



The science behind the report:

Analyze more data at once, faster, when you add Intel Optane persistent memory to Dell EMC PowerEdge R740xd servers

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 [Analyze more data at once, faster, when you add Intel Optane persistent memory to Dell EMC PowerEdge R740xd servers](#).

We concluded our hands-on testing on May 28, 2020. During testing, we determined the appropriate hardware and software configurations and applied updates as they became available. The results in this report reflect configurations that we finalized on May 18, 2020 or earlier. Unavoidably, these configurations may not represent the latest versions available when this report appears.

Our results

Table 1: TPC-H-like workload results for the Dell EMC PowerEdge R740xd server with and without Intel Optane PMem. Source: Principled Technologies.

12-stream-to-8-stream comparison	Without Intel Optane PMem	With Intel Optane PMem	PMem config % faster
	Median run	Median run	
Single query stream (min)	45.63	36.00	26.76
Longest of the query streams (min)	150.10	145.38	3.24
Average of the query streams (min)	143.69	136.61	5.18
Processor time % (single stream)	7.85	10.96	N/A
Processor time % (multi streams)	23.87	43.15	N/A
PMEM config % more users			
Maximum number of streams	8	12	50.00

System configuration information

Table 2: Detailed configuration information for the server under test. Source: Principled Technologies.

Server configuration information	Dell EMC PowerEdge R740xd
BIOS name and version	Dell 2.5.4
Non-default BIOS settings	Performance mode & LLC Prefetcher enabled
Operating system name and version/build number	Windows Server 2019 Standard Version 1809
Date of last OS updates/patches applied	June 1, 2020
Power management policy	Performance
Processor	
Number of processors	2
Vendor and model	Intel Xeon Gold 6240L
Core count (per processor)	18
Core frequency (GHz)	2.6
Stepping	7
Memory module(s) type 1	
Total memory in system (GB)	384
Number of memory modules	12
Vendor and model	Micron 36ASF4G72PZ-2G9E2
Size (GB)	32
Type	DDR-4 PC4-23400 Dual-Rank
Speed (MHz)	2,933
Speed running in the server (MHz)	2,666
Memory module(s) type 2 (PMEM)	
Total memory in system (GB)	1
Number of memory modules	8
Vendor and model	Intel Optane Persistent Memory NMA1XXD128GPS
Size (GB)	128
Type	Persistent memory DDR-4 Single-Rank
Speed (MHz)	2,666
Speed running in the server (MHz)	2,666
Storage controller	
Vendor and model	Dell PERC H730p
Cache size	2,048 MB
Firmware version	25.5.6.0009
Driver version	6.604.6.0

Server configuration information		Dell EMC PowerEdge R740xd
Local storage type 1		
Number of drives	6	
Drive vendor and model	Intel S4510	
Drive size (TB)	1.92	
Drive information (speed, interface, type)	6Gbps SATA SSD	
Local storage type 2		
Number of drives	2	
Drive vendor and model	Intel P4610	
Drive size (TB)	1.6	
Drive information (speed, interface, type)	6Gbps NVMe SSD	
Local storage type 3		
Number of drives	2	
Drive vendor and model	Intel SSDSCKJB120G7R	
Drive size (GB)	120GB	
Drive information (speed, interface, type)	6 Gbps SATA M.2 SSD	
Network adapter		
Vendor and model	Intel Ethernet Converged Network Adapter X710-T4	
Number and type of ports	4x 10GbE RJ45	
Driver version	1.11.101.0	
Cooling fans		
Vendor and model	Delta PFR0612DHE-C	
Number of cooling fans	6	
Power supplies		
Vendor and model	Dell L1100E-S1	
Number of power supplies	2	
Wattage of each (W)	1,100	

How we tested

Testing overview

We installed Windows Server 2019 Standard and SQL Server 2019 Enterprise on a Dell EMC PowerEdge R740xd. We tested with a 3,000 scale TPC-H-like database that Intel provided. We confirmed that the row counts, tables, and columns met the requirements for a TPC-H-like database at the 3,000 scale. To build your own database, you can use either the HammerDB tool or download and use the dbgen tool at <https://github.com/electrum/tpch-dbgen>.

We ran both a single-user and a multi-user test against the database. First, we stored the database on traditional SSD storage that we configured in a RAID 10 for the database files and NVMe storage in a RAID 1 for the log files. We then moved the database files to the persistent memory volumes and tested again to determine the performance advantages that may result from adding Intel Optane persistent memory to a database server. Each user runs a serialized string of 22 read-only queries against the database. With the multi-user test, each user runs through the queries in a different order so the same queries aren't always running at the same time. We report the time it takes the single user to complete the queries as well as the time for the user that takes the longest to finish in the multi-user test.

Installing and configuring Windows on the PowerEdge R740xd server

Before we installed Windows, we made sure the BIOS was set to the latest version available and updated all firmware and drivers. We set the BIOS to performance and enabled the LLC Prefetcher cache.

Installing Windows Server 2019 Standard

1. Navigate to the iDRAC console, and open the remote console.
2. Attach the Windows Server 2019 Standard ISO, and start (or restart) the server.
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 prompted, enter the product key.
7. Select Windows Server 2019 Standard 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 the Unallocated Space on the OS drive (we used the M.2 BOSS cards), and click Next. This will start the install automatically, and Windows will restart automatically after completing the install.
11. When the Settings page appears, fill in the Password and Reenter Password fields with the password of your choice.
12. Log in with the password you set.

Configuring Windows Server 2019 Standard

1. In Server Manager, set the time zone, enable RDP if desired, and disable the firewall.
2. Run Windows updates until you have no new updates to install.
3. In Disk Manager, ensure all drives are online, formatted, and presented to the OS.
4. Navigate to Settings→System→Power & Sleep→Additional Power Settings, and set Preferred plans to High performance.
5. Navigate to Control Panel→System and Security→System→Advanced System Settings.
6. In the Performance box, click Settings→Adjust for best performance.
7. In the Advance tab, choose Adjust for best performance of Programs.
8. In the Virtual memory box, click Change....
9. For all volumes in the system, change the paging file size to Custom size, and set the Initial and Maximum sizes to 4096 MB, and click Set.
10. To close the Performance Options window, click OK on the popup warning about rebooting the system
11. To close the System Properties window, click OK.
12. Reboot the server.

Installing and configuring SQL Server 2019 Enterprise

Installing SQL Server 2019 Enterprise

1. Download or copy the .ISO file to the server, and unzip it.
2. Double-click the Setup application.
3. Click Installation→New SQL Server Standalone installation or add features to an existing installation.
4. Choose the trial version, and click Next.
5. Check the I accept the license terms and Privacy Statement box, and click Next.
6. Check the Use Microsoft Update to check for updates (recommended) box, and click Next.
7. On the Install Rules page, click Next.
8. Check the boxes for the following features, and click Next:
 - a. Database Engine Services
 - b. Full-Test and Semantic Extractions for Search
 - c. Client Tools Connectivity
 - d. Client Tools Backwards Compatibility
9. Leave the Default instance, and click Next.
10. Leave the default Service Accounts, and click Next.
11. On the Server Configuration tab, choose Mixed Mode and enter and confirm a Password for the SQL Server system administrator (sa) account.
12. Click Add Current User to Specify the SQL Server administrators.
13. On the Data Directories tab, change the Data root directory to the database volume.
14. Choose the log volume for the User database log directory.
15. If you plan to have a locally stored backup, change the Backup directory to point to that drive.
16. On the TempDB tab, set the tempdb database and log files to 1024MB with 1024MB autogrowth.
17. Click Next.
18. Once you've passed the rule check, click Next.
19. Click Install.
20. When the install has finished, go back to the SQL Server Installation Center, and click Install SQL Server Management Tools.
21. Download the SSMS file, and install with defaults.
22. When prompted, reboot the server .
23. To ensure there aren't any new updates for SQL Server, run Windows Update one more time. Ensure that Windows Updates are set to get updates for other Microsoft products).
24. To disable Windows Update service, click the Start button. To open the Services list, type `services` to open the Services list, and disable the Windows Update service.

Configuring SQL Server 2019 Enterprise

1. Open SQL Server Management Studio.
2. Select SQL Server Authentication.
3. For your login, type `sa`
4. For your password, type the password you chose earlier.
5. Click Connect.
6. To show advanced options, use the following command:

```
exec sp_configure 'show advanced options', '1'  
go  
reconfigure with override
```
7. To set the maximum memory for SQL to 90% of the available RAM, or 345GB, use the following SQL query:

```
exec sp_configure 'max server memory', '353894'  
go  
reconfigure with override
```
8. To set the maximum degree of parallelism (MAXDOP) to 8,use the following SQL query:

```
exec sp_configure 'max degree of parallelism', '8'  
go  
reconfigure with override
```
9. To set the maximum worker threads to 3,000, use the following SQL query:

```
exec sp_configure 'max worker threads', '3000'  
go  
reconfigure with override
```

Locking pages in memory

1. Click Start, and type `Local Security Policy`
2. When the program appears in the search window, open it. Expand Local Policies, and click User Rights Assignment.
3. In the right-hand pane, double-click Lock pages in memory.
4. Click Add User or Group, type `NT Service\MSSQLSERVER`, and click OK.
5. To close the Properties window and the Local Security Policy window, click OK.

Configuring for Persistent Memory tests

We set the PMem to App Direct Mode and created two interleaved regions. We then used Windows PowerShell commands to format the two regions into two file system direct access volumes with 2MB allocation size. This was in accordance to SQL Server best practices for Hybrid Buffer Pool. Using the database restore file, we alternated the database files between the PMem volumes so that half lived on one and half on the other. We then enabled Hybrid Buffer Pool, a SQL tool that utilizes byte-addressable direct-access volumes to improve performance. We then repeated the tests on the persistent memory configuration that we ran on the traditional storage. The logs and tempdb remained on the original RAIDs, where they were located for the non-PMem testing.

Creating the persistent memory volumes

1. Install the PMEM according to the Dell instructions at <https://www.dell.com/support/manuals/us/en/04/poweredge-r640/dcpmm Ug Pub/dcpmm-recommended-topologies?guid=guid-85f17354-b7af-4c04-ac6a-f5468b4b4ab7&lang=en-us>
2. Boot the server, and log into Windows.
3. Install the IPMCTL tool at <https://downloadcenter.intel.com/download/29380/DCPM-Software-for-Intel-Optane-DC-Persistent-Memory-for-Windows-Server-2019?v=t>
4. To create interleaved, app-direct PMEM regions using all the available space, use the following commands:

```
ipmctl create -f -socket 0x0 -goal MemoryMode=0 PersistentMemoryType=AppDirect
ipmctl create -f -socket 0x1 -goal MemoryMode=0 PersistentMemoryType=AppDirect
```

5. Reboot the server.
6. Log into Windows, and open PowerShell.
7. To create two disks from the regions you created previously, use the following command (this creates disks for both regions, so you only need to run it once):

```
Get-PmemUnusedRegion | New-PmemDisk
```

8. Run the following command, and note the DiskNumber of each PMEM disk:

```
Get-PmemDisk
```

9. To initialize the disks, run the following command for each disk, and use the values for DiskNumber you recorded in the previous step.

```
Initialize-Disk -Number <insert DiskNumber> -PartitionStyle GPT
```

10. Create a new partition on each disk, and assign a drive letter by running the following command for each disk using the values for DiskNumber you recorded in step 8.

```
New-Partition -DiskNumber <insert DiskNumber> -UseMaximumSize -DriveLetter <insert drive letter>
```

11. Format the disk with NTFS, enable direct access mode, set the allocation unit size, and name the volume by running the following command on both disks using the drive letters you set in the previous step.

```
Format-Volume -DriveLetter <insert letter> -FileSystem NTFS -IsDAX $true -AllocationUnitSize 2097152
-NewFileSystemLabel PMEMDAX-<insert number> -Confirm:$false
```

Configuring Hybrid Buffer Pool

We enabled Hybrid Buffer Pool for the tests where the database was stored on the persistent memory. Use the following steps to enable Hybrid Buffer pool:

1. Open SQL Server Management Studio.
2. To open a blank page, click New Query.
3. Type the following, and click Execute:

```
ALTER SERVER CONFIGURATION SET MEMORY_OPTIMIZED HYBRID_BUFFER_POOL = ON;
```

4. If you need to confirm the Hybrid Buffer Pool status, click New Query, and execute the following commands:

```
SELECT * FROM sys.configurations WHERE name = 'hybrid_buffer_pool';
SELECT name, is_memory_optimized_enabled FROM sys.databases;
```

5. To disable Hybrid Buffer Pool on the TPC-H-like database, click New Query, and execute the following command:

```
ALTER DATABASE <databaseName> SET MEMORY_OPTIMIZED = OFF;
```

Running the TPC-H-like workload

We ran the OLAP TPC-H-like workload using the HammerDB benchmark. As the documentation instructs, we ran the HammerDB test directly on the server under test as the overhead on the hardware is negligible. Thus, this test does not require any clients.

According to official TPC-H documentation, a multi-stream test should run a set number of streams based on the size of the database. For a 3,000-scale database, that stream count should be 8. However, since we are not running official, audited TPC-H testing, we opted to increase the number of streams on the persistent memory testing until we reached roughly the same amount of time as the 8-stream test without persistent memory. This approach allows us to show the reader how they can increase the number of queries run against a database in the same amount of time.

Installing HammerDB on the PowerEdge R740xd server

1. Download HammerDB from the following location: <https://hammerdb.com/download.html>
2. Double-click the .exe file, choose English, and click OK.
3. Click Yes.
4. Click Next.
5. Chose a destination location, and click Next.
6. Click Next.
7. Click Finish.

Running the test

1. Open HammerDB.
2. Select Options→Benchmark.
3. Choose MSSQL Server and TPC-H.
4. Expand SQL Server→TPC-H→Schema Build.
5. Double-click Options, change the driver to ODBC Driver 17 for SQL Server, set the scale to 1000, set MAXDOP to 8, and check the box for Clustered Columnstore. Click OK.
6. Expand Driver Script, and double-click Options. To load, click OK.
7. In the Script Editor pane, change the scale factor to 3,000.
8. Expand Virtual User, and double-click Options.
9. Choose 1, 8, or 12 users depending on which test you are running.
10. Check the boxes for Show Output, Log Output to Temp, and Use Unique Log Name.
11. Click OK.
12. To load the driver script, double-click Load.
13. Double-click Create users.
14. To capture performance metrics on the system, start Performance monitor, and set it to record CPU, Memory, and drive usage information.
15. To begin the test run, click Start.
16. When the run finishes, stop Perfmon, and save the HammerDB results file and Perfmon output.
17. Repeat the test two more times for a total of three runs at each user count. Once you have run each test, record the median results for each user count.

Read the report at <http://facts.pt/v71sw6a> ►

This project was commissioned by Dell EMC.



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