NVMe, SAS, and SATA

A straightforward guide to help PowerEdge customers choose the most appropriate SSD type based on their business needs and goals

Summary

PowerEdge customers optimize their server configurations based on their applications and business needs. Multiple factors must be taken into consideration to make an informed decision, such as workload, budget, scale, and even roadmap. Still, when all of the factors are understood, it can be difficult to discern whether the optimized Solid State Drive (SSD) is NVMe, SAS, or SATA.

This DfD (Direct from Development) tech note was written to simplify and guide customers in their choice of SSD. We hope customers will find this document to be a valuable reference guide when it becomes unclear which storage medium is the optimized decision.

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This paper can be used as a reference guide to help PowerEdge customers make an informed decision on which SSD interface will presumably bring the greatest value in relation to their intended business needs and goals. First, let's summarize the history and architecture around the NVMe, SAS, and SATA SSD interfaces:

NVMe (Non-Volatile Memory Express)

The NVMe interface is the newest type of flash storage with the highest performance. The driving architectural differentiator of NVMe is that it uses the PCIe interface bus to connect directly to the CPU and streamline the travel path. This design contrasts with SAS and SATA, which require data to first traverse to an HBA before reaching the CPU. By removing a layer from the stack, the travel path is optimized and produces reduced latency and improved performance. Scalability is also significantly improved, because NVMe drives can go beyond the traditional four lanes by using lanes from the same "pool" of lanes connected to the CPU. Furthermore, NVMe performance will continually improve as each new generation of the PCIe standard becomes available.

SAS (Serial Attached SCSI)

The SAS interface was released a few years after SATA and introduced new features that are beneficial for modern workloads. Instead of building upon the ATA (Advanced Technology Attachment) standard used in SATA, it serialized the existing parallel SCSI (Small Computer System Interface) standard. SAS cable architecture has four wires within two cables, creating more channels available for moving data and more connectors available for use by other devices. Furthermore, the channels are full duplex, allowing for reads and writes to traverse concurrently. Improved reliability, error reporting, and longer cable lengths were also introduced with SAS. SAS improvements are made to this day, with 24GB/s available soon, so it still remains valuable and relevant within the market.

SATA (Serial Advanced Technology Attachment)

The SATA interface was released in 2000 and is still commonly adopted within modern servers since it is the most-affordable of the three. It replaced parallel ATA with serial ATA, which resolved various performance and physical limitations at that time. The SATA cable architecture has four wires within one cable—two for sending data and two for receiving data. These four channels are half-duplex, so data can only move in one direction at a time. SATA write speeds are sufficient for storing information, but its read speeds are slow compared to more modern interfaces, which limits its application use for modern workloads. The last major SATA revision occurred in 2008, and will not see further advancement in the future.

Table 1. Ranking performance metrics of Enterprise NVMe, DC NVMe, Enterprise SAS, Value SAS, and SATA drives

✓✓✓ = Best	Enterprise NVMe	DC NVMe	Enterprise SAS	Value SAS	SATA
Performance	✓✓✓	✓✓✓	✓✓	✓✓	✓
Latency	✓✓✓	✓✓✓	✓✓	✓✓	✓
Price	✓	✓✓	✓	✓✓	✓✓✓
Performance Per Price	✓✓✓	✓✓✓	✓✓	✓✓	✓
Scalability	✓✓✓	✓✓✓	✓✓	✓✓	✓
Ongoing Development	✓✓✓	✓✓✓	✓✓	✓✓	✓

Table 1 lists key metrics for five storage-drive types most commonly attached to PowerEdge servers: Enterprise NVMe, Data Center (DC) NVMe, Enterprise SAS, Value SAS, and SATA. This comparison helps clarify which storage interface type is most applicable in relation to business needs and goals.

Performance: Performance can be measured in various ways. For this example, Random 4 KiB 70/30 (70% reads, 30% writes) data was compared and published by Dell, with higher IOPS being better. Enterprise NVMe SSDs produce 1.13x more IOPS than DC NVMe SSDs. DC NVMe SSDs produce 1.99x more IOPS than Enterprise SAS SSDs. Enterprise SAS SSDs produce 1.42x more IOPS than Value SAS SSDs. Lastly, Value SAS SSDs produce 2.39x more IOPS than SATA. Figure 1 below illustrates the IOPS performance variances on a bar graph for a visual representation:

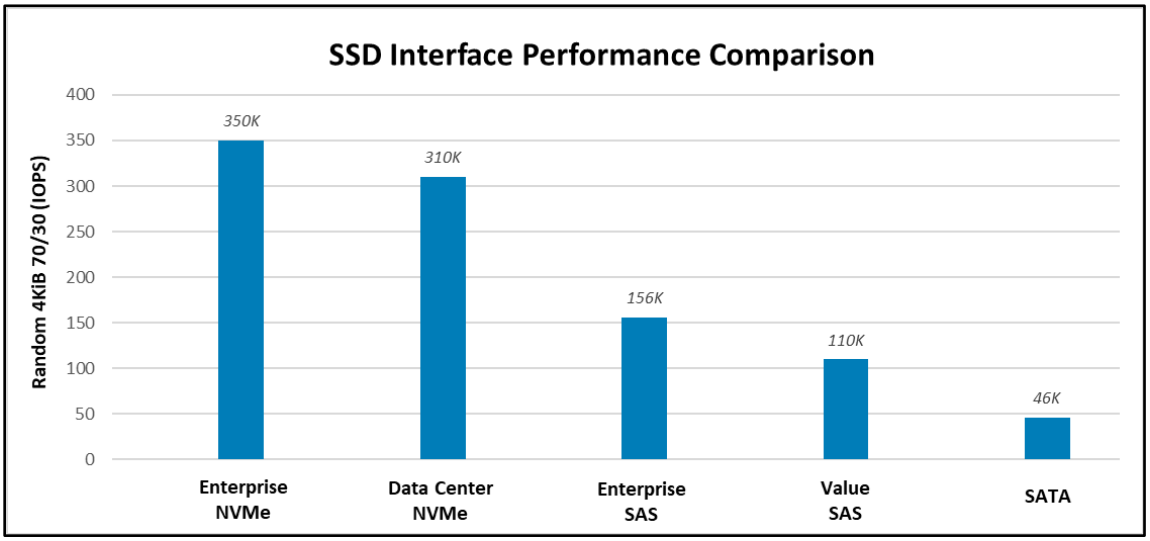


Figure 1. Random 4KiB 70/30 IOPS variances for each storage interface

Latency: The NVMe protocol reduces the number of touchpoints data must travel to (bypassing the HBA) before reaching the CPU. It also has less overhead, giving it **significantly** lower latency than SAS and SATA. The SAS protocol is full-duplex (as opposed to half-duplex) and offers two channels (as opposed to one) for data to use, giving it over 50% lower latency than SATA.

Price: According to Dell pricing in Q1 2022, SATA SSDs are the least expensive storage interface, at ~0.9x the price of Value SAS SSDs. Value SAS SSDs are ~0.85x the price of DC NVMe SSDs. DC NVMe SSDs are ~0.85x the price of Enterprise SAS SSDs. And Enterprise SAS SSDs are ~0.97x the price of Enterprise NVMe SSDs. Pricing is volatile and these number variances are subject to change at any time.

Performance per price: PowerEdge customers that have not identified which metric is most important for their business goals should strongly consider performance (IOPS) per price (dollar) to be at the top of the list. Because NVMe has such a significant performance lead over SAS and SATA, it is easily the golden standard for performance per price. DC NVMe SSDs have the best performance per price, followed closely by Enterprise DC NVMe SSDs, followed by Value SAS SSDs, followed closely by SAS SSDs, followed by SATA SSDs. This tech note gives more performance/price detail.

Scalability: Currently, NVMe shows the greatest promise for wider-scale implementation due to the abundance of lanes that can be available with low-overhead. However, it can be a costly investment if existing data center infrastructures must be upgraded to support the NVMe I/O protocol. SAS is more flexible, since SAS expanders are cost-effective and most data center infrastructures already have the required hardware to support it. However, SAS does not have the potential to scale out as aggressively as NVMe. SATA does not scale well with SSDs.

Ongoing development: The NVMe interface has consistent and substantial advancements year-over-year, including updates like NVMe 2.0b (released in Jan. 2022) and PCIe Gen5 (released on Intel CPUs in Nov. 2021). The SAS interface also has regularly cadenced updates, but the impact is marginal, with the exception of upcoming updates like 24Gb/s and 48Gb/s. The SATA interface has no plan to extend capabilities beyond its current limitations.

Assigning these ranks for each storage interface and metric, and explaining why the rank was given, will make it easier to understand which drive type will be the most valuable in relation to business needs and goals.

Guidance in accordance with business goals

Every business is unique and will have different requirements for their storage drives. Factors such as intended workload, business size, plan to scale, budget, and so on, should be considered to confidently make an investment decision. Although this decision is ultimately up to each business, we have provided some guidelines below to help businesses that are still on the fence to make an educated choice:

Enterprise NVMe: Businesses that desire maximum performance and have a flexible budget should consider purchasing Enterprise NVMe SSDs. Heavy workloads like HPC or AI will immediately benefit from the additional cache gained from the non-volatile nature of this storage interface. The fast-paced performance growth seen in Enterprise NVMe SSDs will also allow smaller workloads like databases or collaboration to easily keep up with the ever-increasing size of data. Ultimately, because Enterprise NVMe undergoes consistent valuable changes with every passing year, such as performance increases and cost reduction/optimization, we recommend futureproofing your data center with it.

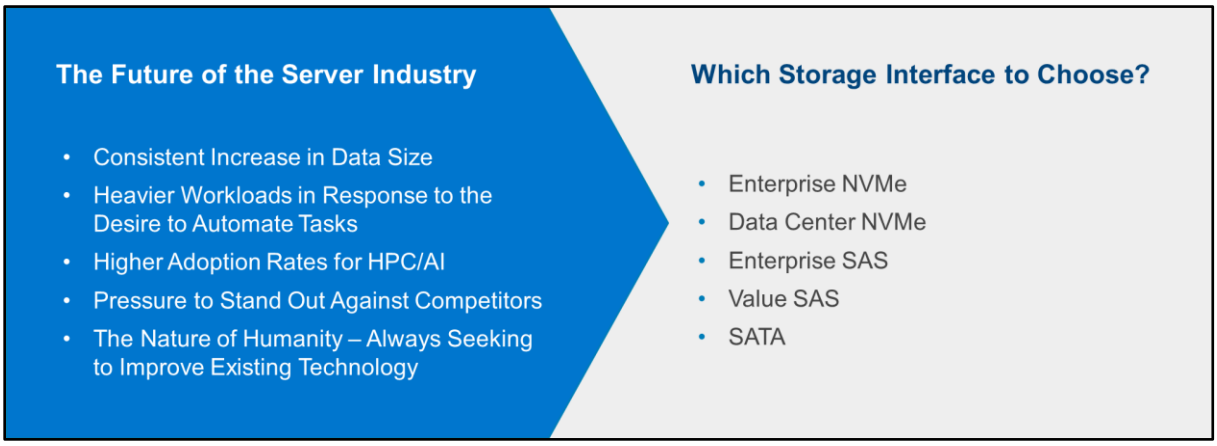
DC NVMe: Businesses that desire a budget-conscious NVMe solution, in addition to the greatest value, should consider purchasing DC NVMe SSDs. These drives have the exact same value proposition as stated above for Enterprise NVMe SSDs, but with a sizeable price reduction (0.83x) and performance hit (0.86x). Businesses that want to get the best value will be pleased to know that DC NVMe drives have the best performance-per-price.

Enterprise SAS: Businesses that desire to continue using their existing SCSI-based data center environment and have maximum SAS performance should consider purchasing Enterprise SAS SSDs. Although the Enterprise SAS interface does not currently have any ranking leadership for performance or pricing, it is established in the industry as highly reliable, cost-effective to scale, and it shows promise for the future, with 24Gb/s available soon and 48Gb/s on the horizon. Enterprise SAS SSDs will adequately handle medium-duty workloads, like databases or virtualization, but will operate best when mixed with NVMe SSDs if any heavy-duty workloads are at play.

Value SAS: Businesses that desire a budget-conscious SAS solution should consider purchasing Value SAS SSDs. These drives have the same value-proposition as stated above for Enterprise SAS SSDs, but with both a sizeable price reduction (0.73x) and performance hit (0.71x). For this reason, it actually has a slightly lower performance-per-price than Enterprise SAS, and therefore is more of a "value" play when compared against SATA. This storage interface has a purpose for existing though, as small-to-medium businesses with a smaller budget can leverage this lower-cost solution while still receiving the many benefits of the SAS interface.

SATA: Businesses that desire the lowest price storage interface should consider purchasing SATA SSDs. However, caution should be applied with this statement, as there is currently no other value proposition for SATA SSDs, and the price gap for these flash storage interfaces has been shrinking over time, which may eventually remove any valid reason for the existence of SATA. With that being said, SATA is currently still a solid choice for light workloads that are not read-heavy.

Conclusion



The story of competing NVMe, SAS, and SATA storage interfaces is still being written. Five plus years ago, analysts made the argument that although NVMe has superior performance, its high-cost warranted SAS the title of 'best value for years to come'. What we see today is a rapidly shrinking price gap for all of these interfaces. We observe that SATA performance has fallen far behind SAS, and very far behind NVMe, with no plan to improve its current state. We also see NVMe optimizing its performance and price-point to yield more market share every year. Most importantly, we expect rapid growth in the industry adoption of heavier workloads and ever-increasing data requirements. Both storage drive and industry trends incline us to believe that the best option for any business desiring to build a future-proofed datacenter would be to begin making the investment in NVMe storage. However, the remaining types of storage still hold value for varying use cases, and it is the customer's choice to decide which storage type is best for their business goals. We hope this guide has helped that decision become more apparent.

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