SAS vs. SATA Flash Devices

Technology Paper

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Introduction

Virtualization and cloud computing are rapidly gaining acceptance. This creates the need for much higher IOPS (Input/Output Operations per Second) performance and data transfer rates beyond the physical capabilities of traditional hard disk drives (HDD). Solid state drives (SSD) can deliver orders of magnitude more IOPS than HDDs. This accelerates the performance of key applications such as business analytics, e-commerce, high-performance computing, online transaction processing (OLTP), virtual desktop infrastructure (VDI), Web 2.0 and more.

In the past, IT decision makers were concerned with many issues when considering HDD storage solutions. Some of those general issues, such as integration with existing platforms, manageability, redundancy, reliability and scalability, are also valid for SSD solutions. However, the details may be considerably different.

Consumer vs. Professional

Currently the two main interfaces for the connection of flash SSDs or magnetic HDDs to a computer are SAS in a professional-grade environment and SATA in a consumer-grade environment. There are significant differences between these environments, like in RAS (reliability, availability, serviceability) and in other features and therefore also in price. These differences should be carefully investigated before investing in either technology. Some suppliers offer consumer-grade drives using a SAS (professional-grade) interface with a SATA bridge. This really does not improve any of the SATA parameters, since higher-grade features on a SAS drive cannot be used in a consumer-grade drive attached to such an interface. It is important to make sure that features are implemented end-to-end.

Newcomers vs. Professionals

Many newcomers think they can easily solder consumer-grade flash chips together in an SSD drive and on interface circuits and make a profit. Such products are not a good buy, not even in a consumer-grade environment. However, some may get by in selling such soldered-together products in a price-sensitive market. High-speed data transmission, even on short cables or over a backplane is not a trivial matter. Long-term experience is needed to make such a signal channel fast and reliable under various environmental conditions. A company like Seagate has decades of continuous experience making reliable products in both environments.

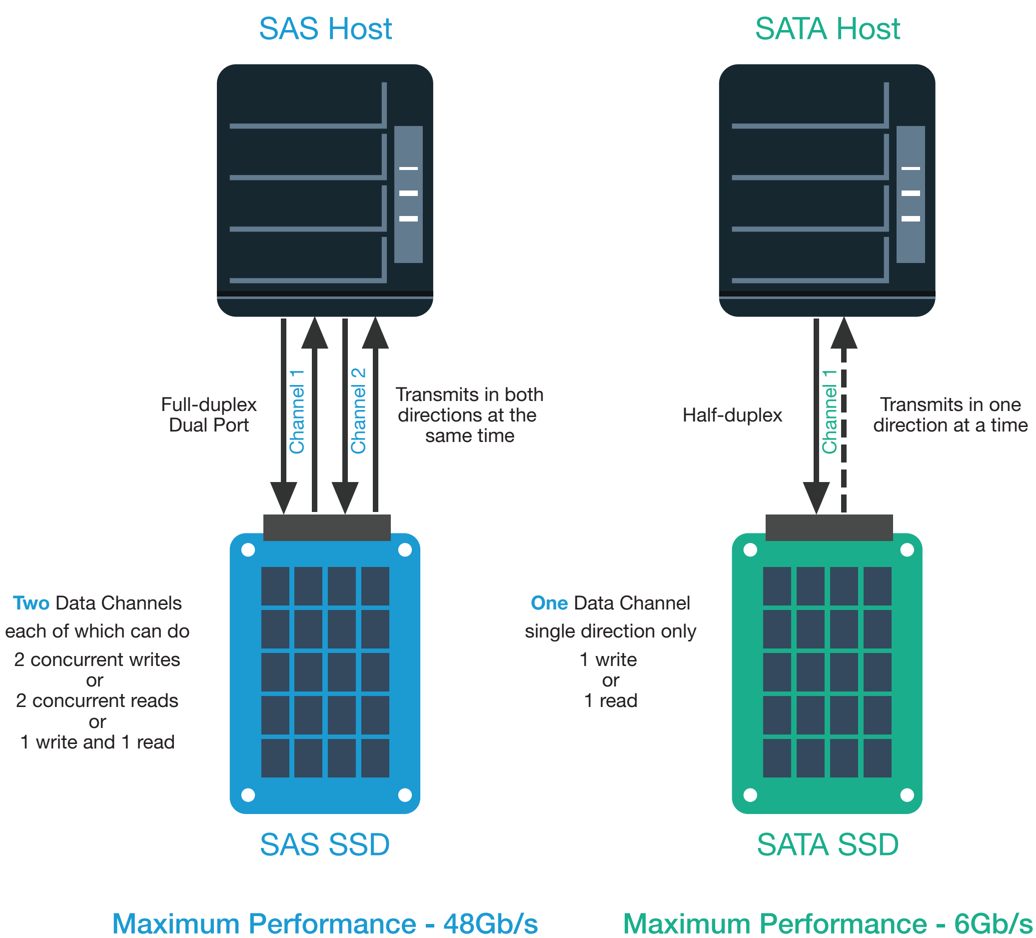

Figure 1. SAS with 2 full-duplex channels is ready for dual-port, multi-port multi-link operation

Source: Seagate Technology

Electromagnetic Interference Is Important to Watch

Things that might be overlooked by inexperienced producers are electromagnetic interference (EMI), both in (susceptibility) and out (emission). There are also rules for high-speed data transmission on circuit traces as well as on interface cables and connectors. The impedance over the whole length should be the same from sender via traces, connectors and cables to the receiver for reliable signal quality. The differential pairs of a high-speed transmission signal lane must be exactly the same length to prevent signal distortion. Signal traces on a printed circuit board (PCB) should not be routed using right-angle turns. As a minimum, all 90° traces should be changed to two 45° turns. The traces of a signal pair on a PCB should be physically close together over their whole length because the area between the traces acts as an antenna, which is more sensitive if the traces are not close together. There are many more such design rules, which are not described in either SATA or SAS standards, but are known to experienced designers. They are part of the internal design culture in well-established manufacturers.

Features of SAS

SAS utilizes the well-established and time-proven SCSI protocol. There are three basic protocols available to set up basic or expanded SAS configurations. The serial SCSI protocol (SSP) controls the communication between host controller (adapter) and device (drive). The SAS management protocol (SMP) manages multiple point-to-point connections and expanders, which may be utilized in a large system using thousands of drives (devices). Then there is the SATA tunneling protocol (STP), which is available to integrate SATA devices into a SAS system.

Some SAS interface features for mission/business critical applications:

- Full-duplex transmission (bidirectional or 2x unidirectional)
- Two concurrent channels (ports)
- Wide ports (x2 and x4)
- Available speed: 12Gb/s, up to 48Gb/s with two full-duplex ports
- Multilevel expanders for large topologies
- Distance: up to 100m
- End-to-end data integrity
- Full IOECC (input/output error correction)
- Hot-plug
- Enterprise-type command queuing (128 to 256)
- Full SCSI command set
- Variable sector size
- High-voltage signal level (1.2V)

The high-voltage signal level (1.2V) provides improved error resistance and makes it possible to drive long cables using equalization and training. A management interface (not with mini SAS connectors) supports port configuration and signal quality adjustments. SAS supports the aggregation of multiple ports, which improves throughput by logically binding multiple and simultaneous data paths (typically x2 or x4) between one or more hosts and/or devices for high-availability redundant configurations or for additional speed. A SAS interface can support SATA drives. As mentioned above, this requires an STP (SATA transmission protocol) on the host. An interposer is required if multi-host or dual-port capability is needed for a SATA device attached to a SAS port.

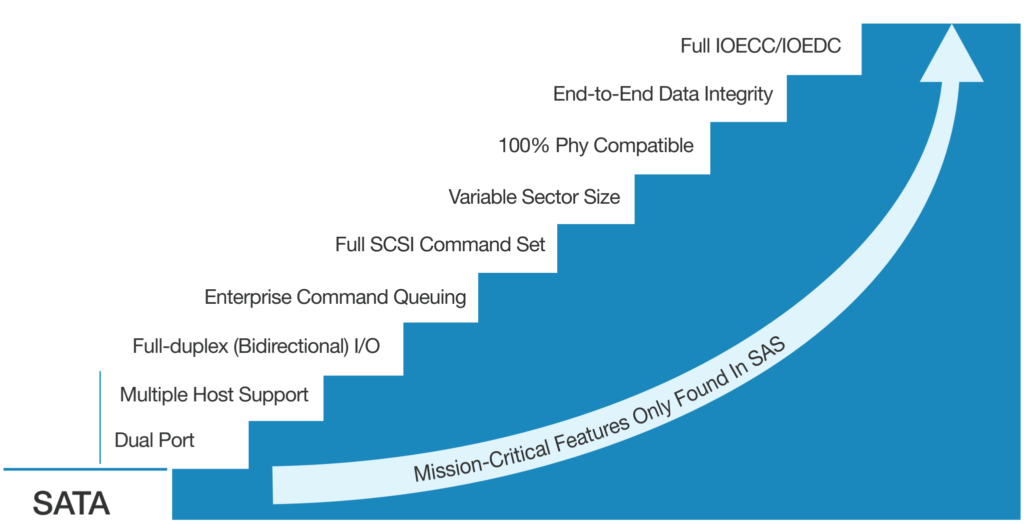

Figure 2. SAS includes a large number of professional features and functions
Source: Seagate Technology

SAS provides a number of benefits, including dual-porting support, as a standard. If one port goes down, there is a second port available for failover to another host. This allows for active/active and active/passive failover. It may also be used for redundant data paths or connections to multiple hosts, eliminating the risk of a single point of failure. SAS provides end-to-end data protection using DIF, IOECC, IOEDC and other methods on the communication path between the computer system, the device (data-in-flight) and on the device medium (data-at-rest). This includes prevention of silent data corruption while stored on a device. These features protect the data seamlessly on its round trip through the system, from the host in transit via SAS to storage, during storage and back. They will be described in a future systems-oriented article. Together these features improve the overall protection of a SAS system by several orders of magnitude. Such features are not available with SATA drives.

Features of SATA

Today Serial ATA (SATA) supports 6.0Gb/s, 3.0Gb/s and 1.5Gb/s transfer speeds. Features such as native command queuing (NCQ) for a depth of up to 32 improves consumer-grade performance. If advanced power management and the ability to reduce radiated emissions are implemented, SATA becomes a consumer-friendly interface. Features such as optional hot plug and staggered spin-up enable SATA in multi-drive applications. External Serial ATA (eSATA) doubles the supported cable length to two meters for connecting external storage devices (only for speeds up to 3Gb/s).

Some SATA interface features for consumer/office grade applications:

- Half-duplex transmission
- Single channel (port) for non-concurrent reads or writes
- Available Speed: 6Gb/s
- Distance: 1m (2m for eSATA, and only for speeds up to 3Gb/s)
- Command queue depth: 32
- ATA/AHCI command set
- Low-voltage signal level (0.6V to 0.9V, depending on speed)

SATA shows up in three variants. The most common is as motherboard SATA, typically four small connectors. Then there might be eSATA, which is simply an extension out of a PC cage to a maximum of 2 meters. Typically in mixed SAS-SATA cabinets would be SATA devices plugged into a backplane and controlled from a SAS-HBA. The voltage swing of SATA signals is 600mV to 900mV (depending on transfer rate), lower than for SAS signals. Equalization and training, which would improve signal quality more than voltage levels, are not implemented. SATA does not support SAS drives. Lower tiers of storage are used for capacity optimization and not for performance. For this purpose, SATA is a good solution as long as the integrity of the data recording can be ensured by additional appropriate means. SATA devices lack the features to provide end-to-end integrity as part of the standard. Read-after-write added to a SATA system detects and possibly corrects errors only on the write path. However this degrades performance, which is especially significant when lower priced HDDs are used for lower tier storage. Protection can occur at the file system level as well, but this relies on an assumption that all file systems will do a proper job. Even with write caching turned off and flush commands, it is not always guaranteed that a write has been committed to persistent media when the command complete from a SATA drive is received by the host.

Differences Between SAS and SATA

SATA was designed to be a low-cost interface for consumer-type PCs and laptop computers. SAS was designed as a serial version replacement of professional-grade parallel SCSI. Now data centers are installing SSDs to accelerate the performance of business-critical applications, needing the significant performance advantages of SAS versus SATA. SAS contains additional features that support higher levels of availability, performance and reliability, and, in consequence, comes with a slightly higher price tag. SAS can be expanded to thousands of devices, which are easily implemented. SATA is limited to a few point-to-point connections off a motherboard.

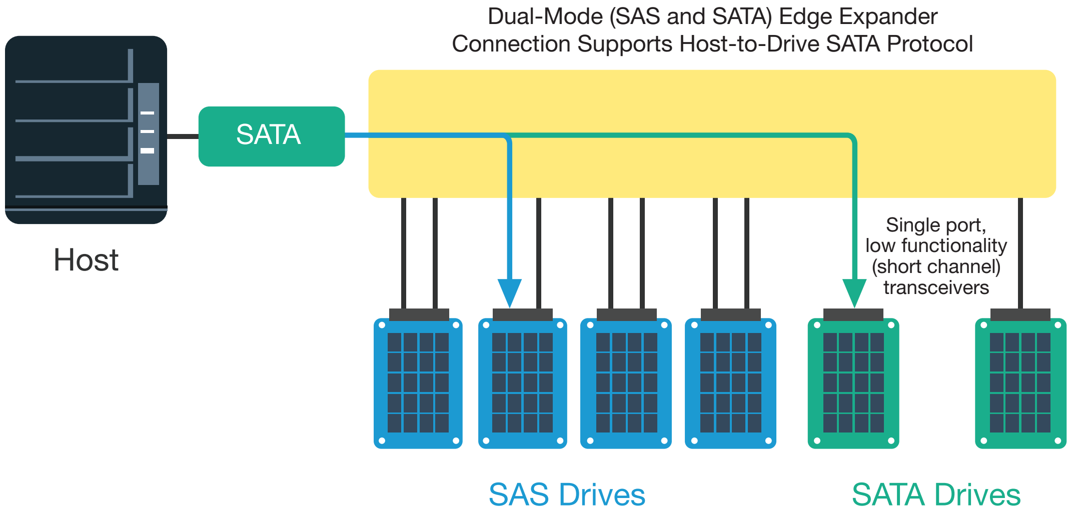

Figure 3. SAS can control SATA devices using the STP protocol
Source: Seagate Technology

SAS is full-duplex. Normally this is used to transfer in both directions simultaneously, but could also be used to transfer on both paths in the same direction. In professional applications, SAS devices use these two channels for redundancy or in multi-host environments serving different hosts/servers on either channel. These combined features explain why up to 48Gb/s (2 x 2 x 12) using 12Gb/s interfaces and drives can be transmitted. In a SATA environment there is only half-duplex transmission and a single channel. This means when you use a typical system, the data transmission rate remains at 6Gb/s since there is only a single simplex channel. For this reason SATA is too slow to utilize the high-speed performance and low latency of flash SSD in most applications.

End-to-End Protection

Because many system-level implementations add additional error protection, SAS remains several orders of magnitude higher in the ability to correct raw bit errors. While SAS and FC drives have about the same mean time between failures (MTBF) rates, SATA drives typically have lower MTBF rates and lack the addressability to provide end-to-end, initiator to target, nexus checking (IOECC/IOEDC), which helps to ensure data integrity. SAS and SATA SSDs might have similar specs, but SAS devices typically have higher reliability compared to SATA devices due to the differences in interface and features.

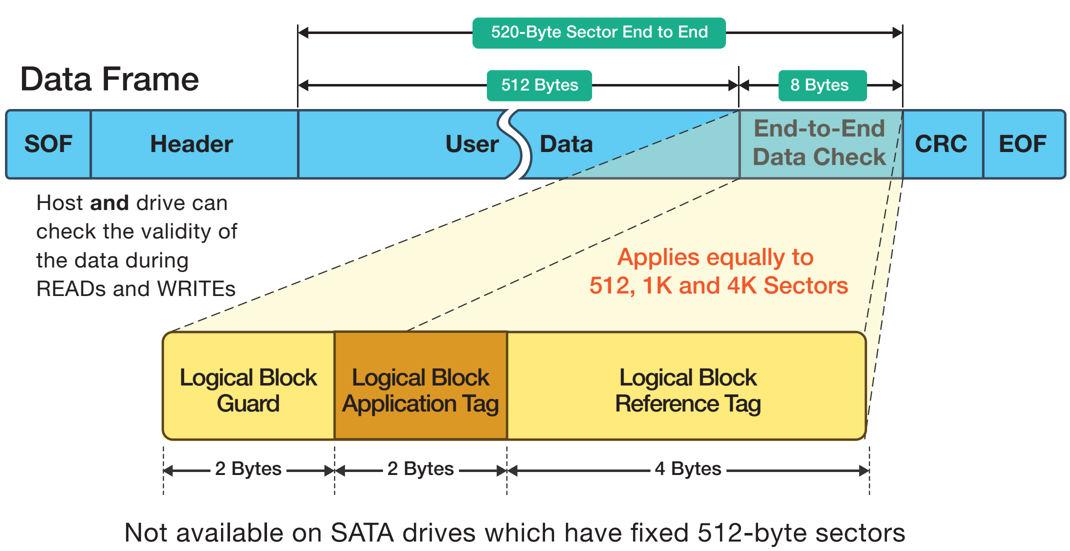

Figure 4. Advanced end-to-end integrity on SAS not possible on SATA
Source: Seagate Technology

One such feature is the ANSI T10 standard data integrity field (DIF), which provides a way to check the integrity of data read or written from the host bus adapter to the drive and back through the communications channel. This check is implemented through the DIF defined in the standard. Before a write, the DIF is generated by the host bus adapter (HBA). It is added to the end of the data block, then the data and DIF are sent through the channel (possibly a fabric) to the storage target, validated and stored. On a read, the DIF is returned along with the data block to the host, which validates the DIF.

Additional Features

Hierarchical file systems are a source of possible data corruption. Volume management, a file system within a volume or storage management, which handles traditional RAID implementation, are separate entities. Each level in the hierarchy commands its own rules and different ways of data transactions and protection. The various parts in a transmission chain also have their own way of doing things. All these interfaces, even within an interface (SAS or SATA in this case), are critical in their handling of protection towards the next function block in the chain. That is why additional features/functions are needed to ensure end-to-end and data-at-rest protection. Individual checksum protection within the various parts of the transmission link is not enough. This may lead to *garbage in, garbage out* (GIGO). There is also the possibility of phantom writes, address errors, DMA parity errors, driver bugs or accidental writes, which need to be taken care of in a professional data system. As mentioned above, features like DIF were standardized by professionals to cope with such potential problems.

Another standard that may apply is the Federal Information Processing Standard 140-2 (FIPS). It describes the encryption and related security requirements that IT products should meet for sensitive, but unclassified, use. The standard ensures that a product uses sound security practices, such as approved, strong encryption.

More detailed descriptions of these and other additional functions will be given in a future article.

Avoid Additional Intermediate Circuits

Signal paths should be as short as possible, not only in physical length, but also in terms of in-between circuits like adapters, repeaters, interposers or converters. Each functional circuit causes delay while translating between protocols and possibly produces errors. This is especially noticeable when flash drives are used because a large amount of the extra speed and lower latency would be lost along the way.

Mission-/Business-Critical Requirements

It is important to use professional-grade products and services when mission- or business-critical data are involved. Since flash-based products are still more expensive than HDDs, it is common practice to use flash drives only where performance and reliability is guaranteed.

Interface Roadmaps

SATA is widely used in computer-grade applications although no further enhancements are planned. SAS is healthy and is widely deployed and continuing enhancements as well as planning for a speed increase to 24Gb/s. Variants of PCIe are expected to take over at some future time. Currently there are still too many proprietary versions of PCIe. Usually it takes a few years before a major standard has settled down. One variant is SATA Express (SATAe), which sends PCIe signals and protocol over SATA cables and connectors when PCIe is used on both ends. SATA signals can be used if both ends are SATA. Experience has to be gained, parameters have to be fine-tuned. The majority of suppliers have to adhere strictly to the standard, not to add proprietary extras.

There are currently more than 300 million enterprise SAS slots in use and the numbers of SAS SSDs used in these enterprise slots are expected to triple by 2017 according to IDC and Seagate research. The consumer market demands different features and prices. It will develop along its own roadmap as in the past. The professional market relies on a well thought-out roadmap with each step proven and verified before resources and funds are committed by professional suppliers and users.

Summary

SAS is the interface of choice for handling critical and large volume data in the enterprise environment. SATA is the interface of choice for handling a limited amount of personal data where retrieval from offline or cloud storage is acceptable. Seagate, as an experienced supplier, has participated for decades in SAS and SATA standardization and product deployment to suit both market segments. In the future, variants of PCIe for SAS and SATA might be developed differently for different market requirements.

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