shutdown
!
interface GigabitEthernet 1/4
 description Node04:BMC
 no ip address
 switchport
 spanning-tree 0 portfast
 no shutdown
!
interface GigabitEthernet 1/47
 description Infra Port3 Uplink
 no ip address
 portmode hybrid
 switchport
 spanning-tree 0 portfast
 no shutdown
!
interface GigabitEthernet 1/48
 description S5048 Management
 no ip address
 switchport
 spanning-tree 0 portfast
 no shutdown
!
```

```
interface TenGigabitEthernet 1/49
 description S5048 Uplink
 no ip address
!
 port-channel-protocol LACP
  port-channel 1 mode active
 no shutdown
!
interface ManagementEthernet 1/1
 ip address 192.168.11.11/16
 no shutdown
!
interface Port-channel 1
 no ip address
 portmode hybrid
 switchport
 no shutdown
!
interface Vlan 1
!untagged Port-channel 1
!
interface Vlan 11
 description Switch & BMC MGMT vlan
 no ip address
 tagged Port-channel 1
 untagged GigabitEthernet 1/1-1/4,1/47-1/48
 no shutdown
!
interface Vlan 100
 description MGMT VLAN
 no ip address
 tagged GigabitEthernet 1/47
 tagged Port-channel 1
 no shutdown
!
ip ssh server enable
!
line console 0
line vty 0
line vty 1
line vty 2
line vty 3
line vty 4
line vty 5
line vty 6
line vty 7
line vty 8
line vty 9
!
reload-type
 boot-type normal-reload
 config-scr-download enable
!
end
```

TOR S5048 switch

```
! Version 9.12(1.0)
! Last configuration change at Sat Mar 10 02:35:50 2018 by admin
! Startup-config last updated at Sat Mar 10 02:36:23 2018 by admin
!
boot system stack-unit 1 primary system://A
boot system stack-unit 1 secondary system://B
!
!
logging coredump stack-unit  1
logging coredump stack-unit  2
```

```
logging coredump stack-unit  3
logging coredump stack-unit  4
logging coredump stack-unit  5
logging coredump stack-unit  6
!
hostname Garcia-S5048
!
protocol lldp
 advertise dot1-tlv port-protocol-vlan-id port-vlan-id
 advertise dot3-tlv max-frame-size
 advertise management-tlv management-address system-capabilities system-description system-name
 advertise interface-port-desc
!
redundancy auto-synchronize full
!
enable password level 15 7 b125455cf679b208977c4f7f88315f9a4bfb576bb4df134f
!
username admin password 7 297a4f435cb9010182895c1658f993e7
!
stack-unit 1 provision S5048F-ON
!
interface twentyFiveGigE 1/1
 description Node01:Port1
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
 no shutdown
!
interface twentyFiveGigE 1/2
 description Node02:Port1
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
 no shutdown
!
interface twentyFiveGigE 1/3
 description Node03:Port1
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
 no shutdown
!
interface twentyFiveGigE 1/4
 description Node04:Port1
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
```

```
 no shutdown
!
interface twentyFiveGigE 1/17
 description Node01:Port2
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
 no shutdown
!
interface twentyFiveGigE 1/18
 description Node02:Port2
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
 no shutdown
!
interface twentyFiveGigE 1/19
 description Node03:Port2
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
 no shutdown
!
interface twentyFiveGigE 1/20
 description Node04:Port2
 no ip address
 mtu 9216
 portmode hybrid
 switchport
 spanning-tree rstp edge-port bpduguard
 spanning-tree 0 portfast
 dcb-policy buffer-threshold RDMA
 dcb-map RDMA
 no shutdown
!
interface twentyFiveGigE 1/47
 description Infra TeGi Port1 Uplink
 no ip address
 portmode hybrid
 switchport
 no shutdown
!
interface twentyFiveGigE 1/48
 description S3048 Uplink
 no ip address
!
 port-channel-protocol LACP
  port-channel 1 mode active
 no shutdown
!
interface ManagementEthernet 1/1
 ip address 192.168.11.12/16
 no shutdown
!
```

```
interface Port-channel 1
 description To S3048
 no ip address
 portmode hybrid
 switchport
 vlt-peer-lag port-channel 1
 no shutdown
!
interface Vlan 1
!untagged hundredGigE 1/49-1/54
!untagged Port-channel 1
!
interface Vlan 11
 no ip address
 tagged Port-channel 1
 untagged twentyFiveGigE 1/1-1/4,1/17-1/20,1/47
 no shutdown
!
interface Vlan 100
 description Node_MGMT
 no ip address
 tagged twentyFiveGigE 1/1-1/4,1/17-1/20,1/47
 tagged Port-channel 1
 no shutdown
!
interface Vlan 101
 description Storage01
 no ip address
 tagged twentyFiveGigE 1/1-1/4,1/17-1/20
 no shutdown
!
interface Vlan 102
 description Storage02
 no ip address
 tagged twentyFiveGigE 1/1-1/4,1/17-1/20
 shutdown
!
service-class dynamic dot1p
!
ip ssh server enable
!
dcb enable
!
dcb-map RDMA
 priority-group 0 bandwidth 50 pfc off
 priority-group 3 bandwidth 50 pfc on
 priority-pgid 0 0 0 3 0 0 0 0
!
line console 0
line vty 0
line vty 1
line vty 2
line vty 3
line vty 4
line vty 5
line vty 6
line vty 7
line vty 8
line vty 9
!
reload-type
 boot-type normal-reload
 config-scr-download enable
!
end
```

HammerDB configurations

Power test

```
#EDITABLE OPTIONS##################################################
set total_querysets 1 ;# Number of query sets before logging off
set RAISEERROR "false" ;# Exit script on SQL Server query error (true or false)
set VERBOSE "false" ;# Show query text and output
set maxdop 8 ;# Maximum Degree of Parallelism
set scale_factor 300 ;#Scale factor of the tpc-h schema
set authentication "windows";# Authentication Mode (WINDOWS or SQL)
set server {(local)};# Microsoft SQL Server Database Server
set port "1433";# Microsoft SQL Server Port
set odbc_driver {SQL Server Native Client 11.0};# ODBC Driver
set uid "sa";#User ID for SQL Server Authentication
set pwd "admin";#Password for SQL Server Authentication
set database "tpch";# Database containing the TPC Schema
set refresh_on "true" ;#First User does refresh function
set update_sets 1 ;#Number of sets of refresh function to complete
set trickle_refresh 1000 ;#time delay (ms) to trickle refresh function
set REFRESH_VERBOSE "false" ;#report refresh function activity
#EDITABLE OPTIONS##################################################
```

Throughput test

```
#EDITABLE OPTIONS##################################################
set total_querysets 1 ;# Number of query sets before logging off
set RAISEERROR "false" ;# Exit script on SQL Server query error (true or false)
set VERBOSE "false" ;# Show query text and output
set maxdop 8 ;# Maximum Degree of Parallelism
set scale_factor 300 ;#Scale factor of the tpc-h schema
set authentication "windows";# Authentication Mode (WINDOWS or SQL)
set server {(local)};# Microsoft SQL Server Database Server
set port "1433";# Microsoft SQL Server Port
set odbc_driver {SQL Server Native Client 11.0};# ODBC Driver
set uid "sa";#User ID for SQL Server Authentication
set pwd "admin";#Password for SQL Server Authentication
set database "tpch";# Database containing the TPC Schema
set refresh_on "true" ;#First User does refresh function
set update_sets 1 ;#Number of sets of refresh function to complete
set trickle_refresh 1000 ;#time delay (ms) to trickle refresh function
set REFRESH_VERBOSE "true" ;#report refresh function activity
#EDITABLE OPTIONS##################################################
```

Read the report at http://facts.pt/0zt00k ▶

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