The SATA Revolution

Introduction

Over the course of 2002 and 2003 Serial Advanced Technology Attachment (SATA) generated a lot of attention as it was positioned as a disruptive technology to the traditional low-end and enterprise-class storage. SATA proved that there are technologies other than the expensive, enterprise-class Fibre Channel (FC) and Small Computer System Interface (SCSI) and that it can make significant inroads not only in desktop applications, but also in server, NAS and SAN applications.

However, the value of SATA in recent years has been more symbolic than anything else. On one side, it has marked a change in paradigm and approach to mass storage, showing that there are other ways to achieve large storage capacities while still preserving both performance and management features.

On the other hand, the SATA interface revealed its shortcomings that made it virtually unusable for a large number of applications, leaving a large portion of the market to FC and SCSI. Ultimately, SATA showed that it is attainable in principle and that there are significant economics to push in this direction.

Based on the above, 2004 and 2005 are poised to become the years when a real alternative to FC and SCSI is available - SATA-II. This new extension-to the original SATA standard is seen as the bridging technology from a desktop-oriented SATA to a server-level storage interface, making it a viable, low-cost storage solution for server, NAS and SAN applications. See Table I for Storage Interface Feature Comparisons.

There will always be a configuration and usage model that will require high end FC and SCSI drives, but SATA-II is making the server alternative viable, with all the economics and alternatives that go with it.

SATA-II is playing to bridge the gap between SATA and FC/SCSI applications, and Native Command Queuing, Enclosure Management, and Port Multiplier are the name of the game. LSI Logic's MegaRAID SATA 300-8X is the RAID controller that will make all of them readily available to the open market.

The paper below analyzes the values and limitations of current SATA solutions and how (and why) SATA-II will address them. It also provides a global over-view of how the LSI Logic MegaRAID SATA line will take advantage of these value propositions to provide the customer with a strong position in the RAID market.

Table I - Storage Interface Feature Comparisons

	ATA	SATA	SCSI	SAS	FC
Interface Type	Parallel	Serial	Parallel	Serial	Serial
Addressing	2	1 or 16 w/SATA II	16	128	16 million
Distance (m)	.5	1	12	10	10km
Connection	80-pin	7-pin	68-pin internal/ext	7-pin	copper/optical internal/external
Dual Port	no	no	no	yes	yes
Topology	bus	pt. to pt.	bus	pt. to pt. with expanders	loop, fabric
Duplex	half	half	half	full	full
Max. Devices	2	1 or 15 with port multiplier	16	4096 with expanders	127-loop 2*24 fabric
Cable Length	0.4m	1m	12m	10m	30m (copper) 300m (optical)
Applications	Internal Storage	ATA RAID, Server & high-end work-station storage	Mid-range & Enterprise servers	Mid-range and Enterprise servers	SAN and Enterprise servers

SATA'S BIG SUCCESS STORY

Few would have predicted that SATA would raise much attention outside desktop applications. Previously, the storage world was clearly divided between IDE for personal computing and SCSI and FC for professional and server oriented computing. These two environments require extremely different feature and value propositions that rarely converge.

ATA users typically worked with personal computers, single-threaded applications, 8x5 usage models, and believed that performance was nice, but cost was by far most important. On the other hand, SCSI and Fibre Channel users worked with servers and high-end workstations, multi-threaded applications, 24x7 usage models, and, while cost was important, performance was first and foremost.

With the commoditization of all computing engines, server and high-end workstations were suddenly available to small offices, schools, and homes, making cost pressure a more important factor. Many manufacturers began introducing entry-level ATA storage solutions in order to attract customers, but with the ultimate goal of selling them a more costly and effective SCSI solution. Although some SCSI and FC manufacturers were concerned with this model, they knew that ATA did not really challenge their current business model; if anything, it spurred the market in a time of crisis after the .com failure.

Then came SATA. Fundamentally, SATA was the same as ATA except that instead of data flowing in parallel, it would flow in a serial stream. The new Serial ATA standard came out silently and was driven by very practical reasons. ATA had passed the point where data could be transferred at reliable speeds, cabling was cluttered and made necessary airflow to cool processors a challenge. Also, 5V power was a dying technology because 0.13 micron and 90nm technology could not withstand that high of a voltage. See Figure 1: *ATA and SATA Interface Diagrams Comparison*.

SATA provided a new concept on how storage can be used in professional environments. The serial interface allows more ports to be integrated into the same piece of silicon, so the traditional 2-channel ATA controller can be replaced with an 8-port SATA controller. Also, the new cabling made it much easier to route many more disks than ATA. Where ATA barely connected up to four disks, SATA can easily add up to eight. See Figure 2: *SATA Cables and Connection Diagram.* This, coupled with the low-cost of the Serial ATA controllers, has created this new business model. Why use four SCSI disks to create a RAID 5 when you can build it with four, five or six SATA disks for much less money?

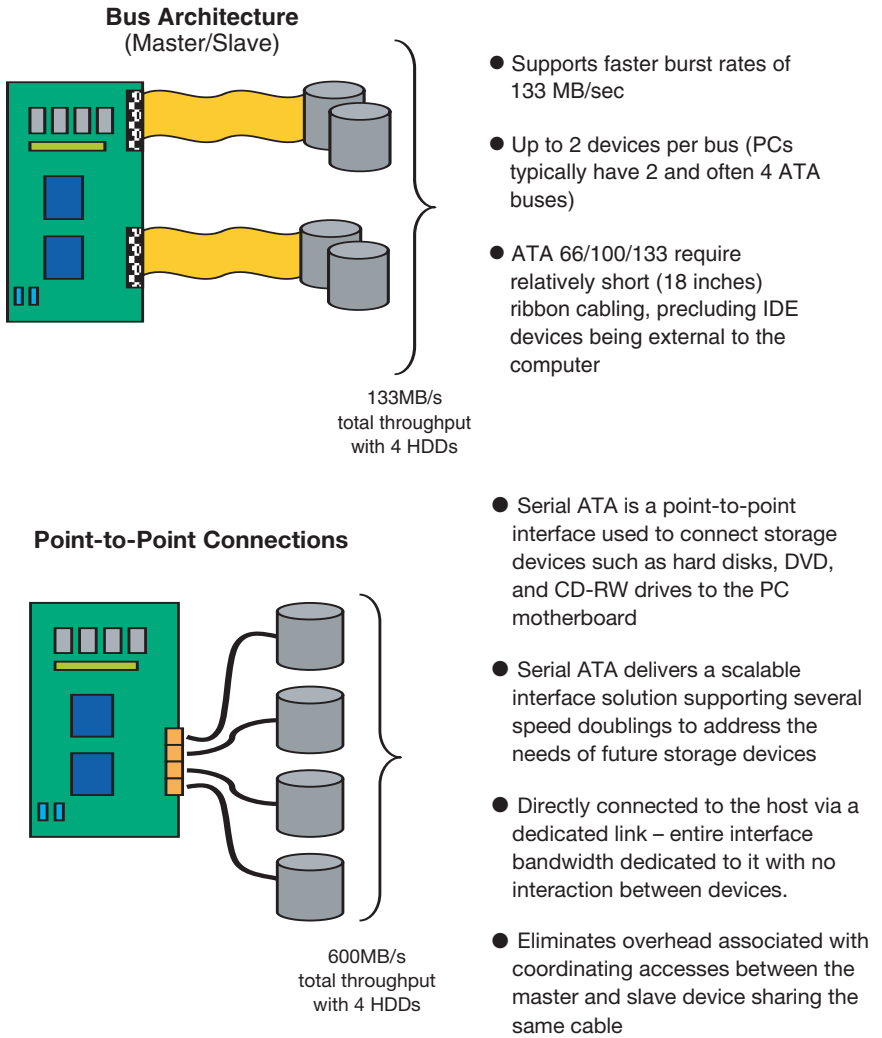


Figure 1 - ATA and SATA Interface Diagram

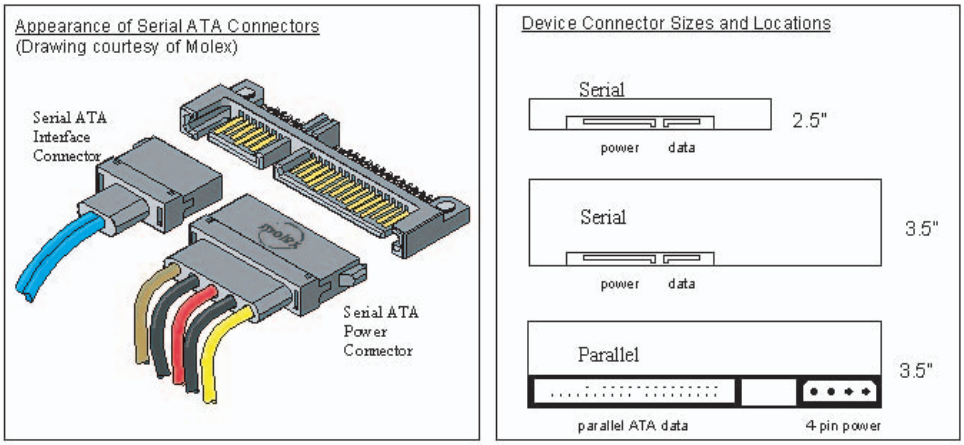


Figure 2 - SATA Cables and Connector Diagram

Even with these new advancements in Serial ATA, there are limitations that make it uncompetitive with SCSI and FC in several areas. The greatest achievement of Serial ATA 1.0 was that it made people realize that there are alternatives in storage and that SATA is blazing the new trail.

WHERE SATA FELL SHORT

The main limitation of SATA - just as its name states - is that it is just a "Serial-ATA." And with that come many of the protocol, manageability, usability, and reliability concerns that existed with Parallel ATA. These limitations are divided into two separate issues: one, mechanical chassis; and two, protocol.

SCSI chassis are designed for high-performance, high reliability, 24x7, multi-threaded protocols. They are designed in tightly packed configurations that are able to survive with high MTBF's and all the mechanical requests that a high-end server environment demands. SATA chassis, on the other hand, are designed to live alone in a PC, not in a server where it is coupled with many disks whose vibrations stress each other's bearings. Unexpected heat generation also becomes a serious factor due to multi-threaded activities.

Both SCSI and SATA have their own value. SCSI, FC, and Serial Attach SCSI (when it is introduced later in 2004) will provide top-notch performance while SATA is still much more economical and will serve less demanding markets or users. As for the protocol issue, there are at least three areas that taint SATA's server potential:

- Performance
- Manageability
- Connectivity

Most of the performance limitations are due to mechanical issues as discussed above. Furthermore, there is no value in a server application, where access profiles are largely random and command reordering gives top-notch benefits.

With SATA you only have one command to work with. For example, if you are using the disk for a video server, performance may be adequate. However, if you are using is for any type of transaction processing, you will most likely see substandard performance.

When you purchase a RAID controller, it is because you want to preserve data integrity and functionality in the event of a disk failure. In the case of SATA, where the die-out rate of disks is higher, you especially want to use RAID. This is where the manageability limitation comes into the picture. Now that you have a failed disk drive, you want to replace it. With SCSI, FC, and SAS, there is a mechanism based on SAF-TE that allows a dead disk to be reported through light indicators. With SATA, there is no indicator to show you which disk has failed. The user then runs the risk of losing invaluable data by pulling a functional disk instead of the failed disk.

Although SATA disks are inexpensive, the total SATA solution will not necessarily be low-cost. The main reason for this is because while using SATA 1.0 controllers, one can only connect one disk per port. If you need eight disk drives, you have to use eight ports. At a price of $40/port, this solution is not inexpensive. Also, using SATA 1.0 controllers is not an efficient use of the transfer speed. Although SATA 1.0 touts a 150MB/sec peak speed, the fastest SATA disk drive is around 60MB/sec. In essence, each port is only using 60% to 70% of its potential.

SATA II: THE BRIDGE TO ENTERPRISE STORAGE

The introduction of Serial ATA II addresses the limitations of SATA 1.0 in order to make this interface a fit for large-scale professional deployment. See Table II: *SATA I to SATA II Comparison*. LSI Logic will provide an entire family of RAID controllers to meet the highest demands of SATA II. There are five main features that epitomize Serial ATA II:

- Higher per-port transfer rate (3Gbs = 300MB/sec)
- Native Command Queuing
- Enclosure management
- Port multiplier
- Provides an upgrade path to SAS

It may sound strange to increase the per-port transfer rate after the issues discussed above. With one disk connected to one port, 150MB/sec is a waste of bandwidth because one disk cannot possibly utilize all that bandwidth. However, because SATA II will allow users to connect multiple disks to the same port (see Figure 3: *Port Multiplier* below), a higher transfer rate is necessary to be able to connect 4-8 disks to a single port.

Table II - SATA I to SATA II

SATA I Features	SATA II Phase I Features	SATA II Phase II Features
100% software compatibilty	Native Command Queuing (NCQ)	Dual host active fail over
Thinner Serial ATA cables up to one meter	SES and SAF-TE enclosure management	Efficient connectivity to a large number of drives
Lower pin counts, and support for lower voltage	Backplane interconnect providing extended trace lengths	3.0Gb (300 MB/s)
Connectors can be blind-mated and hot-plugged	Data scatter/gathering	
Lower power requirements		

Native Command Queuing enables the hard drive to take multiple requests for data from the processor and re-arrange the order to maximize throughput. Performance is still limited by the chassis, but the protocol will begin to close the gap between SATA and SCSI and Fibre Channel. The disk manufacturers will be left to provide hard drives with the proper algorithms and computing power to take advantage of this feature. See Figure 4: *Native Command Queuing* on next page.

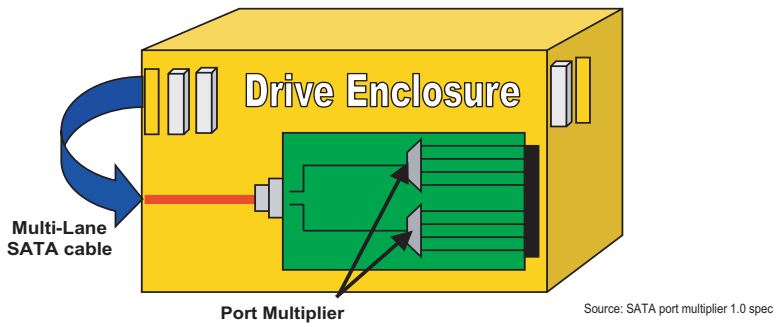
Remember the previous scenarios where the SATA RAID user had a dead disk and did not know which disk it was? Enclosure management is the solution to that problem. The same protocols used for SCSI and Fibre Channel monitoring will be ported to SATA, completely bridging the gap on this front.

Port Multiplier, as briefly discussed above, allows up to fifteen disks to be connected to the same port. While this number of disks will not likely be reached, Port Multipliers will likely attach between four to eight disks to one port. From a cost perspective, this is a very efficient solution. Other advantages include fewer cables, more efficient use of space, and scalability of up to 32 disk drives, which was not possible with SATA 1.0. See Figure 5: *2U Chassis Before and After Port Multiplier Implementation* on next page.

Serial Attached SCSI (SAS) will launch in late 2004. Because the similar physical and electrical interfaces design of SATA and SAS, Serial Attached SCSI system can use either Serial Attached SCSI disks or Serial ATA disks based on the application requirements to reduce overall solution cost. With the same look and feel of the MegaRAID software stack, customers can seamlessly upgrade to a SAS ecosystem by moving the SATA disks to SAS RAID ecosystem.

Port Multipliers increase the number of SATA connections in an enclosure which does not have sufficient connections.

e.g. two 1 to 4 port PM with one multi-lane cable



Source: SATA port multiplier 1.0 spec

Figure 3 - Port Multiplier

- Example:
  - Commands A-B-C-D issued
- Non-Queued
  - A-B-C-D executed
  - ~2 revolutions required
- Queued
  - B-D-A-C executed
  - Only 1 revolution required

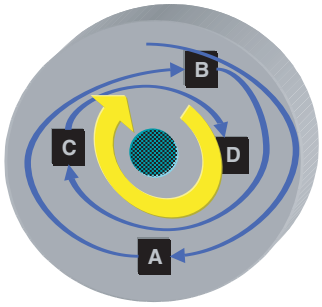


Figure 4 - Native Command Queuing

It is very likely that a number of server and storage suppliers will provide SAS infrastructures (boxes, backplanes, cables, etc) where a user can either plug in high-cost, high performance SAS disks or low cost, lower performance, yet high-capacity SATA disks.

WILL SATA II RULE THE WORLD?

If SATA II is able to bridge all the main protocol and logic limitations between SATA and SCSI, SAS, and Fibre Channel and still remain the significant cost leader, what prevents it from becoming the storage interface of choice? While SATA 1.0 and now SATA II are the building blocks for a new storage ecosystem, it is important to note that they are not necessarily taking over existing ones.

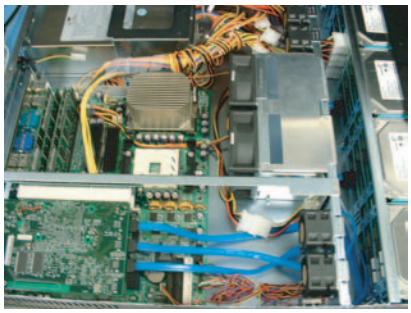
For example:

- There are still a number of applications that require the superior performance and lower pricing is not a reasonable tradeoff.
- SATA disks are inexpensive and even buying spare disks still makes this an attractive and low-cost option. However, many applications require trained personnel to assist the systems and often something as simple as swapping a disk and rebuilding an array may impose too high a cost for the complete solution.
- SATA does not provide a real external storage connectivity solution. There is a push in the standard to provide external storage support, but it is aimed for less intensive applications and would not be a viable option for server environments with external requirements. These environments will require SCSI, SAS and Fibre Channel. In a world where boxes are getting smaller, where 1U racks and blades dominate, external solutions become a very important proposition.

Serial ATA will certainly be a major player in the storage market, but definitely not the only one.

LSI Logic MegaRAID will span the direct attached storage ecosystem; from the very low end SATA to the very high end SAS. All products will share the same proven software stack, management utilities and upgrade path.

Before
2U system with 12 SATA cables connected



After
2U system with 3 SATA cables connected
(includes 3 4-port multipliers on backplane)

Figure 5 - 2U Chassis Before and After Port Multiplier Implementation

For more information,
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