KIOXIA

Data Center NVMe™ SSDs Deliver Elevated Performance at a Cost that Replaces Enterprise SATA in Servers

NVMe™ SSDs deliver accelerated performance and larger capacities (versus SSDs based on legacy protocols) that will position them as the leading storage media in total SSD consumption (in units)[1] over the next five years. This includes both enterprise NVMe SSDs and data center NVMe SSDs. Enterprise NVMe SSDs typically feature enterprise-class reliability, availability and serviceability, and deliver the highest SSD performance currently available when compared to today's legacy storage media. Many customers will pay a premium for these capabilities. Data center NVMe SSDs have emerged and are designed primarily for read-intensive applications in cloud / hyperscale data centers where the focus is on delivering predictable performance and quality of service. The deployment cost is comparable to enterprise SATA SSDs resulting in leading server vendors[2] now offering server platforms with data center NVMe SSD models.

Customers are moving to NVMe SSDs to not only meet current data-intensive application performance requirements, but also to address the requirements of cloud-based data center architectures. NVMe SSDs connect directly to server CPUs through the PCIe® interface bus and use a streamlined storage stack which bypasses host bus adapters (HBAs) that SAS and SATA drives must use for backplane connections. They can move data at speeds up to one gigabyte per second (GB/s) per lane, and with lanes for data to flow, NVMe SSDs can continuously feed today's fast CPUs with data. When PCIe 4.0 becomes available, the x16 PCIe slot can deliver up to 32GB/s of bi-directional data travel, which is double the bandwidth of PCIe Gen3.

The NVMe interface itself was designed specifically for non-volatile memory (NVM) SSDs and uses the PCIe interface as the physical connection between backplane NVMe SSDs and the CPU. Eliminating the HBA results in even higher performance and lower latency. Additionally, host processing of each storage instruction is tremendously more efficient with NVMe as it supports a queue depth of 64K commands in 64K queues. Enterprise SATA SSDs, on the other hand, utilize an instruction set originally developed for hard drives and can only support 32 commands in a single queue. These deficiencies can cause servers with powerful, multicore processors and an abundance of DRAM to be waiting for data transactions to complete, resulting in an underutilization of the server's compute and storage resources.

The SATA interface has plateaued at up to 6 gigabits per second (Gb/s), has reached the end of its product roadmap, and is expected to fall to 5% of total SSD consumption in the data center by the end of 2023[3]. When tested in a KIOXIA lab environment[4], data center NVMe SSDs delivered 5.45x more read bandwidth than SATA, as well as 3.27x more write bandwidth, 5.88x more random read input/output operations per second (IOPS), and 1.43x more random write IOPS (Chart 1).

Read / Write Operation	Enterprise SATA SSD 6Gb/s (1 DWPD*)	Data Center NVMe SSD Gen3x4 (1 DWPD*)	Data Center NVMe SSD Advantage
Sequential Read (128K block size)	550MB/s	3,000MB/s	5.45x
Sequential Write (128K block size)	550MB/s	1,800MB/s	3.27x
Random Read (4K block size / 256 QD^)	85,000 IOPS	500,000 IOPS	5.88x
Random Write (4K block size / 256 QD^)	35,000 IOPS	50,000 IOPS	1.43x

Chart 1: Performance comparisons between enterprise SATA and data center NVMe SSDs
**Drive Write(s) per Day*
^Queue Depth

Differentiating Price and Performance between Enterprise and Data Center NVMe SSDs

Enterprise NVMe SSDs warrant a higher price when compared to data center NVMe SSDs as they deliver the highest performance an SSD can currently achieve, and include enterprise-class reliability features such as data integrity checking, media wear reporting and error reporting. In some cases, enterprise NVMe SSDs provide dual port capabilities for high availability.

Conversely, data center NVMe SSDs are high volume drives with little to no custom firmware or specialized features. Where enterprise NVMe SSDs may support dual-port capabilities, data center NVMe SSDs are typically single-ported and designed for direct-attached storage environments. With fewer bells and whistles, and optimized performance, IT users expect to pay less for data center NVMe SSDs when compared to the fully-featured enterprise counterparts.

KIOXIA offers both data center NVMe SSDs in their CD5 Series and enterprise NVMe SSDs in their CM5 Series. Both NVMe SSD platforms are developed using 64-layer BiCS FLASH™ 3D technology and available in 960GB[5] to 7,680GB capacities - a 15,360GB capacity CM5 Series SSD is also available. Performance differences[6] between the CD5 Series and CM5 Series are shown in Chart 2 below.

Read / Write Operation	Data Center NVMe SSD CD5 Series (1 DWPD*)	Enterprise NVMe SSD CM5 Series (1 DWPD*)	CM5 Series Advantages
Sequential Read (128K block size)	3,000MB/s	3,350MB/s	1.17x
Sequential Write (128K block size)	1,800MB/s	3,040MB/s	1.69x
Random Read (4K block size / 256 QD^)	500,000 IOPS	770,000 IOPS	1.54x
Random Write (4K block size / 256 QD^)	50,000 IOPS	80,000 IOPS	1.60x

Chart 2: Performance comparisons between data center NVMe SSDs and enterprise NVMe SSDs
**Drive Write(s) per Day*
^Queue Depth

In addition to these performance advantages, both NVMe SSD platforms deliver multiple levels of data security that can include SIE (Sanitize Instant Erase), Self-Encrypting Drive (SED) with TCG-Opal encryption and SED FIPS 140-2 (Level 2) support.

Sanitize Instant Erase (SIE)	Self-Encrypting Drive (SED)	FIPS 140-2 (Level 2)
Encrypts all data stored on the SSD. Requires passwords to manage encryptions and help prevent data theft.	Encrypts all data to the SSD and decrypts all data from the SSD, and uses password protection to prevent data theft.	Validates that the cryptographic module within an SSD's security system will maintain the confidentiality and integrity of the data being protected. Higher levels of protection (from 1-4) indicate drives that are progressively more resistant to attack.

Summary

The server and storage market category for NVMe SSDs includes both enterprise and data center models that are penetrating server platforms at an increasing pace. Utilizing a streamlined SSD stack developed specifically for flash-based media, coupled with the ability to move PCIe Gen3 data at up to 4GB/s for a x4 drive, NVMe SSDs can better feed server CPUs with data versus SATA SSD performance that has plateaued and has no planned roadmap in its future. Customers are moving to NVMe SSDs for their enterprise performance requirements and cloud-based data center architectures, replacing SATA in servers. The next-generation of performance-centric and latency-sensitive applications require IT and DevOps organizations to rethink their enterprise and data center storage strategies, and at the center of this requirement is heightened demand for NVMe-based storage.

Notes:

[1] Source: IDC - "Worldwide Solid State Drive Forecast Update, 2019-2023, Market Forecast-Table 12, Jeff Janukowicz, December 2019, IDC #44492119. The market for enterprise and data center NVMe SSDs are forecasted to represent about 42.5% of the total SSD use in the enterprise (in units) by the end of 2019, that is expected to grow to 75% by the end of 2021 and 91% by the end of 2023.

[2] KIOXIA America, Inc. offers the CD5 Series of data center NVMe SSDs that are available in Dell EMC™ PowerEdge™ servers and HPE® ProLiant® servers as follows:

CD5 Series SSD Capacity	Dell™ PowerEdge™	HPE® ProLiant®
960GB	KCD5XLUG960G	P10208-B21
1,920GB	KCD5XLUG1T92	P10210-B21
3,840GB	KCD5XLUG3T84	P10212-B21
7,680GB	KCD5XLUG7T68	Contact HPE

[3] Source: IDC - "Worldwide Solid State Drive Forecast Update, 2019-2023, Market Forecast-Table 12, Jeff Janukowicz, December 2019, IDC #44492119. The market for enterprise SATA SSDs are forecasted to represent about 45.5% of the total SSD use in the enterprise (in units) by the end of 2019, that is expected to decline to 17% by the end of 2021 and 5% by the end of 2023.

[4] An Online Transaction Processing (OLTP) application was used for measurement of server-side performance to provide the data locality benefits of direct-attached storage (high-performance / low-latency). The results showcase SSD interface bandwidth and performance and how many operations/transactions that a server's CPU can process. The performance measurements were derived from existing KIOXIA SSD products configured with 960GB capacities, tested at 1 DWPD (Drive Write per Day), and included the HK4 Series of SATA SSDs and CD5 Series of NVMe SSDs.

[5] Definition of capacity: KIOXIA Corporation defines a gigabyte (GB) as 1,000,000,000 bytes and a terabyte (TB) as 1,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1GB = 2^{30} bytes = 1,073,741,824 bytes, 1TB = 2^{40} bytes = 1,099,511,627,776 bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, or media content. Actual formatted capacity may vary.

[6] An OLTP application was used for measurement of server-side performance to provide the data locality benefits of direct-attached storage (high-performance / low-latency). The results showcase SSD interface bandwidth and performance and how many operations/transactions that a server's CPU can process. The performance measurements were derived from existing KIOXIA SSD products configured with 960GB capacities, tested at 1 DWPD, and included the CD5 Series data center NVMe SSDs and CM5 Series enterprise NVMe SSDs.