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Optimizing Microsoft SQL Server* Databases to Accelerate Response Time and Throughput

Eliminate I/O bottlenecks and boost database performance by adding Intel® Optane™ DC Solid State Drives with Intel® Memory Drive Technology to your Microsoft SQL Server* platform

This solution brief describes how to solve business challenges through investment in innovative technologies.

If you are responsible for...

- **Business strategy:**
  You will better understand how adding Intel® Optane™ DC Solid State Drives with Intel® Memory Drive Technology to your Microsoft SQL Server* platform will enable you to successfully meet your business outcomes.

- **Technology decisions:**
  You will learn how adding Intel Optane DC Solid State Drives with Intel Memory Drive Technology to your Microsoft SQL Server* platform works to deliver IT and business value.

Executive Summary

When relational database technologies are not optimized, bottlenecks occur and businesses suffer. For instance, online retailers risk disappointing customers and losing business when transactions take too long. In fact, 30 percent of online shoppers expect a site to load in one second or less, and almost half of all users who experience slow checkout won't return to the site.[1] What's more, organizations running online analytical processing (OLAP) to leverage big data experience similar I/O bottlenecks that can limit throughput and increase the time needed to achieve actionable insights.

No organization can afford to sacrifice performance or business results. However, replacing existing systems isn't always an option for businesses trying to keep costs down. Adding Intel® Optane™ DC Solid State Drives (SSDs) enables companies to keep their current hardware, protecting their investment while boosting Microsoft SQL Server* response time.

Organizations can see additional benefits by combining Intel® Optane™ DC SSDs with Intel® Memory Drive Technology. The two work together to optimize Microsoft SQL Server for Linux*, creating a solution that helps eliminate storage system I/O bottlenecks. The result is improved transaction response times and query throughput.[2] By deploying Intel Optane DC SSDs with Intel Memory Drive Technology, organizations can avoid replacing servers or adding costly dynamic random-access memory (DRAM). Instead, they can use Intel® Optane™ technology to help eliminate I/O bottlenecks where they cause the most damage and meet specific business needs.

Whether the goal is to serve more customers, process more transactions, or speed data analytics, Intel Optane DC SSDs with Intel Memory Drive Technology can provide a competitive edge.

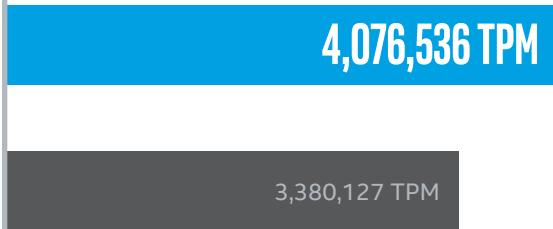**Intel® Optane™ SSD DC P4800X with Intel® Memory Drive Technology and 128 GB DRAM**
377 GB total available memory

4,076,536 TPM

384 GB All-DRAM
377 GB total available memory

3,380,127 TPM

TPM = transactions per minute

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Figure 1. Organizations can experience better performance in Microsoft SQL Server* for Linux* with a lower total cost.[2]

Solution Benefits

Intel® Optane™ DC Solid State Drives (SSDs) with Intel® Memory Drive Technology can help organizations optimize Microsoft SQL Server* for Linux* to gain the following benefits:[2]

- Increases memory for a lower investment when compared to DRAM replacement
- Reduces processor-request bottlenecks
- Supports I/O-intensive workloads
- Lowers latency for read/write to disk for reduced I/O wait times
- Boosts performance in Microsoft SQL Server for Linux with lower total cost of ownership
- Reduces cost per transaction

Intel® Optane™ DC SSD with Intel® Memory Drive Technology: RDBMS-Agnostic

Although this paper focuses on how Intel® Optane™ SSDs with Intel® Memory Drive Technology optimize caching and performance results with Microsoft SQL Server* for Linux*, we anticipate similar benefits with other relational database management systems (RDBMS). Whether working with MySQL* (an open source version of Microsoft SQL Server), Oracle SQL*, PostGreSQL*, or any fully featured relational database, users should experience comparable performance and caching improvements.

Business Challenge: Do More with Your Current Hardware

Organizations of all types must do more with fewer resources. To hold down the total cost of ownership, they must use existing technology investments whenever possible, optimize their hardware infrastructure, and stretch functionality to boost performance without going over budget. This can enable businesses to run efficiently while still providing a satisfying and productive customer experience.

Each organization's IT department faces its own individual challenges. However, all businesses need their technology to keep up with demands such as speeding and streamlining responses to queries, reducing wait time, and eliminating or reducing I/O bottlenecks. Time is money, so waiting and lag time represent risk for any company to run efficiently.

Intel® Optane™ SSDs with Intel® Memory Drive Technology can help corporate IT departments optimize Microsoft SQL Server* for Linux*, a relational database management system (RDBMS) used to support transaction processing, business intelligence, and analytics applications. Intel® Optane™ DC SSDs offer low latency and high endurance. Intel Memory Drive Technology increases memory capacity beyond the limitations of dynamic random-access memory (DRAM) and can deliver DRAM-like performance at a lower cost than an expensive DRAM replacement.

Realize Significant Performance Improvements

Organizations don't need to make dramatic and expensive changes, such as purchasing expensive DRAM, to keep up with business demands. To gain significant and measurable performance improvements, companies can instead swap out current storage devices with Intel Optane DC SSDs at strategic points where I/O bottlenecks are most problematic.

Improve system responsiveness. Fast, efficient information processing is essential for business success. For online retailers, reducing the time lag between customer queries

and responses is imperative. Customers expect instant gratification, and online retailers who can't deliver run the risk of losing buyers at the point of sale. In fact, research from ReadyCloud shows that USD 4 trillion worth of merchandise was projected to be abandoned in 2017, and for each passing second that a website takes to load, the cart abandonment rate climbs by seven percent.[3]

Storing transactional logs on Intel Optane DC SSDs speeds online transactions by reducing I/O wait times. This decreases the time for transactions to move from memory to disk, which in turn enables more transactions per minute (TPM), creates a more satisfying buyer experience, and helps ensure smoother purchases. Although Intel Optane DC SSDs can be considered somewhat expensive, their ability to significantly speed TPM means that adding these SSDs to specific places in the I/O path of an SQL solution can provide substantial return on investment by lowering the cost-per-transaction metric. In other words, Intel Optane DC SSDs soon pay for themselves through performance enhancement.

Process more queries in less time. Today's organizations are tasked with managing an overwhelming amount of data. Many of them harness the power of online analytical processing (OLAP) to reveal actionable insights that can give their company a competitive edge and help increase operational efficiency. However, the volume of data that needs parsing can easily overwhelm existing storage systems and create I/O bottlenecks. While not every organization needs to rapidly perform analytics, it's essential to maximize query throughput and eliminate or reduce I/O bottlenecks. Placing the TempDB*—the Microsoft SQL Server database that holds temporary user objects on a scratch drive—on an Intel Optane DC SSD can help organizations quickly and effectively aggregate information from different sources to answer a question or determine a trend. Fortunately, it's not necessary to replace all of an organization's high-capacity data storage drives with Intel Optane DC SSDs. Instead, companies can use Intel Optane DC SSDs where they will gain the most value from the investment.

Solution Value: Speed Responses, Improve Query Throughput

Online retailers and internal IT shops routinely query inventory and other data stores. Lower I/O wait times and write-to-disk latency can help eliminate I/O bottlenecks. As a result, retailers can increase customer satisfaction, reduce cart abandonment, and boost sales; additionally, IT departments and data scientists can process data analytics queries faster. Plus, when workloads run faster, more compute cycles are available to perform additional analysis and derive more insights.

Intel Optane SSDs with Intel Memory Drive Technology can speed I/O-intensive workloads in the following ways:

Extending memory capacity. Intel Memory Drive Technology extends memory capacity with DRAM-like performance but with less cost. Intel Memory Drive Technology transparently integrates Intel Optane DC SSDs and memory subsystems by defining some of the Peripheral Component Interconnect Express* (PCIe*)-based Intel Optane DC SSD capacity as memory instead of storage.

Figure 2 illustrates the performance boost Intel Memory Drive Technology provides to Microsoft SQL Server for Linux compared to an all-DRAM system. In our test, we compared HammerDB* benchmark results from two configurations:[4]

- 377 GB of DRAM
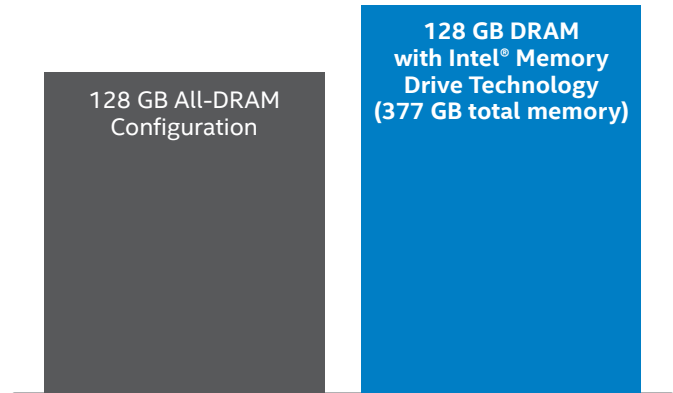- 128 GB of DRAM with Intel Memory Drive Technology (377 GB total memory)

As the figure shows, adding Intel Memory Drive Technology, which is more affordable than adding DRAM, provides an increase in TPM.

Expanding and speeding up storage. Solid state drives deliver significant workload-optimized performance improvements. To further demonstrate the value of Intel Optane SSD technology, we added two Intel Optane DC SSDs and two extra Intel® Optane™ SSD DC P4500 (see Figure 3) to the Intel® Select Base configuration. This increased storage capacity by 200 percent compared to the original configuration, and according to our calculations, lowered the cost per transaction by up to 10 percent. Also, the relative throughput for row store and column store increased by about 16 percent.[5]

In another example of the value of Intel Optane technology, we ran an online transaction processing (OLTP) workload with two configurations: one where all files—data, logs, and TempDB—were on a single Intel SSD DC P4500, and one where the data files were stored on the Intel SSD DC P4500 but the logs and TempDB were placed on an Intel® Optane™ SSD DC P4800X featuring Intel Optane technology.[6]

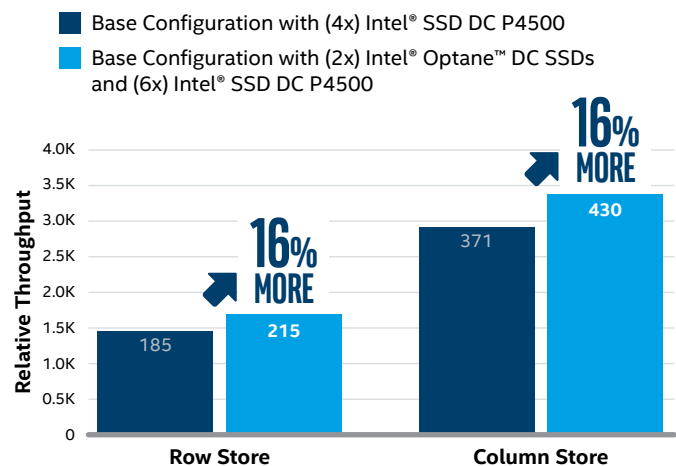## Affordably Increase Throughput with Intel® Memory Drive Technology
Higher Is Better

Figure 2. Using Intel® Memory Drive Technology can boost transactions per minute (TPM) performance without the high cost of dynamic random-access memory (DRAM).[4]

Increase Throughput with Intel® Optane™ DC SSDs
Higher Is Better

Figure 3. Adding Intel® Optane™ DC SSDs can further improve performance and drive down cost per transaction.[5]

Of course, storing the logs and TempDB on a separate volume is standard best practice. And leaving the data files on the 3D NAND-based SSD and placing the logs and TempDB on an Intel Optane DC SSD provides significantly improved performance[6] (see Figure 4), without needing to invest in a large-capacity Intel Optane DC SSD. The test resulted in a 53 percent increase in TPM for a single user, and a 31 percent increase for two concurrent users. Even at 16 concurrent users, the TPM metric was 6 percent higher. This shows that designing Microsoft SQL Server file placement with Intel Optane technology in mind can benefit OLTP workloads, potentially leading to greater customer satisfaction and increased revenue.

Solution Architecture: Affordable Memory Boost

The solution includes two components (see Figure 5):

- **Intel Memory Drive Technology.** Adding this technology to Microsoft SQL Server for Linux gives companies the ability to boost memory and realize significant performance improvements without investing in costly DRAM. Intel Memory Drive Technology transparently integrates Intel Optane DC SSDs into the Microsoft SQL Server memory subsystem, enabling it to simulate DRAM to the OS and applications.

- **Intel Optane DC SSDs.** The Intel Optane SSD DC P4800X works to eliminate data center storage bottlenecks. The technology can accelerate applications, reduce transaction costs, and lower data center total cost.[6]

Intel Optane SSD DC P4800X with Intel Memory Drive Technology can create a solution that caches often-used data to boost the responsiveness of Microsoft SQL Server for Linux. Intel Memory Drive Technology acts as a software middle layer that runs below the OS, converting SSDs into memory. When this software is paired with an Intel Optane

DC SSD and system DRAM, the combination is presented to the OS as a single memory pool, transparent to the OS and applications. This means there is no need to modify applications to take advantage of Intel Optane DC SSDs with Intel Memory Drive Technology.

The combination of DRAM and Intel Optane DC SSDs with the intelligence of software allows background data movement for write-back and read prefetching, which are key for predictable performance. Intel Optane DC SSDs with Intel Memory Drive Technology take advantage of low-latency capabilities of the drive.

Increase Database Transactions Per Minute with Intel® Optane™ DC SSDs
Higher Is Better
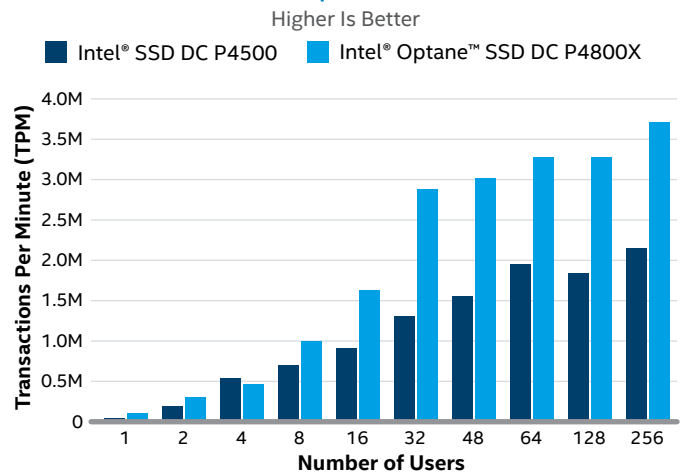
Figure 4. Designing Microsoft SQL Server* file placement with Intel® Optane™ technology in mind, such as splitting logs and the TempDB* across both a standard Intel® SSD and an Intel® Optane™ DC SSD, can increase online transaction processing performance.[6]
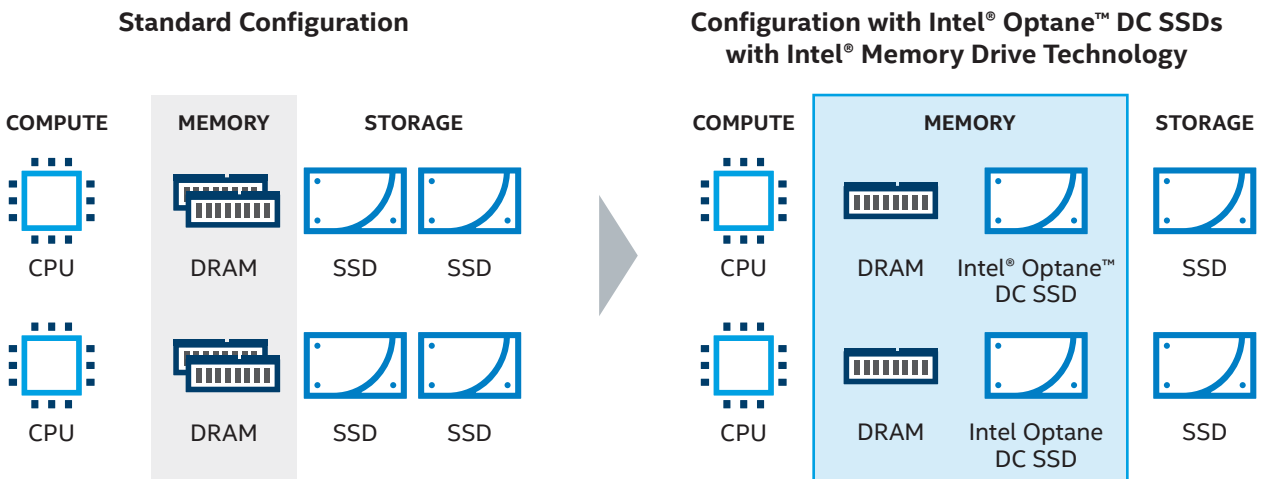
Figure 5. Intel® Memory Drive Technology modifies a part of the system's storage (the Intel® Optane™ SSD DC P4800X) to transparently serve as the system's memory.

Conclusion

Using Intel Optane DC SSDs with Intel Memory Drive Technology on Microsoft SQL Server for Linux optimizes database functionality and delivers significant business value to many types of organizations. Companies can realize substantial benefits at less cost than adding expensive DRAM.

Intel Optane DC SSDs with Intel Memory Drive Technology work together to keep data flowing, reduce I/O bottlenecks, and decrease I/O wait times by helping transactions move quickly from memory to disk. For online retailers, these Intel® technologies increase system responsiveness at the point of sale, which is critical because, according to Google engineers, even a 400ms lag is too long for site visitors.[7] By using these technologies to process transaction logs, online retailers can offer a fast and easy buying experience, minimizing customer disappointment and cart abandonment. Organizations that leverage big data with analytics can place their TempDB on an Intel Optane DC SSD with Intel Memory

Drive Technology to gain fast, timely insights. Companies can improve the performance of their current hardware, producing a greater return on their existing investment while increasing their efficiency and competitiveness.

Find the solution that's right for you. Contact your Intel representative or visit **intel.com/optane.**

Learn More

You may also find the following resources useful:

- Intel® Optane™ SSD DC P4800X
- Intel® Memory Drive Technology
- System Memory at a Fraction of the DRAM Cost Paper
- Empower Your Business with Data Warehousing
- Intel® Select Solutions for Microsoft SQL Server* Solution Brief

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[1] Performance Matters More Than Ever - The Business Impact of Web Performance. blogs.akamai.com/2015/06/performance-matters-more-than-ever

[2] Performance results based on Intel testing March 19, 2019. Configuration 1: CPU: Intel® Xeon® processor E5-268W (2 processors) with 48 HT cores; 384 GB DRAM (377 GB usable); BIOS 01.01.0015. (11/08/2018). One 1 TB Intel® Optane™ SSD DC P4500 (930 GB usable). Running Windows Server* 2016 and Microsoft SQL Server* 2017 Enterprise Edition. Configuration 2: CPU: Intel® Xeon® processor E5-268W (2 processors) with 48 HT cores; 128 GB DRAM. BIOS 01.01.0015 (11/08/2018). One 375 GB Intel® Optane™ SSD DC P4800X + Intel® Memory Drive Technology; Running Windows Server* 2016; and Microsoft SQL Server* 2017 Enterprise Edition. Workload: HammerDB* 3.1 – MS-SQL-TPC-C.

[3] $4 Trillion & Counting: 2017 Shopping Cart Abandonment Statistics. readycloud.com/info/4-trillion-and-counting-2017-shopping-cart-abandonment-statistics

[4] Source: Online transaction processing (OLTP) workload with two configurations: one where all files—data, logs, and TempDB*—were on a single Intel® SSD DC P4500, and one where the data files were stored on the Intel SSD DC P4500 but the logs and TempDB were placed on an Intel® Optane™ SSD DC P4800X featuring Intel® Optane™ technology. Configuration 1: CPU: Intel® Xeon® Gold 6254 CPU @ 3.1 GHz (2 processors) with 72 HT cores; 192 GB DRAM (191 GB usable); BIOS 2.8. (11/23/2018). One 1 TB Intel® Optane™ SSD DC P4500 (930 GB usable). Running Windows Server* 2019; and Microsoft SQL Server* 2017 Enterprise Edition. Configuration 2: CPU: Intel® Xeon® Gold 6254 CPU @ 3.1 GHz (2 processors) with 72 HT cores; 192 GB DRAM (191 GB usable); BIOS 2.8. (11/23/2018). One 750 GB Intel® Optane™ SSD DC P4800X; Running Windows Server* 2019; and Microsoft SQL Server* 2017 Enterprise Edition. Workload: HammerDB* 3.1 – MS-SQL-TPC-C. HAMMERDB Settings: 500 Warehouses, Auto-Pilot – 1, 2, 4, 8, 16, 32, 48, 64, 128, 256 virtual users. Ramp up time – 2 minutes, Test time – 5 minutes. Performance results are based on testing by Intel as of March 19, 2019 and may not reflect all publicly available security updates.

[5] Source: DWFT Solution is a pre-built solution offered by OEMs to customers. The values are hypothetical scores compared by the tool itself against a based validated configuration. The values assume the following: Compression rate: 5:1. The throughput values are percentage of the reference hardware assumed by the tool. Test configuration: download.microsoft.com/download/F/8/6/F8654654-6784-48F5-83C0-2D46186EEC66/Data_Warehouse_Fast_Track_Reference_Guide_for_SQL_Server_2016_EN_US.pdf. The reference architecture can be found on the design principles from Intel® Select Solution. intel.com/content/www/us/en/products/solutions/select-solutions/analytics/microsoft-sql-server-enterprise-data-warehouse. Workload: Microsoft SQL Data Warehouse Fast Track (DWFT). Base configuration: Baseline: 2x Intel® Xeon® Gold 6132 processor (2.60 GHz, 14 cores, 384 GB RAM), BIOS SE5C620.86B.00.01.0012.021320180053; 4x Intel® SSD DC P4500 (1.6 TB for data, logs, and TempDB*). Software: Windows Server* 2016, Microsoft SQL* 2017 Enterprise Edition. Base configuration plus Optane: 2x Intel® Xeon® Gold 6132 processor (2.60 GHz, 14 cores, 384 GB RAM), BIOS SE5C620.86B.00.01.0012.021320180053; 6x Intel® SSD DCP4500 (3.8 TB for data), 2x Intel® SSD DC P4800X (375 GB for logs and TempDB). Performance results are based on testing by Intel as of November 2018 and may not reflect all publicly available security updates.

[6] See endnote 4.

[7] The Google Gospel of Speed. thinkwithgoogle.com/marketing-resources/the-google-gospel-of-speed-urs-hoelzle