PROWESS

Choose the Right System When Upgrading to Microsoft® SQL Server® 2019 on Microsoft® Hyper-V®

Prowess testing found that Dell EMC™ PowerEdge™ servers can provide a strong platform for SQL Server 2019 running on Windows Server® 2019 and Hyper-V.

Many IT organizations are stretched thin from performing a multitude of daily operational tasks and meeting tight development deadlines, in addition to keeping both customers and stakeholders happy. Reaching the end of support for core systems can put overworked IT teams in a bind, especially when those systems are running on old, outdated hardware and unsupported software.

This is especially true for database management systems (DBMSs), which are the foundation for critical applications. For organizations running legacy versions of Microsoft® SQL Server®, Microsoft ended support for SQL Server 2008 and SQL Server 2008 R2 in July 2019, and it will be ending support for SQL Server 2012 in 2022.[1] Yet many organizations running SQL Server are still relying on these legacy versions. Running outdated database software can be risky because security updates and technical support are typically discontinued. Even worse, running outdated hardware could mean costly unplanned outages due to equipment failures.

If your organization is running a legacy version of SQL Server on old hardware, and you've been held back by concerns about the difficulty and cost of upgrading, the best way forward is to find a simple and cost-effective upgrade path from a trusted source.

Validated high-performance solutions

Simplified licensing and support

Custom designs for specific requirements

Dell EMC PowerEdge Solutions for SQL Server 2019 Running on Hyper-V

Dell Technologies provides just such an upgrade path to organizations facing these SQL Server end-of-support challenges by offering Dell EMC™ PowerEdge™ servers with simplified original equipment manufacturer (OEM) licensing for Microsoft® software. This offer of hardware bundled with software, together with Dell Technologies' no-cost pre-sales sizing tool, Live Optics (**liveoptics.com**), helps simplify SQL Server deployments. And Dell Technologies' combination of one-stop technical support, rich tools for smart management, and multi-layer security helps contribute to a dependable solution with a low total cost of ownership (TCO).

Prowess evaluated this option of upgrading to an OEM-licensed version of SQL Server 2019 on Dell EMC PowerEdge servers. As part of this investigation, Prowess completed a performance analysis of running SQL Server 2019 in virtual machines (VMs) on Dell EMC PowerEdge servers running Microsoft® Hyper-V®. This paper examines the results of this evaluation.

Can You Save Money by Moving to the Standard Edition?

Some features that were found only in the enterprise editions of previous Microsoft® SQL Server® versions are now available in SQL Server 2019 Standard edition. As a result, if you require these features, you might be able to save money by moving from an old enterprise edition to the current standard edition.

Transparent Data Encryption (TDE) is one such example. This built-in encryption feature first appeared in SQL Server 2008 Enterprise edition, but beginning with SQL Server 2019, it is now included in the standard edition.

Another example is PolyBase, the technology that lets SQL Server process T-SQL queries for both relational and non-relational data. PolyBase was first introduced in SQL Server 2016 Enterprise edition, but as of SQL Server 2019, it is now available in the standard edition.

Dell Technologies Provides a Foundation for High-Performance SQL Server 2019 Deployments

Dell Technologies is Microsoft's largest partner, and the two companies have collaborated for more than 35 years on industry-leading hardware and software solutions. This collaboration helps ensure that Microsoft software, such as Hyper-V, Windows Server® 2019, and SQL Server 2019, runs optimally on Dell EMC PowerEdge servers.

The collaboration between Dell Technologies and Microsoft can help organizations of all sizes keep pace in today's competitive business environment with a reliable Hyper-V infrastructure running on Dell EMC PowerEdge servers. An infrastructure built with Dell EMC PowerEdge servers and Hyper-V can provide:

- Flexibility and scalability in adapting to quickly changing business needs
- Management simplicity for busy IT professionals
- Higher server utilization, which can improve hardware TCO
- A strong environment for SQL Server workloads

Validated Hyper-V Solutions

Dell Technologies offers a validated Hyper-V design with its Dell EMC™ Ready Stack architecture model. This model offers organizations a selection of server, storage, and networking components designed to optimally run Hyper-V. By providing comprehensive deployment guides and support for Dell EMC Ready Stack solutions, Dell Technologies makes it easy for organizations to deploy their own custom converged infrastructure. Customers can also configure individual Dell EMC PowerEdge servers with Windows Server 2019 preinstalled and the Hyper-V role enabled, saving costs by reducing configuration and deployment time.

Hardware-Based Security Helps Protect SQL Server 2019 Workloads

Security continues to be a high priority, as each day brings new security exploits that can jeopardize company and customer data. Dell Technologies integrates security features into PowerEdge servers that help protect workloads from firmware attacks and provide layers of security from the BIOS to the VM.

Security starts at the hardware level with a silicon-based root of trust. This root of trust cryptographically validates server firmware, such as the Integrated Dell™ Remote Access Controller (iDRAC) and BIOS, as each module boots. Firmware for other critical components, such as host bus adapters (HBAs), RAID controllers, network interface controllers (NICs), power supplies, and storage drives, are also validated.

PowerEdge servers also support Unified Extensible Firmware Interface (UEFI) Secure Boot, which checks the cryptographic signatures of UEFI drivers and other code that is loaded prior to the operating system. This validation creates a root of trust that helps ensure that only authentic firmware is running on the server. Once Windows Server 2019 and Hyper-V are running, Microsoft extends this silicon root of trust in Hyper-V by providing a virtualized Trusted Platform Module that enables VMs to be protected against running on unauthorized servers. For more information on this Secure Boot feature in Hyper-V VMs, see "**Generation 2 virtual machine security settings for Hyper-V**."

Dell Technologies also offers System Lockdown mode, another important security feature of PowerEdge servers. This feature is included with the iDRAC Enterprise license, and it helps prevent inadvertent or malicious modification of server firmware and configuration.

Intel® Optane™ Persistent Memory Provides an Unparalleled Performance Boost for SQL Server 2019 Workloads

Intel® Optane™ persistent memory (PMem) provides a performance boost for single-instance SQL Server 2019 workloads running in a Hyper-V environment. This new type of non-volatile memory provides RAM-like performance with the benefits of persistence that are available with traditional storage media, such as hard-disk drives (HDDs) and solid-state drives (SSDs).[2]

Some performance benefits of running SQL Server 2019 with Intel Optane PMem include:

- Up to 2.7x more transactions per second[3]
- Up to 171 percent faster transactional performance[3]
- Up to 42 percent faster overall performance[4]

Note that actual metrics might vary depending on operating environment.

Intel Optane PMem can also be configured in Memory Mode, in which the persistent memory acts as RAM without persistence. With the higher densities of Intel Optane PMem, this mode provides more memory at a lower price point than would be available in a DRAM-only configuration.

Microsoft® SQL Server®, Then and Now

If you are running SQL Server 2008, SQL Server 2008 R2, or SQL Server 2012, SQL Server 2019 offers a number of notable updated features, including:

- More RAM and CPU support: SQL Server 2019 has grown to support the ever-increasing amount of server CPU cores and RAM. SQL Server 2019 Enterprise edition is only limited by your operating system, whereas SQL Server 2019 Standard edition supports up to 24 CPU cores and 128 GB of memory-optimized data per database in the SQL Server Database Engine.
- Always On Availability Groups: First introduced in SQL Server 2012 Enterprise edition, Always On Availability Groups are an enterprise-grade disaster-recovery alternative to database mirroring. Always On Basic Availability Groups are available in SQL Server 2019 Standard edition.
- Big-data support: SQL Server 2019 introduces SQL Server big data clusters that allow you to deploy large, scalable clusters of SQL Server, Apache Spark™, and HDFS containers running on Kubernetes®.

Performance Test: SQL Server 2019 Running on Windows Server 2019 in a Hyper-V Environment

In a recent series of performance tests, Prowess Consulting created a testing environment to determine the performance of SQL Server 2019 running in Windows Server 2019 VMs hosted on Dell EMC PowerEdge servers running Hyper-V virtualization software. Our performance testing used industry-standard benchmarking tools. Note that for our benchmark testing of SQL Server 2019, we used Intel Optane PMem in App Direct Mode in the PowerEdge hardware configuration.

Testing Configuration and Methodology

In typical Hyper-V deployments, multiple Windows Server 2019 servers running the Hyper-V role are clustered together. This cluster provides a pool of CPU, memory, and storage to VMs running on the Hyper-V servers. VMs running Windows Server 2019 as the operating system and SQL Server 2019, in addition to other VMs, are hosted on servers within the cluster.

We tested SQL Server 2019 in a similar configuration:

- **Two-node Hyper-V cluster**: Two Hyper-V hosts were configured with multiple local SSDs and did not use shared storage. The operating system was installed on a RAID 1 SSD array.
- **Two Windows Server 2019 VMs running SQL Server 2019:** Each VM was configured with 24 vCPUs, 150 GB of RAM, and four virtual disks for the operating system, SQL Server TempDB files, SQL Server log files, and SQL Server data files. The operating system virtual disk was stored on a RAID 1 SSD array. The SQL Server TempDB and SQL Server log file virtual disks were stored on a persistent memory Direct Access Storage (DAX)-enabled volume. The SQL Server data files were stored on a shared Internet Small Computer Systems Interface (iSCSI) target. All of the virtual disks were formatted with the NTFS file system, which is the default file system for Windows Server 2019.

- **SQL Server 2019 configured with a two-node failover cluster and a single instance:** Tests were run in a two-node active/active configuration with shared storage, and again in a single-instance configuration with local storage. The cluster used an iSCSI target for the shared storage. The iSCSI target was created on a Windows Server 2019 VM that was hosted on one of the Hyper-V hosts, and whose virtual disks were stored on that Hyper-V host's RAID 6 array.

Note that SQL Server failover clusters running in VMs require shared storage between two or more failover cluster instances (FCIs). Verify that your Hyper-V environment design includes highly available, fault-tolerant shared storage, such as Dell EMC™ PowerStore storage arrays.

In our configuration, each Hyper-V server was a Dell EMC PowerEdge R740xd server running two Intel® Xeon® Gold 6246 processors (12 cores, each running at 3.30 GHz) with 192 GB of DDR4 RAM and 512 GB of Intel Optane PMem configured in App Direct Mode. The servers were equipped with eight 960 GB Intel® SSD DC S4610 drives. The drives were connected to a Dell EMC™ PowerEdge RAID Controller (PERC) H740P storage controller and configured as follows, in accordance with best practices and recommendations from the Dell support team:

- Two SSDs in a RAID 1 configuration for the host operating system and the SQL Server VM operating system virtual disk
- Two SSDs in a RAID 1 configuration that was not used
- Four SSDs in a RAID 6 configuration that was used for the Windows Server 2019 VM that contained the shared iSCSI target; the iSCSI target was shared by the SQL Server FCIs

The servers contained a dual-port 25 gigabit Ethernet (GbE) Intel® Ethernet Network Adapter XXV710 PCIe® network adapter and a quad-port 10 GbE Intel® Ethernet Converged Network Adapter X710 SFP+ network adapter.

Prowess engineers used HammerDB 3.3 for the performance tests. HammerDB is an open-source database load testing and benchmarking tool that simulates users accessing both transactional and analytical database workloads. The HammerDB workload we used is based on the TPC-C® specification, but it is not a full TPC-C implementation.

HammerDB provides two measurements: transactions per minute (TPM) and new orders per minute (NOPM). TPM measures user commits plus the number of user rollbacks. However, TPM measurements are database-specific, so the TPM performance values generated by HammerDB cannot be used to compare performance between different DBMSs, such as Oracle® Database versus SQL Server. On the other hand, the NOPM value is based on a metric captured from within the test schema itself. As such, NOPM is a performance metric independent of any particular database implementation and is therefore the more relevant metric to use for comparing performance among different DBMSs.

Testing Plan

We performed performance tests specific to SQL Server by running HammerDB five times for 10 minutes each with the following configurations:

- 500 warehouses with 1,000,000 transactions and 5, 10, 20, and 50 users
- 1,000 warehouses with 1,000,000 transactions and 10 users

After each test, the test database was deleted and recreated. We took the variance of the five passes to ensure that they are within plus-or-minus five percent of each other. We ran the tests for both the active/active and active/passive SQL Server configurations.

Testing Optimizations

We configured the following performance optimizations before conducting the testing with HammerDB:

Storage Configuration

- The SQL Server TempDB files were placed on a persistent memory DAX-enabled volume.
- The SQL Server log database files were placed on a persistent memory DAX-enabled volume.
- The database files were placed on an iSCSI target that was shared between the two SQL Server FCIs.
- The HammerDB database and log files were statically sized in the following configurations:
  a. 500 warehouses, 50 GB database size, 12.5 GB log-file size, 10 percent growth
  b. 1,000 warehouses, 100 GB database size, 25 GB log-file size, 10 percent growth

Best Practices Settings

Setting	Description
Enable a hybrid buffer pool for the VM	This setting is new for SQL Server 2019. When database files are stored in persistent memory, SQL Server 2019 can bypass the usual operating system file system APIs and access the database files directly, improving performance. More information about this feature can be found **in this Microsoft article**.
Configure the max_server_memory setting	By default, SQL Server 2019 automatically allocates all available RAM to the SQL Server process. Under some conditions, SQL Server 2019 might use memory that is needed by the operating system or other applications, which can lead to performance degradation due to disk paging. The max_server_memory setting lets administrators manually restrict the amount of memory that SQL Server 2019 accesses, which leaves memory available for other processes. More information about max_server_memory can be found **in this Microsoft article**.
Enable the Lock Pages In Memory (LPIM) option	The LPIM option is used by the account that runs the SQL Server 2019 executable (sqlserver.exe) to keep data in physical memory, rather than paging data to disk. This setting can help boost performance, and it is enabled as a Windows® policy. More information can be found **in this Microsoft article**.
Configure the max degree of parallelism (MAXDOP)	The MAXDOP option determines how many processors or cores can be used to execute a single statement that is part of a query that has a parallel execution plan. Highly parallelized queries can reduce speed, so MAXDOP can limit the amount of parallel executions. More information can be found **in this Microsoft article**.

Testing Results

The following charts display the results of our internal testing. Figure 1 shows the results of the active/active SQL Server 2019 cluster, while Figure 2 shows the results of the active/passive SQL Server 2019 cluster. Figure 3 shows the results of a single, non-clustered instance of SQL Server 2019.

These scores are useful as a model of good performance results, with the NOPM scores being the most useful for cross-platform comparison purposes.

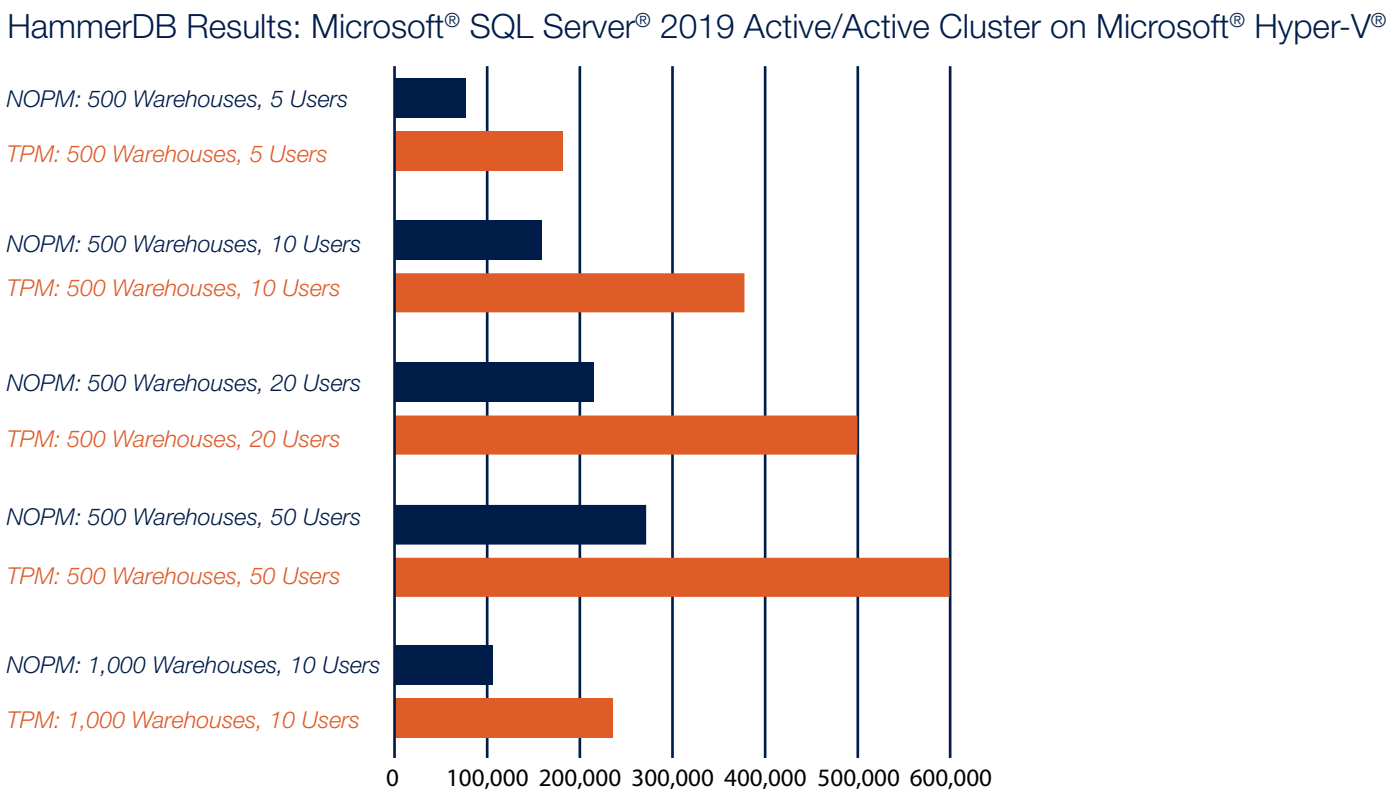

Figure 1. NOPM and TPM HammerDB scores for an active/active Microsoft® SQL Server® 2019 cluster running on Microsoft® Hyper-V®

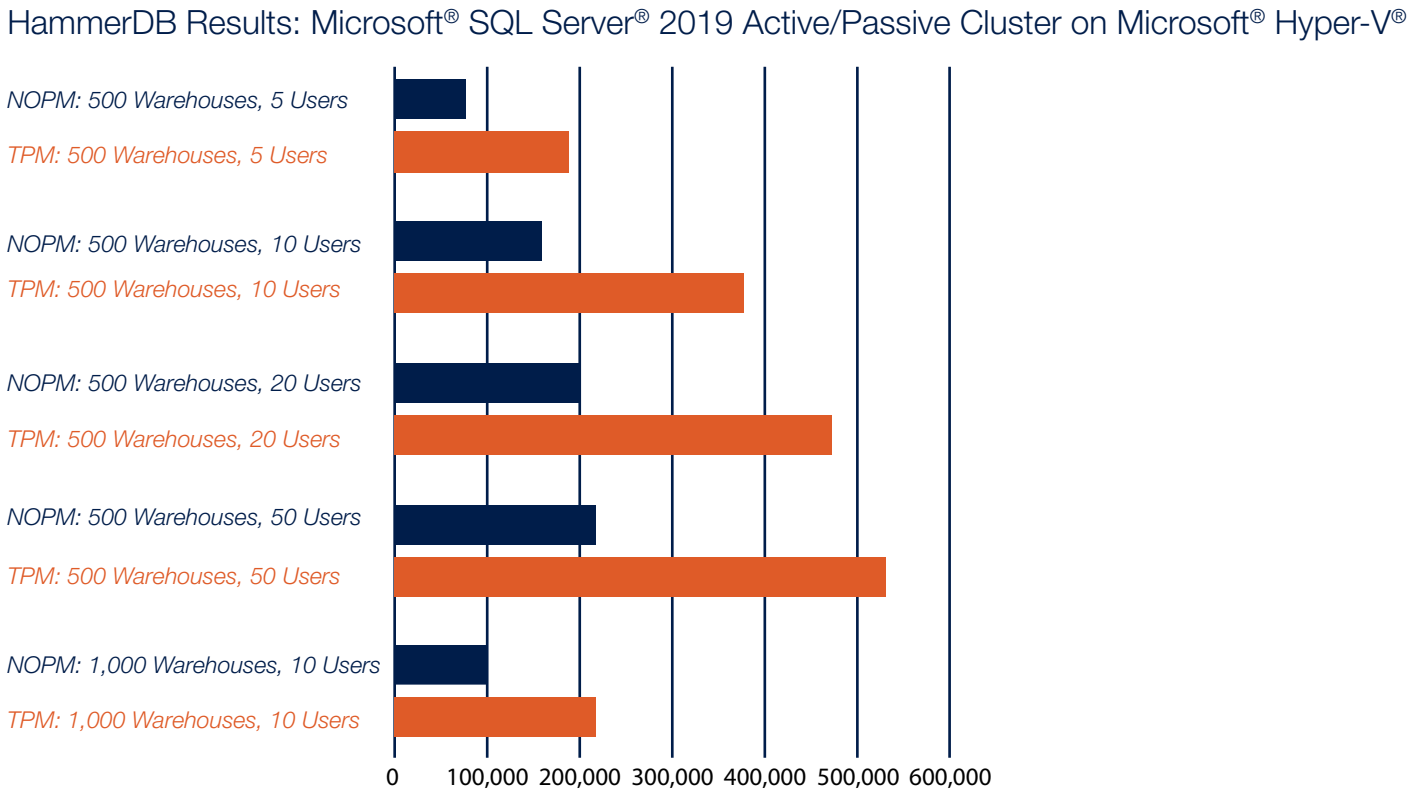

Figure 2. NOPM and TPM HammerDB scores for an active/passive Microsoft® SQL Server® 2019 cluster running on Microsoft® Hyper-V®

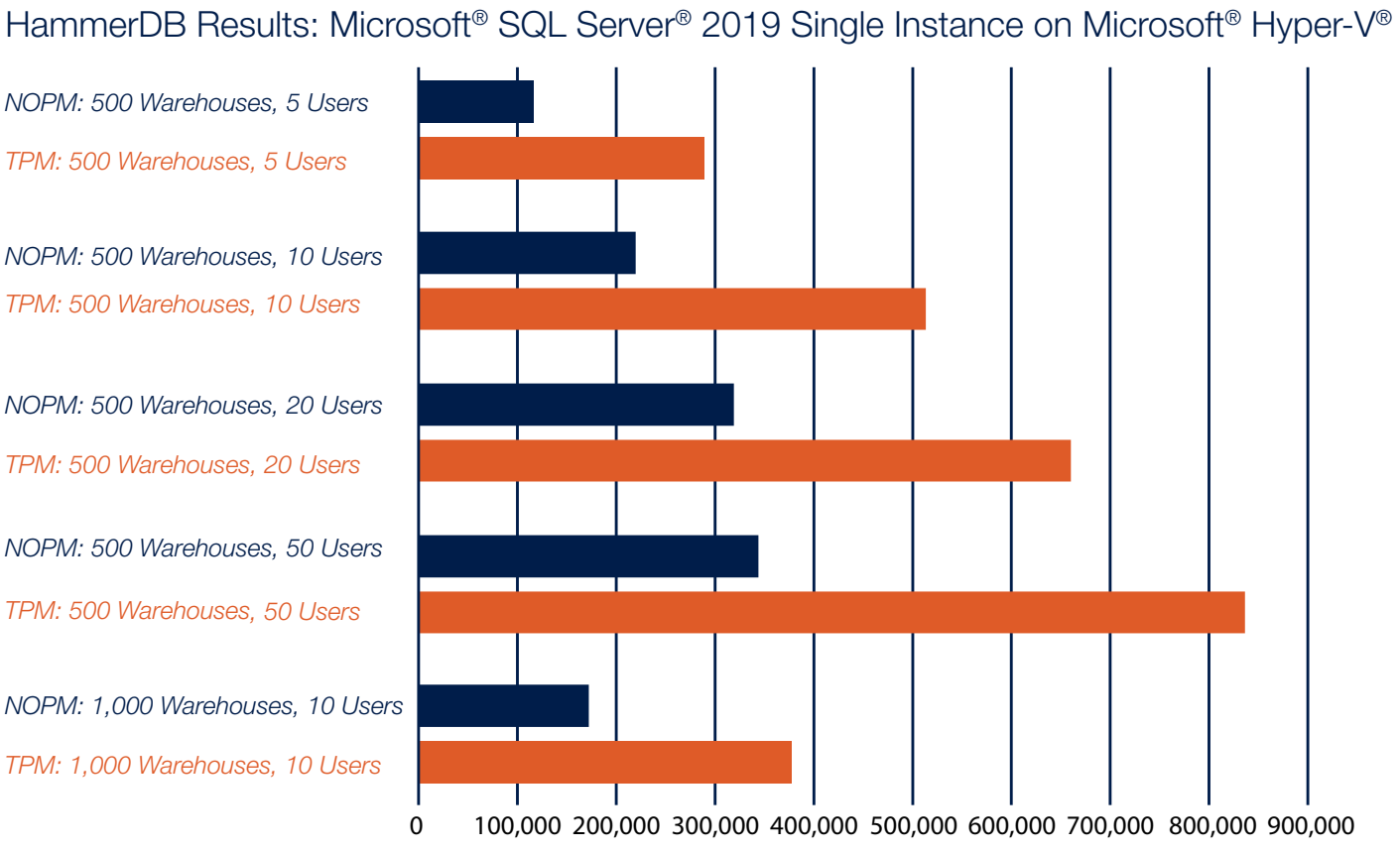

Figure 3. NOPM and TPM HammerDB scores for a single instance of Microsoft® SQL Server® 2019 running on Microsoft® Hyper-V®

These results show that SQL Server 2019 is capable of achieving high-performance results running in a Hyper-V virtualized environment on PowerEdge servers. In a single-instance configuration, SQL Server 2019 was able to obtain more than 833,000 TPM and 362,000 NOPM with 500 warehouses and 50 users. In an active/active cluster configuration, SQL Server 2019 was able to obtain nearly 600,000 TPM and 260,000 NOPM with 500 warehouses and 50 users. In an active/passive cluster, SQL Server 2019 was able to obtain more than 540,000 TPM and nearly 235,000 NOPM. During the course of these performance tests, the Hyper-V servers did not exceed 80 percent CPU utilization.

The results serve as a reminder that maximum performance is tied to specific load levels. The maximum level of performance for the PowerEdge server we tested was found at a load of 500 warehouses and 50 simultaneous users for the HammerDB TPC-C workload. SQL Server 2019 performance will vary depending on factors such as the number of users, query complexity, indexing, database size, and availability group or cluster configuration. Depending on your environment, your results may vary.

Dell Technologies Simplifies Microsoft Licensing and Support

Our tests indicate that SQL Server 2019 running on Hyper-V and Dell EMC PowerEdge servers offers an attractive option for organizations intent on upgrading legacy hardware and versions of SQL Server. But what about licensing? Software licensing can be confusing and difficult to track, especially for busy IT professionals. Licenses for SQL Server 2019 and Windows Server 2019 can be purchased through third-party resellers or directly from software vendors, but these purchases can lock organizations into long-term volume licensing agreements with potentially confusing and expensive terms. In addition, technical support is often divided between hardware and software vendors, which can lead to frustrating and time consuming support calls.

Dell Technologies provides an easier way to manage software licenses and support for Microsoft products through OEM licensing. Software licenses are combined and sold with Dell Technologies hardware as part of a complete server and software solution, and pricing is competitive for organizations of any size.

OEM licensing also simplifies support for Dell Technologies hardware and OEM-licensed software. Dell Technologies gives you one number to call for your OEM-licensed products and Dell Technologies hardware, and it has thousands of Microsoft-certified experts that can help solve even the most complex issues.

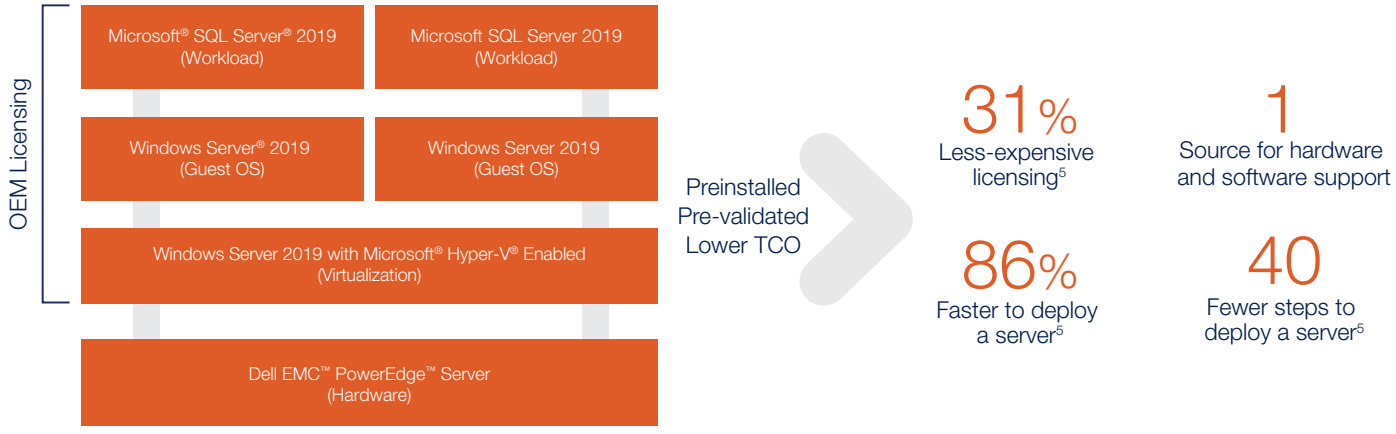

Figure 4. Dell Technologies provides OEM licensing and validated Dell EMC™ PowerEdge™ server solutions that provide better value than purchasing hardware and software separately

SQL Server Downgrade Kits

While Dell Technologies and Microsoft can provide you with OEM-licensed SQL Server 2019 software, suppose your organization's application requires SQL Server 2017 or SQL Server 2016. Dell Technologies and Microsoft can provide you with downgrade kit options for older, supported SQL Server versions. You can use these earlier versions of SQL Server until you are ready to migrate to SQL Server 2019.

Customer Solutions Centers Help Organizations Design and Build Solutions

In addition to OEM licensing and comprehensive support, Dell Technologies provides Customer Solution Centers, a global network of technical labs that can help you architect, validate, and build solutions that meet your organization's particular needs. Customer Solution Center engagements are a collaborative effort designed to help you find solutions to specific business requirements. Dell Technologies labs offer the latest technology products and remote connectivity that enable you to connect with solutions and Dell Technologies team members from any location. Customer Solution Center engagements can help you design a proof of concept that incorporates best practices and expert recommendations.

Dell Technologies Provides Comprehensive SQL Server 2019 Solutions, Licensing, and Support

Upgrading from legacy versions of SQL Server running on old hardware can be frustrating, time-consuming, and risky. Our research showed that Dell Technologies offers a high-performance upgrade path for legacy SQL Server deployments with Dell EMC PowerEdge servers. Dell Technologies also provides simplified Microsoft OEM licensing and support options, in addition to Customer Solution Centers that help you architect, validate, and build solutions. For more information, visit the following sites, or contact your Dell Technologies representatives for more information.

Learn More

Microsoft SQL Server 2019: **www.microsoft.com/en-us/sql-server/sql-server-2019**

Dell Technologies and Microsoft solutions: **www.delltechnologies.com/microsoft**

Learn about Dell Technologies solutions for Microsoft SQL Server: **https://infohub.delltechnologies.com/t/sql-server/**

Appendix

Configuration

Hardware

PowerEdge R740xd server:

- 2 x Intel Xeon Gold 6246 processors (12 cores at 3.30 GHz)
- 12 x 16 GB DDR4 DRAM at 2,667 megatransfers per second (MT/s) (192 GB total)
- 4 x 128 GB Intel Optane PMem at 2,677 MT/s (in App Direct Mode—512 GB total)
- Dell EMC PERC H740P storage controller
- 8 x 960 GB mixed-use Intel SSD DC S4610 drives
  - Two in a RAID 1 configuration that was used for the host operating system and to store the SQL Server VM virtual disk files
  - Two in a RAID 1 configuration that was unused
  - Four in a RAID 6 configuration that was used for the Windows Server 2019 VM that contained the shared iSCSI target; the iSCSI target was shared by the SQL Server FCIs
- Dual-port 25 GbE Broadcom® network daughter card

Software

Windows Server 2019 with the Hyper-V role enabled on Dell EMC PowerEdge R740xd servers, with SQL Server 2019 installed on Windows Server 2019 in the VMs.

Storage Configuration

- The SQL Server TempDB files were placed on a persistent memory DAX-enabled volume.
- The SQL Server log database files were placed on a persistent memory DAX-enabled volume.
- The SQL Server database files were placed on an iSCSI target that was shared between the two SQL Server FCIs. The iSCSI target was created on a Windows Server 2019 VM that was hosted on one of the Hyper-V hosts, and whose virtual disks were stored on that Hyper-V host's RAID 6 array.
- The HammerDB database and log files were statically sized in the following configurations:
  a. 500 warehouses, 50 GB database size, 12.5 GB log-file size, 10 percent growth
  b. 1,000 warehouses, 100 GB database size, 25 GB log-file size, 10 percent growth

Best Practices Settings

1. Enable a hybrid buffer pool for the server:

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

2. Configure the SQL Server 2019 memory settings. Note that the memory size of 140,336 is specific to the test servers these performance tests were run on. Your memory needs may vary. For more information about calculating the maximum server memory value, see "**Server memory configuration options**."

```
sp_configure 'show advanced options', 1;

GO

RECONFIGURE;

GO

sp_configure 'max server memory', 140336;

GO

RECONFIGURE;

GO
```

3. Configure LPIM:
   a. In the **Local Group Policy Editor** console, expand **Computer Configuration**, and then expand **Windows Settings**.
   b. Expand **Security Settings**, and then expand **Local Policies**.
   c. Select the **User Rights Assignment** folder. The policies are displayed in the details pane.
   d. Double-click **Lock pages in memory**.
   e. In the **Local Security Setting – Lock pages in memory** dialog box, click **Add User or Group**.
   f. In the **Select Users, Service Accounts, or Groups** dialog box, add an account that has privileges to run sqlservr.exe.
   g. Log out and then log back in to implement the change.
4. Configure the SQL Server 2019 MAXDOP settings:

```
EXEC sp_configure 'show advanced options', 1;

GO

RECONFIGURE WITH OVERRIDE;

GO

EXEC sp_configure 'max degree of parallelism', 12;

GO

RECONFIGURE WITH OVERRIDE;

GO
```

Testing Plan

1. Run five separate configurations of HammerDB:
   a. 500 warehouses, 1,000,000 transactions, 5 users
   b. 500 warehouses, 1,000,000 transactions, 10 users
   c. 500 warehouses, 1,000,000 transactions, 20 users
   d. 500 warehouses, 1,000,000 transactions, 50 users
   e. 1,000 warehouses, 1,000,000 transactions, 10 users
2. Set **Run Time** to **10 minutes**.
3. Run five passes of each configuration of HammerDB.
4. Take the variance of the five passes and ensure that they are in the range +/– 5 percent of each other.
5. After each test, delete the test database, recreate it, and then run the test again.

Microsoft Windows Server 2019 intel OPTANE™ TECHNOLOGY DELL Technologies

[1] End-of-support date according to **https://support.microsoft.com/en-us/lifecycle/search**.

[2] Intel® Optane™ persistent memory must be configured in App Direct Mode for data to persist.

[3] Based on Dell EMC internal testing in March 2019 comparing a Dell EMC™ PowerEdge™ R740xd with 2nd Generation Intel® Xeon® Scalable processors and 2 x 1.6 TB mixed-use NVM Express® (NVMe®) drives using Microsoft® SQL Server® 2019 CTP 2.3, VMware ESXi™ 6.7U1, and Red Hat® Enterprise Linux® 7.6GA against the same PowerEdge R740xd configuration except for substituting the NVMe drives for 12 x 256 GB DIMMs of Intel® Optane™ PMem. The workload used is derived from TPC-C® to SQL Server 2019 CTP 2.3 performance. The results obtained with the derived workload are not comparable to published TPC-C results. Actual results will vary.

[4] Based on a Dell EMC engineering study using the TPC-C® benchmark to test Microsoft® SQL Server® 2016, July 2017. Actual performance will vary.

[5] Prowess Consulting. "Streamline Your Server Deployments by Choosing Dell EMC™ PowerEdge™ Servers with Preinstalled Microsoft® Software." January 2020. **www.prowesscorp.com/project/dellemc-poweredge-windowsserver-report**.