Understanding the Transition to Serial Attached SCSI (SAS) Technology

- Embraces best features of other serial storage solutions
- Provides storage choice for customers
- Provides best investment protection

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Scope of Paper

This paper provides guidance for customers in understanding the transition from parallel U320 SCSI solutions to Serial Attached SCSI (SAS) technology in enterprise server environments. Cost, performance, benefits, ideal audience, and architecture information for SAS are included in this document in addition to a comparison with the other serial storage technologies, Fibre Channel and Serial ATA (SATA).

Introduction

Current server solutions are not very flexible with respect to the type of storage they deploy. Systems designers for direct attached storage (DAS) must choose between a low cost storage interconnect like parallel ATA; a mainstream interconnect like parallel U320 SCSI or a high-end interconnect like Fibre Channel. The interface decision dictates the remaining storage infrastructure costs. This limits a users' ability to deploy and redeploy core technologies, and can add significant cost and management burden to the enterprise.

Serial Attached SCSI (SAS) solves this flexibility problem by providing a single interface that provides customers with a choice in storage. The SCSI Trade Association (STA) board of directors has recognized the benefit of SAS over its predecessor U320 parallel SCSI and has endorsed SAS technology as the future of mainstream SCSI. HP is committed to provide enterprise solutions based on SAS technology for its next generation servers.

"Serial Attached SCSI is poised to become the dominant disk interface for enterprise servers and storage systems."
– Kevin Wittmer, Director of Technical Marketing
Maxtor's Server Products Group."[1]

SAS Technology

Serial Attached SCSI (SAS) technology is challenging to describe, because it encompasses a set of innovations that changes the familiar parallel SCSI interconnect between a server and its storage devices. Along the way, SAS embraces the best features of other serial storage solutions and provides a roadmap for innovation and improvement for many years to come.

Primarily SAS is the logical technology evolution beyond U320 parallel SCSI. When attached to SAS disk drives which are the successors to mainstream U320 disk drives, it provides all the value propositions of traditional U320 SCSI solutions; availability, scalability, manageability and performance.

By designing in compatibility with Serial ATA (SATA) drives at the connector, SAS allows a low cost alternative to the higher reliability SAS disk drives. SAS can communicate with the existing 1.5-Gb/s data rate SATA drives and extends the high-speed serial signaling by introducing 3-Gb/s data rate SAS drives with a roadmap to 12-Gb/s and beyond. SAS also enhances the point-to-point SATA topology by introducing expanders, which are low cost switches that allow a significant number of SATA or SAS disk drives to be connected to the server. Expanders allow SAS storage solutions comparable to Fibre Channel arbitrated loop implementations with performance characteristics of Fibre Channel switch implementations and at a lower cost than Fibre Channel.

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[1] http://www.lsilogic.com/news/product_news/pr20030624a.html

SAS borrows reliability and performance enhancements from Fibre Channel to support dual-port and full duplex communication between servers and disk drives. SAS extends the reliability and bandwidth opportunities by using expanders to create wide ports, which are multi-path connections between the server and storage solutions. SAS also improves manageability of the storage solution by providing the Serial Management Protocol (SMP) to monitor connections between individual devices and identify points of failure or reduced performance.

Finally, the use of the smaller interface connector for SAS, takes advantage of small form factor SAS drives, which will enable the development of more space-efficient, lower power server and storage solutions.

By virtue of its multi-protocol support, a SAS based storage solution will enable customers to deploy a standardized server interface and choose the most appropriate storage for their application. Low-cost SATA disks currently being used in desktop solutions will be available for less demanding applications while, enterprise SAS disks will provide the reliability and performance demanded of mainstream server applications. The native SAS protocol uses the familiar SCSI command set and aspects of the Fibre Channel transport layer, which prepares SAS for low cost bridge solutions to Fibre Channel or iSCSI Storage Area Networks (SAN) in the future.

Audience

Users who are looking for a choice in storage are the ideal audience for SAS. SAS solutions complement midrange to high-end enterprise servers and workstations using internal storage, direct attached storage (DAS) or network attached storage (NAS). The flexibility provided by SAS allows customers to tailor storage for solutions that must provide mixed pools of storage within cost constraints.

When Serial Attached SCSI enters the enterprise storage market in 2004, it should carry the robust reliability for which SCSI is well known.

"Its expected compatibility with Serial ATA will be a market advantage for current, as well as new SCSI users, who want the flexibility of both Serial Attached SCSI and Serial ATA hard drives in a Serial Attached SCSI system." –Dave Reinsel, Hard Disk Drive Research Manager at IDC[2]

SAS key benefits

Key customer benefits include: enterprise class robustness, investment protection, and the choice of direct-attach storage devices. In addition, smaller form factors and greater addressability will lead to a new level of flexibility when deploying mainstream data center servers and subsystems. As an extension of industry-leading SCSI specifications, SAS provides reliability and availability characteristics that will satisfy users' needs for continuity in the data center.

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[2] STA Announces Completion of Serial Attached SCSI Specification, Story from For SCSI Trade Association via BizWire Copyright 2003

Tuesday, 20-May-2003 3:20AM PDT (via ClariNet)

Moreover, HP SAS customers will be able to enjoy the following SAS advantages:

- **Increased storage connectivity**
- **Flexibility in server deployment**
- **SAS disk drive/SATA disk drive compatibility**
- **Total management of the storage solution**
- **Lowered cost of ownership**

SAS/SATA Compatibility

The compatibility between SAS and SATA has widespread benefits for the industry and for enterprise users. For OEMs and integrators, one of the primary benefits of compatibility between SAS systems and SATA disk drives will be the ability to have a common infrastructure of cables, connectors, backplanes, cabinets, etc. SAS leverages the SATA interconnect technology to provide:

- simplified cable, connector, and back-plane design
- compatibility with lower-cost drives

SAS extends the SATA interconnect technology to provide:

- increased device support and bandwidth scalability
- support for multi-port and multi-path connections
- support for topology and link management
- support for enclosure management
- support for the design of new small form factor hard disk drives
- improved backplane support

Industries have noted the benefits of using SAS architecture for its compatibility with SATA drives and with its reliability:

"When Serial Attached SCSI enters the enterprise storage market in 2004, it should carry the robust reliability for which SCSI is well known. Its expected compatibility with Serial ATA will be a market advantage for current, as well as new SCSI users, who want the flexibility of both Serial Attached SCSI and Serial ATA hard drives in a Serial Attached SCSI system."[3] –Dave Reinsel, Hard Disk Drive Research Manager at IDC[4]

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[3]STA Announces Completion of Serial Attached SCSI Specification

Story from For SCSI Trade Association via BizWire. Copyright 2003 by Business Wire (via ClariNet)
Tuesday, 20-May-2003 3:20AM PDT

[4]"Serial interface groups target compatibility", By Dave Simpson, InfoStor, March 31, 2003

Table 1. SATA and SAS Interface Comparison

Topology	SATA	SAS
	Point to Point	Point to Point with expanders
Addressing	1	16,384
Distance (m)	1	8**
Dual Port	No	Yes
Connection	P to P	P to P*
Performance		
Speed Gb/s	1.5	1.5, 3.0
Duplex	Half	Full
Protocols	ATA	SCSI (SSP), SATA, STP, SMP***

Notes:

* Point to Point with Expanders providing Addressability

**External cable. Transmission levels are higher than SATA to support backplane use.

**** SAS supports multiple protocols. The native SCSI protocol (SSP) support for SAS devices.
SATA and STP protocols support SATA devices. SMP protocol support for expanders.*

Backplane Design

Today, many backplane manufacturers develop a backplane for parallel SCSI drives and a separate backplane for parallel ATA drives. Parallel SCSI and ATA interfaces each require a large number of routed signal traces, which require many interconnect layers in the backplane. Each interconnect layer in the backplane increases cost and large numbers of traces introduce signal noise and conditioning problems. The signal noise and conditioning problems delay the introduction of faster interfaces and increases the opportunity for interoperability failures. The reduction in routed signal traces in serial implementations like SAS means that manufacturers are able to develop simpler backplane designs with fewer layers and fewer signal traces.

SAS technology leverages the backplane connector introduced by SATA and extends it by adding support for a second communication link for a dual-ported SAS drive. SAS also improved the signal characteristics of the physical components to allow for greater length cables with increased reliability. In contrast, desktop SATA controllers and drives are designed with cost and power constrained physical link components, which limit the length of cables and increase the opportunity for link errors in SATA backplane solutions. To minimize link errors when SATA drives are connected to SAS devices, SAS expanders and controllers are designed to compensate for the limitations of SATA drives. As a result, vendors can use the same Stock Keeping Unit (SKU) for the backplane to support both SAS and SATA drives. This reduces interoperability issues and inventory costs and simplifies product support costs.

Existing parallel SCSI backplanes support multiple SCSI disk devices and may be capable of multi-initiator access for improved system reliability. By comparison, the ATA protocol is not capable of multi-initiator access and backplane designs require an ATA host port for each ATA disk drive attached. This can make parallel ATA backplanes more complex than equivalent parallel SCSI backplanes.

A SAS backplane with expanders allows any mixture of SAS disk drives or SATA disk drives. The SAS disk drives can fully support multi-initiator access, and SCSI Tunneling Protocol (STP) enhances SATA disk drives by enabling a limited form of multi-initiator access.

Finally, the location of the backplane connector with respect to the disk device allows enclosures designed for 3.5" disk drives to also support 2.5" small form factor disk devices to maximize interoperability.

VARS and system integrators

SAS and SATA compatibility enables VARs and integrators to easily configure a custom system for an individual customer, simply by installing the preferred disk drives. VARs can focus on matching the processing and storage needs of the customer with fewer compromises because of storage interface limitations. There is no longer a need to worry about installing the proper backplane, and cables. The reduced complexity and flexibility can improve the overall customer experience.

End Users

End users benefit from the cost reductions that SATA/SAS compatibility provides to backplane manufacturers, system OEMs and VARs. The ability to change from SATA to SAS drives without purchasing new systems simplifies the upgrade process and helps future-proof end-user investments.[5]

End users will be able to buy one type of system and populate it with either Serial SCSI or Serial ATA drives.

"The benefit is flexibility . . .users will be able to customize systems based on application, performance, and cost requirements."
–Karen Flores, a member of the Serial ATA II Working Group and market development manager at Intel.[6]

Point to Point Architecture

In existing parallel SCSI or shared-access Fibre Channel arbitrate loop topologies, only two devices can communicate at once, and as throughput needs increase, the shared-access medium can become a bandwidth bottleneck which affects scalability. Shared access topologies also are typically more complex and have arbitration schemes that are more time consuming than point-to-point architectures.

SAS as a point-to-point architecture establishes a link directly from the controller to a disk drive or through an expander-switching matrix.

Point-to-point or serial architectures can connect multiple devices simultaneously, have simplified cabling requirements, and provide greater scalability and performance than with shared-access topologies.[7]

The SAS point-to-point architecture will provide performance scalability beyond what is available in today's storage arrays based on the Parallel SCSI bus or the Fibre Channel arbitrated loop. The ability to configure arrays with low-cost SATA disks or high performance, dual-port, SAS drives will simplify storage purchasing and deployment by enabling one storage array to meet a broad range of application requirements.

In addition, SAS utilizes a smaller connector than Parallel SCSI disks. The smaller connector is conducive to the design of high-density, small-form-factor servers, hard disk drives, and RAID arrays. Serial interfaces also require fewer signal lines, which reduce the complexities of board layout in space-constrained systems.

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[5] http://www.scsita.org/aboutscsi/SAS_SATA%20Compatibility
[6] http://www.i-tech.com/Storage%20Info%20Center/indnews145.php, I-TECH
[7] http://www.lsilogic.com/products/islands/sas/features.html#p-to-p

Universal Interconnect

SAS technology makes a significant step toward a universal interconnect for direct attached storage (DAS). A SAS initiator supports four standard protocols:

- Serial SCSI Protocol (SSP) supports full duplex connections to SAS devices. SSP maximizes throughput and minimizes latency to complement the high performance characteristics of SAS disk drives. In a heavily queued environment, SSP support data transfers in both directions simultaneously, so the effective throughput of a single 3-Gb/s link can increase to 6-Gb/s. Because SSP is based on the Fibre Channel information structures, solutions that bridge SAS to Fibre Channel can occur with minimal translation and performance penalties.
- Serial Management Protocol (SMP) supports connections to the SAS expanders within the topology to manage links between devices.
- Serial ATA Tunneling Protocol (STP) supports half duplex connections to the SATA devices attached to expanders. Expanders using STP allow SAS controllers to generate simultaneous requests to multiple SATA devices.
- Serial ATA (SATA) supports half duplex connections to the SATA devices directly attached to the SAS controller. A SATA device directly attached to a SAS controller, effectively forces the SAS controller to become a high performance SATA controller.

SAS technology continues in the SCSI tradition of allowing hot swappable disk drives. In addition to support for hot swapped SAS disk drives, SAS allows SATA disk drives to be hot swapped. This enables online replacement of the lower cost and lower reliability SATA disk drives in RAID solutions making it practical to deploy SAS with SATA disk drives in less demanding or cost sensitive applications.

Cabling and Hot Swap

Current parallel SCSI or parallel ATA solutions use bulky cables that have limitations in overall length. SAS external cables operate in lengths up to 8 meters while remaining thinner and easier to route in rack enclosures. In an intentional break with SATA compatibility, SAS solutions are optimized for backplane interconnect and do not support connection to SATA cables. This departure from compatibility with SATA prevents insertion of SAS drives into SATA-only backplanes and prevents potential damage to the SATA physical components.

Designed from the onset to provide cost effective hot swap support for disk drives, SAS has built-in protocol support to ensure SAS drives safely come on-line and avoid unnecessary loads on system power supplies.

Management and Fault Isolation

Constrained by the parallel restrictions, existing SCSI and ATA solutions are limited to small numbers of disk drives directly attached to servers. Because of this limitation, the management of the storage is less complex than larger installations available in Fibre Channel solutions. With the introduction of SAS, the number of disk devices directly attached to a server can rival Fibre Channel arbitrated loop solutions. SAS has incorporated features throughout that maintain the simplicity of direct attached storage and enable system management agents to properly identify degraded or failing connections as well as degraded or failing devices. Because of the increased connectivity, storage systems based on SAS will spawn innovation in hierarchal storage.

Graded pools of storage

Up to this point, hierarchal storage solutions have been either expensive to deploy or difficult to architect because a low cost high-speed interconnect was missing. SAS will facilitate the development of lower cost hierarchal storage solutions by permitting IT managers to create graded pools of storage that will be allocated as needed based on an application's requirements for performance, availability, capacity, and cost.[8]

Total Cost of Ownership

By taking a lead role in the development and encouraging the adoption of SAS technology, HP recognizes that customer needs are outgrowing the capabilities of parallel solutions. SAS is the culmination of efforts by OEM and Independent Hardware Vendors (ISV) in the server and storage community to allow direct attached server storage to meet the increasing demands of customers. For HP customers, SAS also provides the best investment protection by:

- Allowing flexible server and storage deployment
- Providing a choice in SAS or SATA disk drives based on application demands
- Increasing storage connectivity
- Reducing the penalty for incremental capacity increases
- Enabling improvements in fault detection and fail over
- Improving clustering solutions
- Reducing inventory costs

SAS and Fibre Channel Compatibility

SAS technology is architected to complement Fibre Channel in the SAN. SAS has adopted some Fibre Channel features; a dual ported serial storage interface, full duplex transfers, and a compatible framing structure to make it simpler to bridge SAS devices into the SAN. SAS did not adopt the optical support and fabric capabilities of Fibre Channel. As a result, SAS is not intended to replace either Fibre Channel or the emerging iSCSI storage solution as a SAN interconnect.

Both FC and SAS offer the maturity, richness, depth and scope of the SCSI command set. They are differentiated by their drive-to-drive connectivity, their inter-box connectivity, and their addressability. FC's combination of shared media access, data rate, optical support and fabric compatibility has made it the interface of choice for SANs and high-speed switching environments. SAS is built on the strong foundation laid by the SCSI protocol and the serial technology of FC.[9] SAS borrowed heavily from FC, making it very feasible to bridge FC to SAS. This bridge opens the opportunity to encompass FC SAN storage components with the compatibility of SAS and SATA devices internally.

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[8] http://www.maxtor.com/en/documentation/white_papers/graded_pools_storage.pdf

[9] Serial Interfaces in the Enterprise Environment From: Willis Whittington, ESG Interface Planning, Seagate Date: December 2002 • Number: TP-306

Table 2. Fibre Channel and SAS Interface Comparison

Topology	Fibre Channel Switched Fabric and Arbitrated Loop	SAS
	Point to Point	Point to Point with expanders
Addressing	FC-AL 128 FC-SW 16 million	16,384
Distance (m)	FC (copper metal) 10 FC (Optical Media) 10K	8**

Summary

SAS was developed to meet the changing demands of mainstream enterprise class storage system customers. SAS will allow customers ultimate configuration, flexibility, and simplicity in their storage environments. By accommodating, both low cost bulk storage (SATA devices) and the performance and reliability demands of mission critical applications (SAS devices), SAS minimizes customer investment while at the same time maximizes customer choice and ease of deployment. As storage requirements change, the customer can easily adjust the solution to match, without a 'fork-lift' upgrade.

SAS holds the promise of the future for enterprise users who will eventually need more power, easier connectivity, and greater scalability as storage requirements continue to escalate. By late 2004, as SAS products start entering the market, the customers will appreciate the time and effort that has gone into the definition, development and standardization of this innovative and essential new SCSI technology. SCSI is truly ubiquitous and perpetual.[10]

- SAS is the best choice for mainstream and 24x7 operation enterprise server and storage market segments.
- SAS meets the requirements for enterprise storage by providing strict quality, reliability standards, and universal compatibility.
- SAS is evolving from 20 years of SCSI infrastructure—enabling better performance, scalability, and flexibility.

More affordable than Fibre Channel and more robust and reliable than SATA, SAS will have the capability of fulfilling escalating and complex enterprise storage requirements as well as providing the necessary performance and scalability to move data at gigabit speeds—speeds that meet or exceed current storage I/O performance found in ATA, SATA, SCSI or Fibre Channel systems.

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10 http://www.lsilogic.com/products/islands/sas/SCSI_SAS.pdf

For more information

www.t10.org

serial attached SCSI spec development, meeting notes, presentations, and proposals

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If you would like to provide feedback, please mail to: Levi.Norman@hp.com

Other contacts:

tonya.comer@hp.com – SAS Product Manager

brandon.fears@hp.com - SATA Product Manager

Other SAS technology information is located at:

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and http://www/hp.com