Technical Research Report

PROWESS

Life After SATA: Application Benefits of KIOXIA Data Center NVMe™ SSDs vs. Enterprise SATA SSDs

Prowess Consulting tested KIOXIA CD8 Series Data Center NVM Express™ (NVMe™) PCIe® solid-state drives (SSDs) and 6 gigabits per second (Gb/s) Serial ATA (SATA) Samsung® SSDs, comparing overall storage performance, price/performance, power/performance, and reliability.

Executive Summary

The demand for high-capacity, high-throughput, and low-latency storage keeps going up. In addition to meeting current demands for cost and power savings, data centers need storage solutions that can provide better total cost of ownership (TCO).

When it comes to choosing the data-storage technology that best fits your needs, understanding the differences between NVM Express™ (NVMe™) PCIe® 4.0 and 6 gigabits per second (Gb/s) Serial ATA (SATA) solid-state drives (SSDs) is key. To quantify the performance differences between these two storage technologies, Prowess Consulting conducted benchmark testing for read data, along with price-performance and power-performance analyses, on the KIOXIA CD8 Series Data Center NVMe PCIe SSD and the Samsung® 6 Gb/s SATA SSD. The NVMe technology significantly outperformed the older SATA storage across the random and sequential read data metrics we tested. Our price-performance analyses revealed that the NVMe SSD can deliver superior performance/dollar and performance/watt compared to the SATA SSD for a variety of read workloads.

Read more to learn why upgrading to NVMe SSDs could be the right storage solution for data centers running virtualized applications.

Market and Technology Trends

Driven by the need to store and access massive volumes of data coming from an ever-widening range of sources, the storage market is growing at an exponential rate. For example, installed data capacity is expected to double globally between 2019 and 2024, reaching 13.2 ZB.[1] An influx of new technologies—such as artificial intelligence (AI), edge computing, blockchain ledgers, business information modeling (BIM), engineering rendering and simulations, Internet of Things (IoT) sensors, and high-throughput medical imaging—is generating more data than ever before. Powerful technologies such as these encourage organizations to apply data-driven decision making to everything from strategic planning to business operations to customer interactions.

Many organizations use write once, read many (WORM) data storage because it provides better data protection than write workloads or mixed workloads. Read-only storage limits the risk of data corruption or loss from a cyberattack, unauthorized user access, or even accidental overwriting. Financial, healthcare, and government organizations might use WORM storage to help them comply with information-security regulations. By storing data in WORM-compliant storage, research organizations can perform complex data analytics on large datasets without worrying about accidentally altering the data. Read data is also faster to process than write data or mixed data, which can be useful for applications that rely on real-time data processing.

These are some of the key factors driving data centers to switch to modern storage solutions that provide higher capacity, higher throughput, and lower latency. In addition to boosting storage performance, comprehensive solutions also help organizations lower their TCO through energy efficiency, cost savings, extended system lifecycles, and future proofing.

If you're running hundreds of virtual machines (VMs) on a single server, then a storage technology upgrade could be vital to preventing application slowdowns caused by input/output (I/O) bottlenecks. When considering storage solutions, it's also important to consider the big picture. The optimal data storage solution not only addresses your immediate needs, but it also helps you prepare for future growth. This growth might include platform upgrades, infrastructure scale-outs, legacy system repurposing, and optimal storage utilization. To find the storage solution that makes the most sense for your business, it's critical to understand what storage technologies are available, what they do, and what makes the most sense for your needs.

We suggest you use this report to make informed decisions about whether upgrading to NVMe SSDs is the best solution for your data-center environment.

Methodology

The explosive growth of data volumes, the increasing complexity of modern workloads, and the growing demand for near-real-time database access and delivery are a few of the factors straining the limits of traditional SATA storage technology. Faced with skyrocketing energy and other costs, data centers are also seeking to lower their TCO. In the face of these demands, many virtualized data centers are asking the critical question, "Is now the time to switch to NVMe storage?"

In response to this question, Prowess Consulting engineers started with the hypothesis that NVMe SSDs could provide a better user experience for virtualized applications than SATA drives. We quantified this experience by measuring the drives' comparative performance (outputs), price-performance (performance/US dollar [USD]), power efficiency (performance/watt), and reliability (mean time to failure [MTTF] or mean time between failures [MTBF]).

We measured read-only storage performance using the three most commonly cited outputs: throughput in megabytes/second (MB/s), I/O operations per second (IOPS), and latency in milliseconds (ms). Following industry standards, our engineers tested storage performance using 4 KB block sizes for random read workloads and 128 KB block sizes for sequential read workloads. For full testing details, see the methodology report at prowessconsulting.com/project/kioxia-nvme-ssd-vs-sata-price-performance/.

Samsung documentation lists 6 Gb/s SATA SSD performance based on the Flexible I/O (fio) benchmarking tool.[2] However, we were interested in assessing how storage performs under real-world conditions. We ran benchmark testing on two different system configurations—one with KIOXIA CD8 Series Data Center NVMe PCIe SSDs and another with Samsung 6 Gb/s SATA SSDs. On the NVMe system, our engineers used Microsoft® Storage Spaces to create a mirrored storage disk pool with a new volume on the NVMe drives, and on the SATA system, we created a mirrored storage disk pool with a new volume on the SATA drives. We used Hyper-V® to create six virtual machines (VMs) to host the virtual workloads. With workloads running, we used DISKSPD to run performance testing (see Table 1 for the configuration details).

Table 1 | System configurations used for testing

	Dell™ PowerEdge™ R6525 with KIOXIA SSDs	Dell™ PowerEdge™ R6515 with Samsung® SSDs
Server	Dell™ PowerEdge™ R6525	Dell™ PowerEdge™ R6515
Processor	AMD EPYC™ 7543 processor	AMD EPYC™ 7702P processor
Number of CPUs	1	1
Cores/threads per CPU	32/64	32/64
Storage technology	NVMe™ PCIe® 4.0	SATA
Disk	3.84 TB KIOXIA KCD8XRUG3T84	3.84 TB Samsung® MZ7LH3T8
Number of disks	4	4
Storage pool	Microsoft® Storage Spaces, two-way mirror	Microsoft® Storage Spaces, two-way mirror
Installed memory	256 GB error correction code (ECC) DDR4	256 GB error correction code (ECC) DDR4
Memory DIMM	32 GB Hynix® HMAA4GR7CJR8N-XN	16 GB Micron® 18ASF2G72PDZ-3G2J3
Active power consumption (typical usage)	Up to 14 W[3]	Up to 3.6 W[2]
Reliability	MTTF:* 2.5 million hours[3]	MTBF*: 2.0 million hours[2]
Virtualization platform	Hyper-V®	Hyper-V®
Virtual machines (VMs)	1 x Microsoft® Active Directory® 1 x file server 1 x Microsoft® SQL Server® 3 x Windows® 11	1 x Microsoft® Active Directory® 1 x file server 1 x Microsoft® SQL Server® 3 x Windows® 11
Operating system (OS)	Windows Server® 2022	Windows Server® 2022
DISKSPD	DISKSPD 2.0.21a 9/21/2018	DISKSPD 2.0.21a 9/21/2018

***MTTF and MTBF are treated as equivalent for the purposes of this study.**

Results and Analysis

In our benchmark testing for throughput, IOPS, and latency, we found that the KIOXIA CD8 Series SSD delivered multifold improvements in read workload performance over the Samsung SATA SSD. Our analyses also revealed that the KIOXIA CD8 Series SSD delivered superior price-performance and power-performance, confirming its potential to lower TCO for a variety of read-only workloads.

100 Percent Random Read

The 100 percent random read testing simulates a multi-user environment running read-intensive operations, such as media streaming workloads. Figure 1 and Table 2 illustrate that the KIOXIA CD8 Series SSD performed up to 5.90x higher for 100 percent random read outputs (throughput and IOPS), with up to 6.12x lower average latency, than the Samsung SATA SSD. KIOXIA CD8 Series SSD latency was also considerably more consistent than the Samsung SATA SDD, showing up to a 6.36x smaller standard deviation.

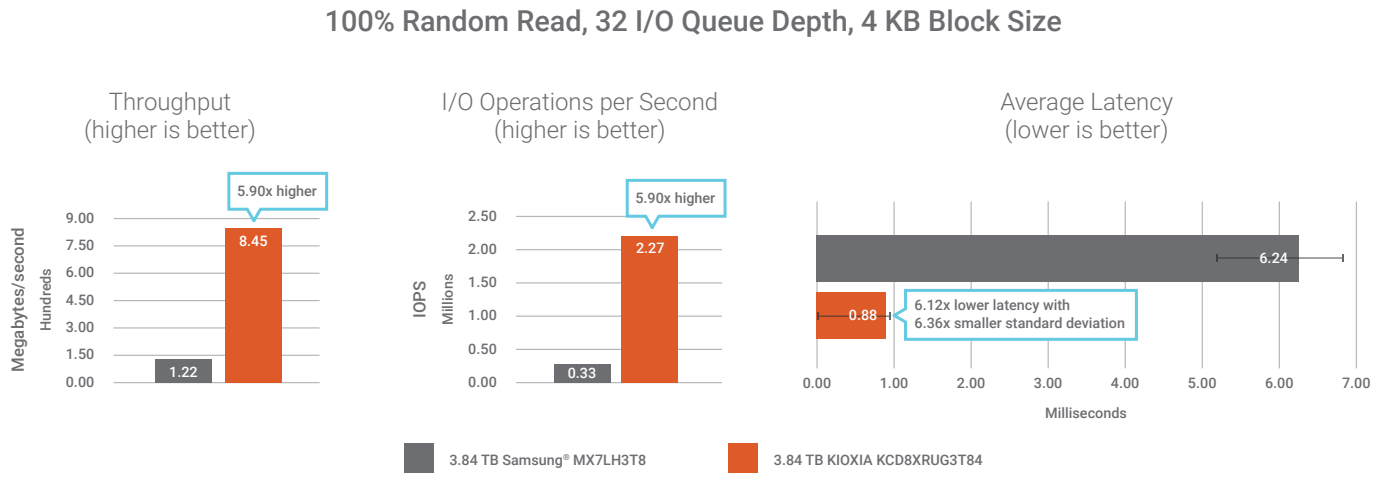


Figure 1 | Outputs for 100 percent random read, 32 I/O queue depth

Table 2 | 100 percent random read outputs at a queue depth of 32 I/O requests and a block size of 4 KB

100 Percent Random Read	KIOXIA SSD	Samsung® SSD
Throughput (MB/s)	8,447.29	1,223.26
IOPS	2,267,561.30	328,367.63
Average latency (milliseconds)	0.88	6.24
Latency, standard deviation (SD)	0.08	0.60

Video on demand (VOD) and other streaming media services typically rely on read-intensive applications. Our benchmarking results indicate that customers could experience nearly six-fold faster media delivery, along with less buffering, from content delivery networks (CDNs) that use KIOXIA CD8 Series SSDs rather than the Samsung SSDs we tested.

100 Percent Sequential Read

Sequential read data testing simulates storage used for object detection and big data analytics. Figure 2 and Table 3 illustrate that the KIOXIA CD8 Series SSD again showed multifold improvements in 100 percent sequential read outputs compared to the Samsung SATA SSD—up to 6.60x higher throughput and up to 6.84x lower average latency. The KIOXIA CD8 Series SSD's latency standard deviation (SD = 0.80) was a fraction of the Samsung SATA SDD's SD (SD = 6.26), smaller by 25.67x.

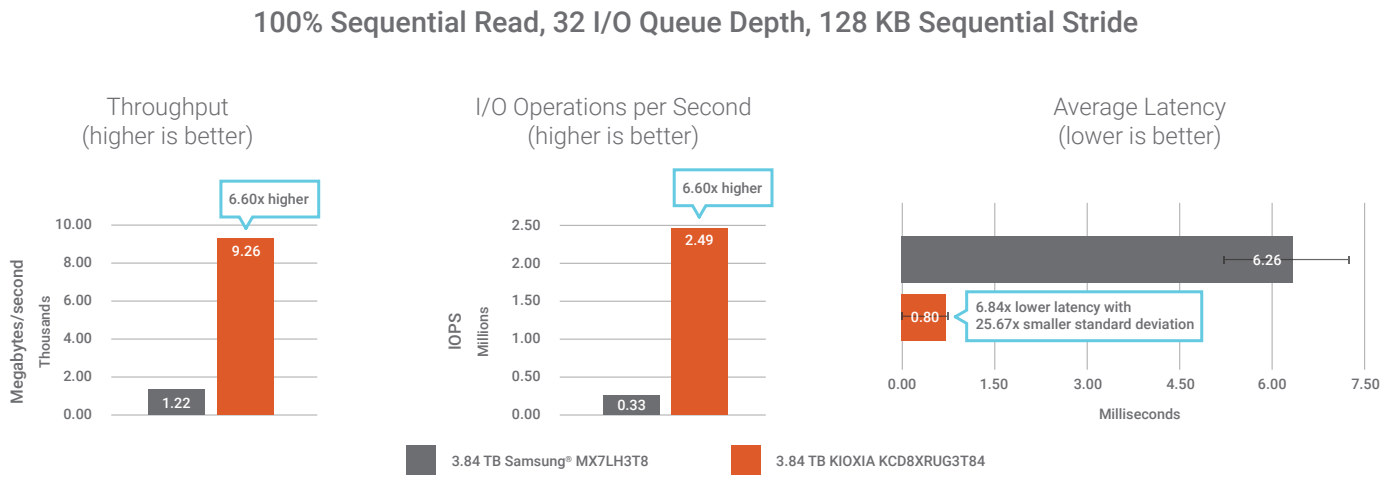


Figure 2 | Outputs for 100 percent sequential read, 32 I/O queue depth

Table 3 | 100 percent sequential read outputs at a queue depth of 32 I/O requests and a block size of 128 KB

100 Percent Sequential Read	KIOXIA SSD	Samsung® SSD
Throughput (MB/s)	9,262.24	1,218.14
IOPS	2,486,324.15	326,994.26
Average latency (milliseconds)	0.80	6.26
Latency, standard deviation (SD)	0.04	0.99

Read-only operations are ideal for object store (storage) databases that are used to back up and archive emails, videos, photos, web pages, audio files, sensor data, and other types of massive-volume, unstructured datasets. The results shown in Figure 2 indicate that virtualized databases running on KIOXIA CD8 Series SSDs can access larger files than Samsung SATA SSDs, because the KIOXIA drives deliver up to 6.60x higher throughput. The low variability (standard deviation) translates into smoother content delivery, with fewer "valleys" that could cause extended buffering.

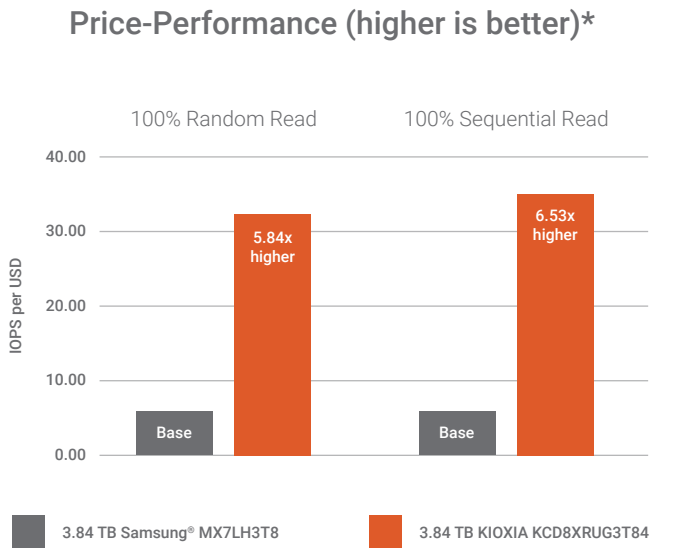
Price-Performance Analysis

Lower database latency can deliver substantial financial benefits for your business. A financial exchange study concluded that a 5-millisecond delay in order processing can result in traders executing up to 50 percent fewer trades. This reduction in transaction frequency can translate into a 10 percent penalty on the financial exchange's rates of return.[4]

How can you benefit from a faster database?

5 milliseconds faster response time = 50% more trade transactions[4]

The price-performance comparison shown in Figure 3 reveals that NVMe SSDs can help lower TCO across a variety of read workloads. For this analysis, we compared prices for system configurations, including all the hardware needed to deploy a SATA or NVMe storage server. For example, to ensure the motherboard supports the full complement of RAID capabilities, the KIOXIA CD8 Series SSD server configuration includes a RAID card. The chart shows price-performance measured as IOPS per USD, using the Samsung SATA SSD server configuration as the baseline. Our MB/s per USD analyses showed similar price-performance trends, with the NVMe drives outperforming the SATA drives across the tested workloads.[5]



*Pricing based on an NVM Express™ (NVMe™) server configuration that includes a RAID controller card.

Figure 3 | Performance per US dollar (USD) results for read operations[5]

Reliability and Power-Performance Analysis

Reliability and power usage can be useful complements to the overall performance results. It is important to note that overall performance results should be your primary concern for workloads that require extremely high data throughput or that are intolerant of latency or jitter (throughput variability). One example is a heavy-edge deployment that supports high numbers of VMs, servers, users, and/or transactions.[6] Real-time messaging and language translation platforms that serve a global customer base of millions of users are other examples.

With 2.5 million hours MTTF, the KIOXIA CD8 Series SSD is up to 25 percent more reliable or longer lasting than the Samsung SATA SSD, with 2.0 million hours MTBF.[2,3] This means that when you upgrade to NVMe SSDs, you can expect 25 percent fewer errors and timeouts.

One interesting result we noted is that NVMe SSDs are substantially more energy-efficient than SATA SSDs for read-only workloads (see Figure 4). In other words, it might be possible to lower your power usage for high-throughput medical imaging, graphics-heavy e-commerce pages, and high-definition VOD services by switching to WORM-compliant storage running on NVMe SSDs.

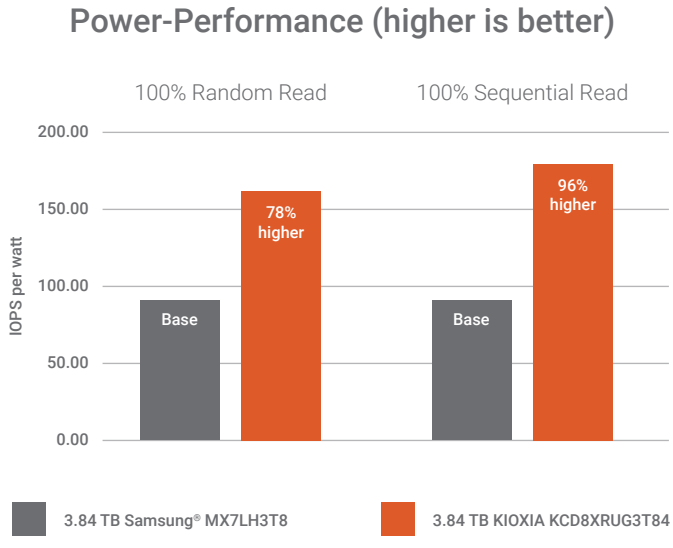


Figure 4 | Performance per watt results for read operations[2,3]

Conclusion

Faced with latency-sensitive applications, data-heavy workloads, growing data volumes, and high VM numbers per server, today's data centers need storage solutions that can deliver high capacity, fast access, low TCO, and long-term reliability. Our testing and analyses confirm that many of these challenges can be resolved by modernizing your data storage with NVMe SSDs. If you are wondering, "Is now the time to switch to NVMe storage?", we offer a resounding "Yes." Our performance benchmarking results indicate that KIOXIA CD8 Series Data Center NVMe PCIe SSDs deliver outstanding read performance for virtualized applications. And the KIOXIA CD8 Series SSDs' superior price-performance over the Samsung SATA SSDs we examined can very quickly make up for the initial cost of upgrading your storage technologies. We also like the power savings for read-intensive workloads and better overall reliability, features that can further reduce your TCO.

Learn More

Learn more about KIOXIA CD8 Series SSDs at LifeAfterSATA.com.

See more research reports by Prowess Consulting.

[1] IDC. "Enterprises Rely on Public Cloud Object Storage to Manage Data Growth, Ensure Resilience, and Generate Value." Sponsored by IBM. February 2021. www.ibm.com/downloads/cas/ZW9Z057J.

[2] Samsung. "Product Brief: SATA SSD 883DCT: Samsung SATA SSD 883 DCT—Optimized for data center demands." 2018. https://semiconductor.samsung.com/resources/brochure/Data_Center_SSD_883_DCT.Product_Brief.pdf.

[3] KIOXIA. "Product Brief: KIOXIA CD8-R Series (KCD81RUG/KCD8xRUG/KCD8DRUG) Data Center NVMe™ Read-intensive SSD." 2023. https://americas.kioxia.com/content/dam/kioxia/shared/business/ssd/data-center-ssd/asset/productbrief/dSSD-CD8-R-U2-product-brief.pdf.

[4] The Informaticists. "The price of latency in financial exchanges." August 2020. https://theinformaticists.com/2020/08/25/the-price-of-latency-in-financial-exchanges/.

[5] Prices quoted for server system configurations and provided by Dell Technologies as of April 7, 2023. SATA: US $70,616. 31.80 IOPS per USD. 0.0173 MB/s per USD. NVMe: US $71,303. 4.65 IOPS per USD. 0.1100 MB/s per USD.

[6] Red Hat. "What is a latency-sensitive application?" January 2023. www.redhat.com/en/topics/edge-computing/latency-sensitive-applications.

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