The science behind the report:

Meet growing online transaction demands and make smarter business decisions

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 "Meet growing online transaction demands and make smarter business decisions."

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 Benchmark Factory's TPC-E-like workload to measure the transactional database performance of the Dell EMC Storage Spaces Direct Ready Nodes cluster, and HammerDB's 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's recommendation. 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 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 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					14,049.49
Average					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

About the benchmarking tool, Benchmark Factory for Databases

To measure OLTP database performance, we used the Benchmark Factory for Databases tool, which lets you conduct database workload replay, industry standard benchmark testing, and scalability testing. It enables you to deploy changes to your database environment with confidence by reducing the risks associated with patches, upgrades, migrations, and adjustments to configurations. We used an OLTP database test in Benchmark Factory to run a TPC-E-like workload, and tuned the workload to drive for maximum performance.

Our Benchmark Factory workload consisted of a TPC-E, scale 30, 300GB database. We set a pre-sampling length of 30 and a sampling length of 60. Our tests were not official TPC results and are not comparable in any manner to the official TPC audited results.

For more information on Benchmark Factory, visit https://www.quest.com/products/benchmark-factory/.

About the benchmarking tool, HammerDB

HammerDB is an open-source benchmark tool that tests the database performance of many leading databases, including Oracle® Database, Microsoft SQL Server, PostgreSQL®, MySQL™, and more. The benchmark includes two built-in workloads derived from industry-standard benchmarks: a transactional (TPC-C-like) workload and a data warehouse (TPC-H-like) workload. For this study, we used the OLAP analytics or data warehouse workload. Our tests were not official TPC results and are not comparable in any manner to the official TPC audited results.

For more information about HammerDB, visit http://www.hammerdb.com.

Configuring the out-of-band management switch

We used a Dell S3048 1GbE 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. Switch configuration can be found in Switch configurations.

Configuring the top-of-rack switch

We used a Dell 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. Switch configuration can be found in Switch configurations.

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 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 Dell EMC Microsoft Storage Spaces Direct 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, as the domain administrator, open a PowerShell window 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, to change the host name and restart the server, run the following command:

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

Configuring the VM switch and adapters

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

```
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. To join the active directory domain, as the domain administrator, open a PowerShell window, and run the following command:

```
$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 view the driver and firmware versions, 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. Be 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 previously downloaded drivers and firmware.
7. Run Windows Update and once it completes, reboot.
8. Repeat steps 3 through 7 until all windows updates are installed.

TPC-E testing

Creating the volumes

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

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

3. To create a 3TB data volume, run the following command:

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

4. To create a 1TB log volume, run the following command:

```
New-Volume -FriendlyName "Node01-Log" -FileSystem CSVFS_ReFS -StoragePoolFriendlyName "*S2D*" -Size
1TB -ResiliencySettingName Mirror
```

Creating the VMs under test

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 24,576 MB, and click Next.
7. Select the previously created SET switch, 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. In the left-hand menu, select the SCSI Controller. In the right-hand menu, select the Hard Drive selection, and click Add.
12. Repeat step 11 three more times for a total of four drives.
13. In the left-hand menu , select the new Hard Drive, and, in the right-hand menu under Virtual hard disk, click New.
14. Click Next.
15. Select Fixed Size, and click Next.
16. Name the Virtual Hard Disk, and change the storage location to the OS volume on the local node.
17. Click Next.
18. Set the size to 40 GB, and click Next.
19. Click Finish.
20. On the new hard drive, repeat steps 13 through 19. Change the size of the Virtual Hard Disk to 600 GB, and change the storage location to the data volume on the local node.
21. On the third new hard drive, repeat steps 13 through 19. Change the size of the Virtual Hard Disk to 200 GB, and the storage location to the log volume on the local node.change
22. On the fourth new hard drive, repeat Steps 13- through 19. Change the size of the Virtual Hard Disk to 600 GB, and the storage location to the Backup volume on the local node.
23. Set the number of virtual processors to 16.
24. Change the automatic stop action to Shut Down.
25. In the left-hand menu, select the SCSI controller, click on the DVD Drive selection, and click Add.
26. Select ISO Image File, and click Browse...
27. Enter the location of the Windows Server 2016 installation media, and click Open.
28. In the left-hand menu, select Firmware, and change the boot order to the DVD drive.
29. Click Apply.
30. Click OK.
31. Power on the VM.
32. To boot from the CD/DVD location, at the prompt, press any key.
33. Click Next.
34. Click Install Now.
35. Select Windows Server 2016 Datacenter Edition, and click Next.
36. Check I accept the license terms, and click Next.
37. Select the OS VHD, and click Next.
38. After installation, enter a password for Administrator, and click Finish.
39. Run Windows Updates, and when prompted, reboot.

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. To check for updates, click Use Microsoft Update, 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 preferred authorization method. 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. Select 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. Select 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, in the Installation Center, go to the Installation tab, 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 the download.
31. Click Run.
32. Click Install.
33. When the installation has completed, close the installation window.

Enabling lock pages in memory

1. Click Start, 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 the SQL user account `(NT SERVICE\MSSQLSERVER)`.
7. Click OK.

Setting up the benchmark

We used a client VM running Windows Server 2016 and installed Benchmark Factory for Databases to target our VM under test.

Creating a database on the VMs under test

1. Open SQL Server Management Studio.
2. Select SQL Server Authentication, type `sa` and `Password1` as your login and password respectively, and click Connect.
3. Right-click Databases→New Database.
4. Name the database. We named ours tpce.
5. Click OK.

Installing Benchmark Factory for Databases 8.0.1 on the clients

1. Navigate to the Benchmark Factory for Databases 8.0.1 installation media, and launch the installer.
2. At the first screen of the install wizard, click Next.
3. At the License Agreement screen, accept the license terms, and click Next.
4. At the Destination Folder screen, select an installation path, and click Next.
5. At the Ready to Install the Program screen, click Install.
6. After the wizard completes, click Finish.

Populating the database

1. On the client VM, to open the program, double-click the Benchmark Factory shortcut.
2. Select whether to participate in the Product Improvement Program or not, and click OK.
3. When the program first opens, a New Job Wizard window appears. to create a connection profile to the VM under test, click Create Connection Profile.
4. From the drop-down menu under Database Type, select Microsoft SQL Server.
5. In the Server name field, type the name or IP address of the server.
6. In the Authentication field, select SQL Server Authentication.
7. Enter the Login and Password credentials for the VM under test.
8. From the database drop-down menu, select the prerviously created tpce database.
9. Enter a connection name.
10. Click Test Connection, and verify that the connection is successful.
11. Click Create Connection.
12. In the New Job Wizard, under the Database Under Test section, to ensure that the connection is properly set up, test the connection again. Optionally, the Benchmark Factory wizard can also detect the environment information.
13. Click Add Workload.
14. From the test type drop-down menu, select Create / Delete Benchmark Objects Test.
15. From the Benchmark Type drop-down menu, select TPC-E.
16. If no backups sets are created, click the bubble next to Create/Load objects.
17. Click Add Test.
18. Click Test Options.
19. Change the Benchmark Scale to 30.
20. Click Job Setup.
21. Click Agent Setup.
22. Select the Agent on the local machine, and click Run Job. This build could take several hours.

Backing up the database

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

Cloning the VMs under test

1. Shut down the gold VM.
2. Copy and paste the OS, Data, Log, and Backup VHD files 11 times, distributed evenly across the cluster shared OS, Data, Log volumes, where the OS and Backup VHDs are placed on the OS volume on each node.

Running the test

After cloning the VMs under test, we joined each VM to the AD domain. We also cloned out 12 client VMs, with each VM targeting one of the VMs under test. On the VMs under test, we started perfmon counters and let them run while the system was idle for 10 minutes before starting the test. On the client, we opened Benchmark Factory and created and ran a new TPC-E job, making use of the schedule function so that we could start all of the VMs at the same time. Below are the steps that we took to configure and test the benchmark:

1. On the client VM, open Benchmark Factory for Databases.
2. Click New.
3. From the drop-down menu, select the database for the VM under test.
4. Click Add workload.
5. From the type of test drop-down menu, select Industry Standard Benchmark Test.
6. Select TPC-E, and click Add Test.
7. In the left-hand menu, select the TPC-E Transaction Mix.

8. Click Test Options.
9. Edit each transaction and select No delay for the latency.
10. Select the User Load Tab.
11. Click Delete All.
12. Change the user load to 50, and click Add.
13. Select the Timing Tab.
14. Set the Pre-Sampling period to 30 minutes and the Sampling period to 1 hour.
15. Click Job Setup.
16. Aelect the Schedule Tab.
17. Enter the desired test start time.
18. Click Agent Setup.
19. Select the agent on the local machine, and click Run Job.
20. Repeat the test two more times, and take the median of the three runs.

TPC-H testing

Creating the volumes
1. As the domain administrato, open a PowerShell window.
2. To create a 3TB OS & backup volume, run the following command:

   ```
   New-Volume -FriendlyName "Node01-OS" -FileSystem CSVFS_ReFS -StoragePoolFriendlyName "*S2D*" -Size
   3TB -ResiliencySettingName Mirror
   ```
3. To create a 3TB data volume, run the following command:

   ```
   New-Volume -FriendlyName "Node01-Data" -FileSystem CSVFS_ReFS -StoragePoolFriendlyName "*S2D*" -Size
   3TB -ResiliencySettingName Mirror
   ```
4. To create a 500GB log volume, run the following command:

   ```
   New-Volume -FriendlyName "Node01-Log" -FileSystem CSVFS_ReFS -StoragePoolFriendlyName "*S2D*" -Size
   500GB -ResiliencySettingName Mirror
   ```
5. Repeat steps 1 through 4 on the remaining nodes.

Creating the VMs
1. On one of the cluster nodes, open Hyper-V Manager, and click New Virtual Machine.
2. Click Next.
3. In the name field, type the name of the virtual machine.
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 previously created SET switch, 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. In the left-hand menu, select the first SCSI Controller. In the right-hand menu, click on the Hard Drive selection, and click Add.
14. In the left-hand menu, select the new Hard Drive. In the right-hand menu, under Virtual hard disk, click New.
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 40 GB, 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 420 GB, and change 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 75 GB, and the storage location to the log volume on the local node.change
23. Repeat Steps 13 through 20 on the fourth SCSI controller. Change the size of the Virtual Hard Disk to 295 GB, and change 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. In the left-hand menu, select the first SCSI controller, select 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. In the left-hand menu, select Firmware, and change the boot order to the DVD drive.
30. Click Apply.
31. Click OK.
32. Power on the VM.
33. To boot from the CD/DVD location, at the prompt, press any key.
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 when prompted, reboot.

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 are 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, 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 preferred authentication method. 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. Select 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. Select 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, check that there are no failures or relevant warnings, and click Next.
27. At the Ready to Install screen, click Install.
28. When the install is finished, 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, select the download.
31. Click Run.
32. Click Install.
33. When the installation is complete, close the installation window.

Expanding TempDB and 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 in MB for both files. The size required will depend on the scale of the 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 are finished expanding, click OK.

Enabling lock pages in memory

1. Click Start, 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, 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 the SQL user account (NT SERVICE\MSSQLSERVER).
6. 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. Click Add to add seven more database files for a total of eight.
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 TPCH database, and click Tasks→Back up…
3. Choose a location to store the backup, and click OK.

Cloning the VMs

1. Shutdown the gold VM.
2. Copy and paste the OS, Data, Log, and Backup VHD files 7 times, distributed evenly across the cluster shared OS, Data, Log volumes, where the OS and Backup VHDs are placed on the OS 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 the refreshes to prime S2D and SQL for the throughput run. Our goal was to show how much throughput we could get out of our S2D Ready Nodes, so we wanted to run through the queries at least once to get them all loaded into the cache. The configurations we used for the power test and throughput test can be found 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. To distribute the driver script to the 7 slave VMs, click the Master Distribution button.
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. To capture CPU, RAM, and disk counters on each VM and node in the cluster start Perfmon.
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 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/x42bHF ▶

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