# NVMe and VSL®

NVMe Express (NVMe) is an interface specification that can be deployed across a variety of of flash-based storage form factors (SSD, PCIe, M.2). Non-Volatile Memory Host Controller Interface Specification (NVMHCI) is a standards based protocol for accessing solid-state storage attached through the PCI Express (PCIe) bus. NVMe was released in March 2011 by the NVM Express Work Group. SanDisk® is a contributing member of the consortium. SanDisk supports the NVMe standard and will utilize the NVMe standard where beneficial to customers.

"By designing NVMe to meet the needs of so many form factors, tradeoffs were made."
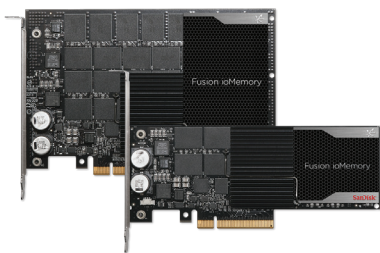
Fusion ioMemory™ PCIe Application Accelerators

Why NVMe

The main goals of NVMe are to simplify and reduce the driver stack, and to provide a next-generation low latency, high performance replacement of the SATA interface. NVMe will become a great replacement for 6Gb/s SATA-connected SSDs when deployed in the 2.5" SFF (small form factor), NVMe will also be deployed in PCIe. SanDisk supports the NVMe standard and will have NVMe based products starting in 2016.

NVMe – Promised Benefits and Associated Realities

NVMe is an offload architecture and can consume up to 25 watts per device. Given that this far exceeds what a standard SATA-connected SSD uses, only selected new servers support NVMe-based devices. When a server supports NVMe based devices (also known as Small Form Factor or SFF), it is usually limited to 4 SFFs per server which limits storage capacity. The devices also required a PCIe redriver card to be installed to isolate them from the system. The additional power, technology, cabling and cooling needed to make them work today is very expensive. This is not a lower cost solution. SATA is still much more cost effective. Another thing to remember is that a legacy SATA-connected SSD and the new SFF still use the same flash, enclosure and flash management, which means the cost to build them are equivalent.

On the PCIe front, NVMe has a lot of promised benefits and a number of associated realities.

- Only the newest generation of Intel based servers support NVMe-based PCIe cards

When you build a standard to cover and replace everything from lowest cost SATA-connected SSDs along with the largest capacity and highest performance Flash Storage PCIe cards, tradeoffs are made.

The first reality is the promised NVMe "inbox driver" story. While there is an inbox driver for a growing number of enterprise operating systems, Intel recommends you use their separately installed, proprietary driver for best performance and stability. That means that NVMe drivers are still installed and updated over time by the customer.

For an OEM customer there may be additional delays for updated drivers for their vendor unique version of that NVMe based product. OEM's traditionally test all key driver updates extensively, which may delay when an OEM customer has access to any performance or stability enhancements that an OS (with a new NVMe driver) update provides. If the customer wants those performance or stability enhancements earlier they will be required to install it manually, just like they do today.

VSL® (Virtual Storage Layer)

The VSL from SanDisk relies on an onload architecture. This means that the VSL uses the processing capabilities of the CPU as part of the flash management which can provide additional performance. In contrast, the NVMe uses an onboard controller which limits performance. The NVMe design does not allow it to take advantage of faster server processors. Recent SanDisk tests show that VSL based cards can be as much as 16% faster than the NVMe based cards on data warehouse type workloads.

Be aware, only the newest generation of servers fully support NVMe-based PCIe cards, whereas VSL is supported across multiple generations of servers providing significantly more flexibility.
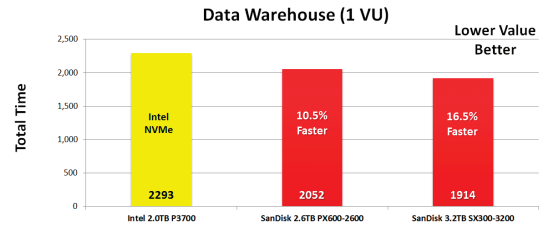
In regards to capacity, the largest shipping NVMe-based card only supports 2TBs (A 3.2TB card has been announced). By comparison, the largest Fusion ioMemory™ PCIe card supports up to 6.4TBs. Less capacity requires installing more cards, consuming more power, more slots and more IT resources than a single larger card.
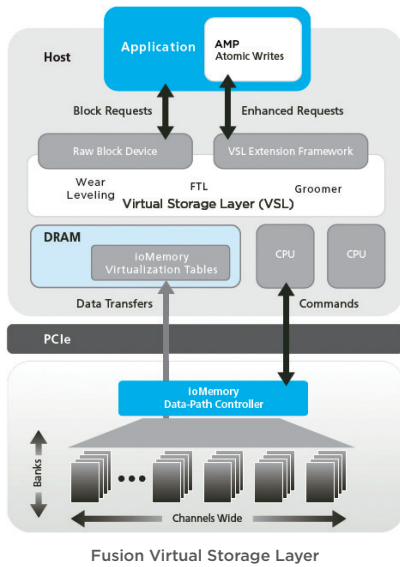
The Fusion PCIe Advantage

Today, Fusion ioMemory PCIe cards with VSL are time tested and customer proven while NVMe is a promising technology that is just starting the adoption journey. VSL is the proven choice to accelerate your key applications. SanDisk has hundreds of thousands of Fusion ioMemory PCIe card installations, thousands of customers and is the first vendor with over 8 years' experience providing best in class application acceleration solutions.
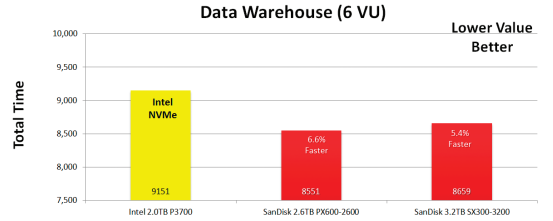
Data Warehouse Simulation (1 Virtual User)
Intel P3700 vs. SanDisk PCIe with VSL

Data Warehouse (1 VU)

Lower Value Better

Intel NVMe	10.5% Faster	16.5% Faster
2293	2052	1914
Intel 2.0TB P3700	SanDisk 2.6TB PX600-2600	SanDisk 3.2TB SX300-3200

Server: HP DL380 G9, 2.6GHz, 3.06GHz In Turbo, Intel E5-2697 v3, 58 Logical Cores, MS SQL Server 2012
Database: TPCH - 300 Scale, 629 GB, 1 Data File, Log and TempDB on Flash
Injector: HammerDB v2.16, 1 Instance, 6 Virtual Users, 0 Think Time 1 ms User Delay

SanDisk In-house Testing

Data Warehouse Simulation (6 Virtual Users)
Intel P3700 vs. SanDisk PCIe with VSL

Data Warehouse (6 VU)

Lower Value Better

Intel NVMe	6.6% Faster	5.4% Faster
9151	8551	8659
Intel 2.0TB P3700	SanDisk 2.6TB PX600-2600	SanDisk 3.2TB SX300-3200

Server: HP DL380 G9, 2.6GHz, 3.06GHz In Turbo, Intel E5-2697 v3, 58 Logical Cores, MS SQL Server 2012
Database: TPCH - 300 Scale, 629 GB, 1 Data File, Log and TempDB on Flash
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SanDisk In-house Testing

Fusion Virtual Storage Layer

Where NVMe fits/doesn't fit	The VSL fits/doesn't fit
• Focused on Enterprise Data Centers and HyperScale versus Small/ Medium Business or Small Office	• Focused on Enterprise Data Centers and HyperScale versus Small/ Medium Business or Small Office
• Limited to Flash-based cards smaller than 3.2TBs	• Fits on Flash-based PCIe cards from 1TB to 6.4TBs
• Although supported by inbox driver, customers encouraged to use vendor's proprietary driver for full performance	• Fusion has shipped for 8 years with over thousands of customers who have deployed hundreds of thousands of Fusion ioMemory PCIe cards.
• May not fully work in previous generation servers (Shipping prior to Intel "Grantley platform")	• Shipped in multiple generations of servers from multiple vendors, its high performance is proven and stable.
• Mainstream OEMs do not currently support Hot Swap/Hot Plug with 2.5-inch NVMe drive	• VSL continues to get faster with every new generation of Intel CPU
• 2.5-inch drives can pull up to 25W and can limit Server configurations due to thermal challenges	• Only works on Fusion ioMemory PCIe cards

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At SanDisk, we're expanding the possibilities of data storage. For more than 25 years, SanDisk's ideas have helped transform the industry, delivering next generation storage solutions for consumers and businesses around the globe.