EXECUTIVE SUMMARY

Two new serial interfaces to disk drives are replacing two venerable parallel interfaces. The advanced technology attachment (ATA) interface will be succeeded by serial ATA (SATA), and the small computer system interface (SCSI) will be replaced by serial attached SCSI (SAS). These new point-to-point technologies provide greater dedicated bandwidth and smaller connectors, and SAS technology supports both SAS and SATA disk drives. While Fibre Channel interface technology will continue to be leveraged in the enterprise storage marketplace (specifically storage area networks), IDC believes that SAS technology also will find its place in this market. SAS and SATA disk drives will appear in the storage middle market, and SATA disk drives will become a wholesale replacement for any ATA drive that is used in PCs, workstations, and low-end servers.

Continuing growth in the demand for storage capacity and performance is driving the need for faster point-to-point disk drive interfaces, as opposed to shared bus topologies. In addition to traditional categories of data, such as transactional data, reference data has emerged as a new class. Unlike transactional data, which is constantly changing and updated regularly, reference data remains unchanged after it is written. Among the many examples of reference data are corporate email, multimedia presentations, digital voicemail, and digital images.

Storage systems for reference data need high-capacity disk drives, low cost per gigabyte, and only modest storage system performance. Using new SAS and SATA disk drives, OEMs can design storage systems that mix higher-performance, higher-cost SAS drives with higher-capacity, lower-cost SATA drives. These next-generation storage products will support both performance-intensive and capacity-intensive enterprise storage needs.

While IDC believes that OEMs and customers will find next-generation storage products based on SAS and SATA valuable, some challenges lie ahead. First, the multiple suppliers of SAS and SATA products must meet their objectives for interoperability and their road maps for improved performance. Second, OEMs must accept and trust the new technology, and the products that drive vendors ship using SAS and SATA must meet customer expectations for cost, performance, and ease of use. Finally, SAS and SATA must find their place alongside an incumbent disk interface and storage interconnect technology: Fibre Channel.

IDC encourages storage OEMs and storage system users to evaluate the deployment of new SAS and SATA technologies. These successor interfaces to SCSI and ATA will be important players in the storage market over the months ahead.
Introduction

The overall performance of a computing system depends on the capabilities of processors, storage devices, and interconnect technologies. For magnetic disk storage systems, these capabilities include overall capacity and reliability as well as the speed with which data can be stored and retrieved. Improvements in storage technologies are crucial to overall system performance.

Demand for Storage Capabilities Continues to Grow

New sources of information, such as digital images, sound, and video, demand both high-capacity and high-performance disk storage. These multimedia workloads are increasingly prevalent beyond the boundaries of traditional entertainment. Industries such as healthcare, which utilize online storage of X rays and other medical images, demand increased storage capability.

Improved storage capability is also required for traditional business systems. Enterprises accumulate more data in the internetworked world of supply chain, customer care, remote service, and retail operations. In addition, tightened regulatory requirements call for more of enterprises' transactional and other operational data (e.g., email, presentations, memoranda) to be immediately available for retrieval, both internally and externally (by auditors and regulators).

IDC expects corporations' data storage requirements, driven increasingly by the workloads mentioned previously, to double every 18 to 24 months over the next several years, prompting IT managers to look for the most efficient means of storage.

A New Class of Reference Data

Traditionally, enterprise data sets were read, modified, and rewritten at specified checkpoints. For example, a company's general ledger was updated daily or weekly. Data such as a company's cash position and the inventories of raw materials and finished products was constantly changing.

Reference data, on the other hand, is data that does not change after it is first written. Email is a good example of reference data. Email messages remain the same after they are written, require increasing amounts of storage capacity, and must remain available for retrieval (i.e., referencing) in the future. Other emerging categories of reference data include X-ray images, mentioned earlier, along with image, sound, and video information. These new categories join traditional categories of data, such as corporate financial records and transactions.

In the trade-off between performance (i.e., speed of access to data) and capacity, reference data is more demanding of storage capacity and more tolerant of storage system performance. This is in sharp contrast to transaction processing data where dataset read/write times can and often do limit overall system performance.
Enterprise Storage Requirements

To provide for enterprise storage needs, IT architects look for products that are scalable as well as highly available and that preserve data integrity:

- To gain scalability, storage subsystems are assembled as arrays of hard disk drives (HDDs). Capacity is increased by adding HDDs to the arrays. Storage arrays can be attached directly to workstations and servers or attached over a network. Pooled storage systems such as networked attached storage (NAS) and storage area networks (SAN) consolidate storage arrays for ease of maintenance and to promote greater utilization.

- Data integrity is addressed by redundant storage techniques (e.g., RAID). The same data is written to more than one HDD so that the data is protected even if a component hard drive were to fail.

- Availability is also addressed by redundant techniques that provide not only for component hard drive failures but also for hot-swap replacement of the culpable drive and automatic recreation of the replicated data.

Storage Performance and Capacity Requirements

Storage performance requirements vary with workloads and often trade off against capacity requirements. Traditionally, storage performance is measured both by the ability to support transaction processing workloads and in inputs and outputs per second (IOPS). While the amount of data needed to support each transaction is relatively small, IOPS for a large transaction workload is usually quite large.

In contrast to transaction processing workloads, reference data workloads have capacity requirements that dwarf performance requirements. IT planners must consider the cost of storing and occasionally retrieving large datasets rather than sheer IOPS. Thus, for reference data workloads, storage requirements shift to capacity costs including the storage footprint in the datacenter and away from the speed with which data can be read and written.

Drive Interfaces: ATA, SCSI, and Fibre Channel

Hard drives can be classified by the way they interface with a host device. The primary interface standards are ATA, SCSI, and Fibre Channel. Figure 1 depicts the relative share of worldwide HDDs by interface for all application segments. Given ATA's stronghold on desktop and laptop PC computing, it is no surprise to see that the interface has garnered such a large share of the market.
However, a closer look at disk drive interface share within just enterprise storage solutions reveals a different market. As Figure 2 shows, products with SCSI and Fibre Channel interfaces dominate the enterprise storage market, and there are some early signs of growth for ATA in this market. While Fibre Channel share is smaller than SCSI share in the enterprise storage market, it is important to understand the magnitude of its installed base.
Traditional ATA and SCSI disk interfaces are parallel and shared when multiple HDDs are installed. The Fibre Channel disk drive interface is a shared-access arbitrated loop topology and, when connected through a loop switch, provides a point-to-point interface, as shown in Table 1. Transfer rates for ATA and SCSI have doubled many times over the years, but no further growth is expected. In addition, while the SCSI interface has a transfer rate of 3.2Gbps, which is faster than that of Fibre Channel, it is important to remember that SCSI is a shared bus architecture and multiple HDDs quickly consume the transfer rate. The introduction of point-to-point architectures such as fiber loop switches and SAS expanders can eliminate this bottleneck, thus making interface speed less relevant. Other characteristics of the ATA, SCSI, and Fibre Channel protocols are shown in Table 1.
Table 2 examines the technical characteristics of typical desktop-class and enterprise-class HDDs. The ATA interface is dominant on the desktop, while higher-performance SCSI and Fibre Channel interfaces are typically used with enterprise-class storage systems. Spindle speed, which is proportional to data transfer rates, is higher for the more demanding enterprise-class workloads. Disk form factors and capacity are larger for desktop-class HDDs.

The large gap in mean time between failures (MTBF) and warranties between desktop-class and enterprise-class drives has led some HDD vendors to create a new family of drives intended to be positioned between the desktop and enterprise classes. However, the only major differences are with respect to MTBF and warranties and a slightly higher $/GB.
### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Desktop Class</th>
<th>Enterprise Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interface</strong></td>
<td>ATA</td>
<td>SCSI/FC</td>
</tr>
<tr>
<td><strong>Spindle speed</strong></td>
<td>5,400rpm; 7,200rpm</td>
<td>10,000rpm; 15,000rpm</td>
</tr>
<tr>
<td><strong>Disk form factor</strong></td>
<td>95mm disks</td>
<td>84mm (10K), 65mm (15K) disks</td>
</tr>
<tr>
<td><strong>Maximum capacity</strong></td>
<td>400GB</td>
<td>300GB (10K), 147GB (15K)</td>
</tr>
<tr>
<td><strong>Average seek</strong></td>
<td>8.5ms</td>
<td>&lt;4ms</td>
</tr>
<tr>
<td><strong>Sustained data rate</strong></td>
<td>5,400rpm @ 4.6Gbps; 7,200rpm @ 5.9Gbps</td>
<td>10,000rpm @ 7.2Gbps; 15,000rpm @ 7.5Gbps</td>
</tr>
<tr>
<td><strong>$/GB</strong></td>
<td>$1</td>
<td>$4</td>
</tr>
<tr>
<td><strong>MTBF</strong></td>
<td>500,000 hours @ 40% duty cycle</td>
<td>1.2 million hours @ 100% duty cycle</td>
</tr>
<tr>
<td><strong>Warranty</strong></td>
<td>1 year</td>
<td>5 years</td>
</tr>
</tbody>
</table>

Source: Maxtor and LSI Logic, 2005

### SAS and SATA: Next-Generation SCSI and ATA

New serial technologies will replace the parallel interconnect technologies of SCSI and ATA drives. SAS and SATA are the next generation. The following sections include descriptions of the features and functionality for SAS and SATA along with analyses of how the two technologies compare and contrast with each other and with storage subsystems using the Fibre Channel interconnect.

**SAS**

Work on the SAS specification began in earnest in 2001 when Compaq/HP, LSI Logic, Maxtor, and Seagate Technologies set upon the task of writing a specification. In 2002, the SCSI Trade Association took ownership of the standard and its marketing. The initial release, in 2004, specified a 3Gbps dedicated interconnect bandwidth, and the SCSI Trade Association road map identified 6Gbps and 1.2Gbps successor standards.

SAS supports a number of compelling features tailored to enterprise storage solutions. The protocol supports HDDs with dual ports, and from a software point of view, legacy SCSI commands remain intact. With cabling lengths of 8 meters or less, SAS may be used to connect HDDs in the server cabinet or to connect arrays of HDDs in an adjoining cabinet. SAS HDDs, like SCSI HDDs, are typically dual-port, high-performance 10,000rpm and 15,000rpm drives.
**SATA**

The SATA standard replaces the venerable parallel ATA protocol first launched in 1985 and is the follow-on interface technology for the ubiquitous PC. Today, serial ATA is a point-to-point dedicated 1.5Gbps interconnect. With a 1 meter maximum cable length, SATA is best suited for PCs, laptops, workstations, and entry-level servers. Typical drive speed for SATA HDDs is 7,200rpm, and SATA drives are single port.

SATA systems are designed to meet the low-cost needs of desktop PCs and notebooks while still incorporating some features to make the technology useful for enterprise second-tier storage. IDC believes that how SATA drives are engineered into storage systems will be particularly important to the upper reaches of the market. A disk array could easily integrate relatively less reliable, higher-capacity disks into a robust constellation. Disk drive vendors recognize the customer's intolerance of storage systems that have lower reliability as well as the "low reliability" stigma associated with ATA drives. In response to this concern, HDD companies, such as Maxtor, have marketed a specific family of (S)ATA drives with improved reliability specifications.

**Comparing SAS and SATA**

Table 3 contrasts the technical characteristics of SAS, SATA, and Fibre Channel HDDs. Most important, SAS and SATA provide greater dedicated (i.e., point to point) bandwidth needed for next-generation HDDs. Further, especially for notebook and workstation deployment, the smaller cables and connectors demanded by a serial interconnect make physical connects and cabling significantly more compact.

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>SATA, SAS, and Fibre Channel Technologies</th>
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<tbody>
<tr>
<td></td>
<td>Serial ATA (SATA)</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Half duplex</td>
</tr>
<tr>
<td><strong>150GBps</strong></td>
<td>300GBps (announced)</td>
</tr>
<tr>
<td><strong>300GBps (announced)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Connectivity</strong></td>
<td>1 meter internal cable</td>
</tr>
<tr>
<td><strong>One device</strong></td>
<td>&gt; 128 devices</td>
</tr>
<tr>
<td><strong>Fan-out devices (demonstrated)</strong></td>
<td>Expanders</td>
</tr>
<tr>
<td><strong>16K physical maximum</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Single-port HDDs</td>
</tr>
<tr>
<td><strong>Single host point to point</strong></td>
<td>Multi-initiator point to point</td>
</tr>
<tr>
<td><strong>Driver and model</strong></td>
<td>Software transparent with parallel ATA</td>
</tr>
</tbody>
</table>

Source: Maxtor and LSI Logic, 2005
Moreover, although SATA and SAS are not hardware compatible with legacy parallel versions, the new serial interfaces provide continuity from a software perspective and offer a solid road map for next-generation speed increases to meet the growing capacities and data rates associated with next-generation HDD platforms.

It is important to note that the SAS interface protocol is designed with advanced functionality to support high-end enterprise storage requirements and that the same protocol can also control SATA drives, making the SAS interface a powerful option for system OEMs to consider when designing new system architectures.

**SAS and SATA Connectors**

The plug and backplane connectors for SAS and SATA HDDs are purposefully similar. Moreover, a single SAS controller can provide sockets for both SAS and SATA connectors. Figure 3 illustrates the similarities and differences between SAS and SATA connectors.

**FIGURE 3**

**SAS and SATA Connectors**

**Serial Attached SCSI**

![Serial Attached SCSI]

**SAS Backplane Receptacle Connector**

**Serial ATA**

Source: IDC, 2005

The ability to mix SAS HDDs (with their superior I/O density) and SATA HDDs (with their superior capacity density) allows system designers to exploit the price/performance and capacity/performance trade-offs between the two categories of HDDs. For applications where low-cost, high-capacity storage is needed, SATA HDDs can be provisioned. When the highest availability and performance are required, then SAS HDDs will be installed. With SAS and SATA, storage requirements based on expected workloads and data criticality can be better matched to HDD technology.
Form Factors and SAS HDDs

Enterprise-class HDDs in a 2.5in. form factor, similar to the size of the drives used in laptop PCs, have begun to appear in some HDD vendor portfolios. Enabled by the smaller connector and cable sizes for SAS (versus SCSI), SAS storage using 2.5in. form factor drives will be small enough to be configured in 1U RAID 5 servers, rack-optimized servers, and other storage solutions, with the goal of increasing the I/O density.

In Summary

SAS is most likely to be offered as a replacement technology to SCSI usage today. IDC would expect SAS to appear in servers with direct attached storage, storage arrays located in the immediate proximity of servers (i.e., rackmount applications), and interconnect technology within SAN and NAS devices.

IDC Analysis

New serial adaptations of ATA and SCSI HDDs are an important step ahead for storage technology in the large. Not only is the greater bandwidth important for next-generation HDDs, but also the smaller cable and connector will allow HDDs to achieve greater storage density.

Opportunities

Continuing customer demand for more storage capacity and performance provides a strong baseline opportunity for storage system providers. With increasingly powerful servers placing greater demands on storage systems, continuing progress in the storage industry is essential to keep computing systems in balance. Customers will be motivated to acquire faster storage systems with greater capacity to ensure that overall system throughput is maximized.

SAS is a natural follow-on technology for today’s SCSI drive applications. The strength of SCSI in internal and direct attached storage should bode well for SAS. In addition, the close correlation between small form factor enterprise-class drives and SAS should provide additional opportunity to solidify the emergence and sustainability of SAS interface technology within enterprise storage products.

The ability to mix SAS and SATA HDDs provides storage system suppliers with the opportunity to more precisely match technology to user needs without the complexity and cost of translating data from one interconnect standard to another. IDC expects to see a mix of SAS and SATA HDDs incorporated into workstations and servers. Similarly, there will be efforts by OEMs and white-box suppliers looking for ways to design in the flexibility offered by combination SAS/SATA array designs.

End users are looking for seamless integration of enterprise storage systems that offer cross-platform functionality, reliability, and cost-efficient management. The new SAS and SATA interfaces are important ingredients in enabling these types of system configurations. Suppliers have the opportunity to make systems more capable, more cost-effective, and simpler to deploy.

New serial adaptations of ATA and SCSI HDDs are an important step ahead for storage technology in the large.

Customers will be motivated to acquire faster storage systems with greater capacity to ensure that overall system throughput is maximized.

IDC expects to see a mix of SAS and SATA HDDs incorporated into workstations and servers.
Challenges

OEMs must recognize that designing storage systems, especially for enterprise-class storage products, to be successful in the marketplace and in the datacenter is a significant challenge. History is replete with examples of unsuccessful NAS companies attempting to leverage low-cost components for enterprise storage applications. The lesson is that cost-effective enterprise storage is not just about low-cost components. Successful storage products built with heterogeneous hardware must manage or mask complexity with sophisticated software. If storage systems are too complex, end users may simply purchase inexpensive full-function servers and avoid network storage devices that are unfamiliar and appear to be difficult to deploy and maintain.

The value proposition offered by SAS, that is, its interface capabilities, road map, and interoperability with SATA, must gain the acceptance and trust of OEMs and end users to be successful in the marketplace. SATA will be the next-generation HDD interface for the PC, and therefore its acceptance in that market space is a given. The migration of parallel SCSI to SAS as an interface for disks installed in servers will ensure its viability as an enterprise disk drive interface. However, SAS as an interconnect technology for the exterior array segment of the enterprise storage market will be challenged by an incumbent competitor: Fibre Channel.

Another challenge for the SAS community is to avoid encouraging competitive behavior that can cloud complementary products and protocols. OEMs and end users must come to believe that SAS, SATA, and Fibre Channel interconnects will coexist. IDC believes that the billions of dollars invested in Fibre Channel infrastructure provides inertia for the future of Fibre Channel. We expect that SAS and SATA will coexist with Fibre Channel as a disk drive interface in the enterprise.

It is important to distinguish between the needs of OEMs that assemble disk arrays and the customers who buy them. Customers should not care whether the drives in an array use Fibre Channel or SAS interface technologies. OEMs, on the other hand, will need a compelling argument to switch from Fibre Channel to SAS interfaces because doing so will introduce new design costs, disrupt existing stable configurations, and even possibly raise the cost of an array's components. The long-term ROI and TCO will and should be thought out carefully. The difficulty in isolating faults within arbitrated loops, along with shared bandwidth limitations, is forcing OEMs to consider point-to-point solutions based on Fibre Channel loop switches or SAS. The cost and difficulty in implementing each of these solutions will be important considerations for OEMs as they architect their next-generation storage systems.

Seamless integration and interoperability are also key goals of the SAS standard. Achieving these goals is a critical challenge for the SAS community. The failure of SAS products from different manufacturers to interoperate would be a serious setback for SAS adoption.
Moreover, OEMs must succeed in packaging SAS technology so that users find it both cost-effective and easy to use. Inexpensive products that are difficult to deploy will be rejected by customers because datacenter decisions must weigh ongoing operational expenses more heavily than initial purchase price. End users are looking for seamless integration of enterprise storage systems that offer cross-platform functionality, reliability, and cost-efficient management. While SAS and SATA are important ingredients, they must be supported by storage system software that successfully masks complexity and reduces deployment cost.

**Meeting the Challenges**

The SCSI Trade Association as well as SAS HDD suppliers and their OEMs are working to provide road maps (i.e., publicly stated milestones for future enhancements), benchmarks (i.e., standard performance metrics on experimental workloads), and proof points (i.e., real-world capacity and performance metrics based on actual production workloads) to garner trust in their products. On-time delivery of road map milestones will be crucial, especially in the early years.

SAS is the plan of record for numerous late 2004 and early 2005 product introductions from OEMs in the standard high-volume (SHV) server space, that is, servers based on Intel processors. The ANSI adoption of SAS as a standard and the early product announcements appear to support this market adoption window.

Users who expect improvements in price/performance across all of IT’s componentry should look favorably at lower-cost solutions based on SAS and SATA storage. Customers will expect high quality and reliability and will likely look to their OEMs for assurances that the new SAS storage systems are indeed ready for enterprise use.

Moreover, system OEMs should look to exploit the uniqueness of SAS and SATA drives within the same system architectures to provide end users with the greatest flexibility and efficiency possible via hardware that operates flawlessly and software that enables cross-functionality and efficient data storage management.

Finally, SAS and SATA suppliers and OEMs should not ignore the vast Fibre Channel infrastructure that many users have put into place. SAS and SATA are not wholesale replacement technologies for Fibre Channel, although they will compete in the enterprise storage market. Fibre Channel and SAS will coexist as high-performance interfaces, while SATA will be recognized as a lower-performing interface, appropriate in less transaction-intense environments. It will be important for the industry to articulate how and where these interfaces are best deployed.

**Conclusion**

Storage systems using SAS and SATA interfaces will be increasing their presence within the marketplace over the next several years. These technologies offer the potential for improved price/performance for storage systems generally and the opportunity to better match disk storage devices to storage workloads. IDC encourages OEMs and storage consumers to monitor progress and evaluate early-adopter experience with storage systems built using these two new standards.
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