SCSI vs. Fibre Channel

White Paper

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Over the past decades, computer's industry has seen radical change in key components. Limitations in speed, bandwidth, and distance have driven evolution and advancements of the technology.

In terms of hardware interface, the development of the Small Computer Systems Interface (SCSI), in the mid 80's, was a considerable advancement because SCSI was the first intelligent interface. SCSI is a standard interface that supports all devices on a single one adapter. Indeed prior to SCSI, interfaces were designed for specific devices. One hard disk interface for hard drive, one tape interface for tape drive, etc…The development of Fibre Channel started in the late 80's in order to provide high-speed via high-bandwidth, and became an approved ANSI (American National Standards Institute) standard in 1994.

Now, storage needs are booming with today's exceptional growth of data-intensive applications such as decision support system, audio, video and Internet/intranet. Fueled by this demand, Fibre Channel is gaining popularity over SCSI however SCSI continues to be the most common interface, and will remain appropriate for some time and some applications. Today's period is a transition period where Fibre Channel and SCSI cohabit in the market and in configuration. Hybrid product (Fibre Channel for host and SCSI for drive) is the step before full Fibre Channel.

Technical Specifications

As mentioned above, SCSI and Fibre Channel are not incompatible but each has its own specifications with its protocol, which are completely different.

SCSI

In the computer industry, the SCSI interface is found on every type of device: disks, host adapters, complex storage controllers, tape, scanners, printers and so. As the current storage interface, SCSI is a bus parallel architecture where a host system communicates with storage devices via a parallel bus. SCSI is an intelligent, parallel interface, which allows transfer of data over multiple pieces of the same medium simultaneously. In consequence, the main issue with SCSI is to be sure that data sent over this medium, but in each individual parallel wire of it, arrives at the same time at the target. If it is not the case, data corruption will occur. Restrictions and limitations of SCSI come from this transfer protocol. In order to avoid data corruption, speed of data transfer and cable length are reduced.

Even if over the years these limitations were far overtaken by technological advancements, there are still present. Indeed, the first SCSI standard adopted in 1986, referred to as SCSI-1, had only a maximum speed transfer of 5 MB/s and supported a maximum of 8 devices.

Essential feature of SCSI is its ability to process multiple overlapped commands. Also known as multi-tasking support, this allows SCSI drives to fully overlap their read and write operations with other drives in the system. Commands can be processed concurrently rather than serially from different SCSI drives. The data can then be buffered and transferred over the SCSI bus at very high speeds with other data in the system.

The common denominator for SCSI is evolution because year after year SCSI pushes forward its limitations although SCSI protocol remains the same with its advantages and its inconveniences. See table 1 for evolution of the SCSI attributes.

Interface	**Maximum Bandwidth (MB/sec)**	**Bus Width (bits)**	**Maximum Bus Length (meters)**			**Maximum Number of devices**
			Single-Ended	Differential	LVD	
SCSI-1	5	8	6	25	NA	8
Fast Narrow SCSI (SCSI-2)	10	8	6	25	NA	8
Fast Wide SCSI (SCSI-2)	20	16	6	25	NA	16
UltraSCSI (SCSI-3)	20	8	1.5	25	NA	8
UltraSCSI (SCSI-3)	20	8	3	NA	NA	4
Wide UltraSCSI (SCSI-3)	40	16	NA	25	NA	16
Wide UltraSCSI (SCSI-3)	40	16	1.5	NA	NA	8
Wide UltraSCSI (SCSI-3)	40	16	3	NA	NA	4
Ultra2 SCSI (Fast-40)	40	8	NA	25	25	2
Ultra2 SCSI (Fast-40))	40	8	NA	12	12	8
Wide Ultra2 SCSI (Fast-40)	80	16	NA	25	25	2
Wide Ultra2 SCSI (Fast-40)	80	16	NA	12	12	16
Ultra3 SCSI (Fast-80)	160	16	NA	NA	12	16

Table 1. Parallel SCSI Attributes

The need of more speed was addressed through the introduction of SCSI-2, which improved SCSI-1 by implementing new connectors, increasing data bus path, and reliability via synchronous transmission scheme and parity checking. SCSI-2 doubles the SCSI bus clock rate from 5MHz to 10MHz which increases the SCSI data transfer rate from 5 MB/second to 10 MB/second. This first evolution of the SCSI was logically called Fast SCSI.

In addition to doubling the transfer rate, SCSI-2 also provides the option to double the maximum bandwidth of the SCSI bus via the use of Wide SCSI. By doubling the bus width from its standard 8 bits to 16 bits, a Wide SCSI bus can transfer twice as much data in the same amount of time and support up to 15 devices. With the combination of a faster (5 to 10MHz) and wider bus (8 to 16 bits), SCSI interface was able to provide a maximum transfer rate of 20 MB/second. In consequence, SCSI-2 or Fast SCSI was available with two bus width, a narrow or a wide, which gave birth to the Fast Narrow SCSI and Fast Wide SCSI.

Two other features of SCSI-2 also enhanced overall performance. The first, called command queuing, refers to queuing multiple commands to a SCSI device. Queuing to the SCSI device can improve performance because the device itself determines the most efficient way to order and process I/O commands. This ability to rearrange or reorder the execution of I/O commands allows an optimization of overlapping and maximization of throughput. The second is called Scatter/Gather. Scatter/Gather is a method of providing multiple host addresses for data transfer in one command packet. Scatter input means issuing 1 read call but scattering the data into multiple arrays. Gather output means issuing 1 write call but gathering the data from multiple arrays. In consequence, Scatter/Gather operations reduce the number of system calls required to perform I/O. This feature greatly increases performance in environments such as Unix, Novell NetWare, Windows NT, Windows 95 and OS/2.

SCSI-3, also referred to as UltraSCSI, incorporates for the first time, serial interconnection schemes in addition to SCSI's traditional parallel interconnect. UltraSCSI doubles the Fast SCSI bus clock rate from 10MHz to 20MHz and reach up to 40MB/sec transfer rate with a 16-bit Wide SCSI bus. In term of technologies, SCSI-3 introduces 3 new serial interconnections: Serial Storage Architecture (SSA), Fibre Channel, and IEEE P1394. These serial SCSI technologies allow increased transfer rates, more devices per bus, longer cables, simplified and hot-swappable connectors. Fast-40, better known as Ultra2, is an enhancement to UltraSCSI with performance up to 80MB/s.

The new development of the SCSI interface known as Ultra3 or Ultra160/m again pushes forward the speed limit of this "old-new" standard, which allow a transfer rate of 160MB/s. Even if the SCSI continues to overcome its limitations in terms of speed; distance limitations and number of devices supported are still a concern. Furthermore, improvements in SCSI performance may be not far from reaching their limits.

Figure 1 below shows an example of SCSI implementation with seven devices.

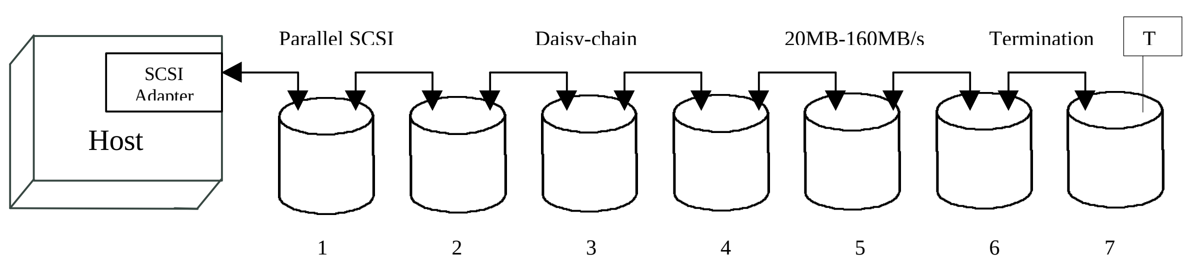

Figure1.Example of SCSI implementation

Fibre Channel

Explosion of needs for high-performance and data intensive network applications have driven the development of Fibre Channel. Fibre Channel is the generic name of an integrated set of standards being developed by the committees accredited by the American National Standards Institute (ANSI). With development started in 1988, Fibre Channel has evolved from a concept technology to a real technology, and is now a mature standard (Approved by ANSI in 1994).

Fibre Channel is an industry standard interconnect and high-performance serial I/O protocol that is media independent and supports simultaneous transfer of many different protocols (SCSI, ATM, and TCP/IP). With a serial interface, data are transferred one bit after the other over a single piece of medium (copper or fiber optic) at the fastest speed allowed by this medium. Because Fibre Channel is serial interface, it is not subject to distance, speed, and scalability restrictions. See Table 2. for Fibre Channel attributes.

Interface	**Maximum Bandwidth (MB/sec)**	**Bus Width (bits)**	**Maximum Bus Length (meters)**		**Maximum Number of devices**
			Copper	Fibre Optic	
Fibre Channel Arbitrated Loop, single loop (FC-AL)	100	16	30	2000-10,000	127
Fibre Channel Arbitrated Loop, dual loop (FC-AL)	200	16	30	2000-10,000	127

Table2.Fibre Channel Attributes

Interests in high-bandwidth, scalability, long-distance connectivity, and reliability are growing more rapidly than ever because interconnects between servers and I/O devices have become a bottleneck. Fibre Channel technology overcomes current I/O and physical limitations, especially in the storage environment. Indeed, Fibre Channel responds to the characteristics of today's demands, but also possesses the features to meet future demands for server consolidation, server clustering, and storage network (SAN, NAS).

Fibre Channel, a gigabit interconnect technology, allows concurrent communications among workstations, servers, data storage systems and other peripherals using different protocols and via multiple topologies. Fibre Channel provides attachment of servers or storage systems (e.g. RAID arrays, disk drives…) across long distance up to 10km with Single-Mode Fiber optic (SMF) enabling floor-to-floor, building-to-building and campus-wide distances. The use of fibre optic also provides extremely low error rates. Furthermore, Fibre Channel integrates both a powerful encoding scheme and a strong cyclic redundancy check (CRC) on each message frame, ensuring data integrity.

In addition to its distance feature, Fibre Channel offers greater performance or bandwidth. The high-bandwidth technology delivers 100MB/s performance with a single Fibre Channel Arbitrated Loop (FC-AL) and 200MB/s when using two loops in fullduplex mode. However, not all systems are designed to take advantage of Fibre Channel and performance of some applications may not be improved because of internal constraints linked to the products themselves.

Another important element of Fibre Channel is its connectivity, its capacity to attached devices or nodes. On a single FC-AL loop up to 127 devices can be attached, and they are visible by simply plugging them in. Furthermore, large subsystems of devices can be added to nodes on expansion modules, and expansion modules can be cascaded to connect far more subsystems. This scalability allows different architectures to be implemented enabling multiple levels of storage management and future growth.

Fibre Channel supports three topologies, which are implemented to meet the specific needs of an application. Fibre Channel nodes each have one or more ports that enable external communication. Each port uses two Fibres, one for outgoing information and the other for incoming information. The pair of Fibres is called a link. All the components that connect ports comprise an interconnect topology. The three topologies are Point-to-Point, Loop (Hub), Switched (Fabric), and are illustrated in figure 2, 3, and 4.

In a Point-to-Point topology, Fibre Channel storage components are connected directly to a host. This is a simple configuration for attaching a single RAID array to a single server or host. Point-to-Point does not require a hub or a loop as only two devices are involved. However, Point-to-Point is not a standard, and does not operate with standard full-speed adapters, storage devices, hubs or switches. Therefore, it is important to know that point-to-point topology is not compatible with the FC-AL industry standard.

Figure 2.Point-to-Point Topology

The Fibre Channel Arbitrated Loop is a serial interface that creates logical point-to-point connections between ports with a minimum of transceivers and without centralized switching function. The bandwidth is shared by all ports on the loop. A single pair of ports on the loop communicates at one time, while the other ports on the loop act as repeaters.

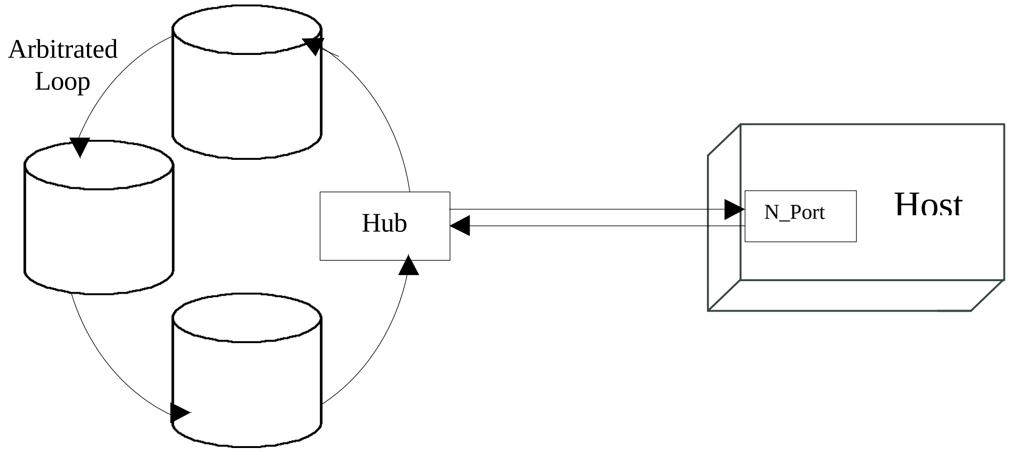

Figure 3. FC-AL with Hub Topology

Fabric refers to the Fibre Channel topology, which connects one device to all of the other devices on the network. A fabric switch allows multiple pairs of nodes to communicate with each other simultaneously. Therefore, as more nodes are added, the aggregate data throughput capacity can increase incrementally. A fabric requires a cross-point switching function and the intelligence to make connections. A pair of transceivers is required to form the link between the attaching port and the port on the switch. Switches and fabrics provide more performance and redundancy for larger systems and environments, and enable large, complex systems.

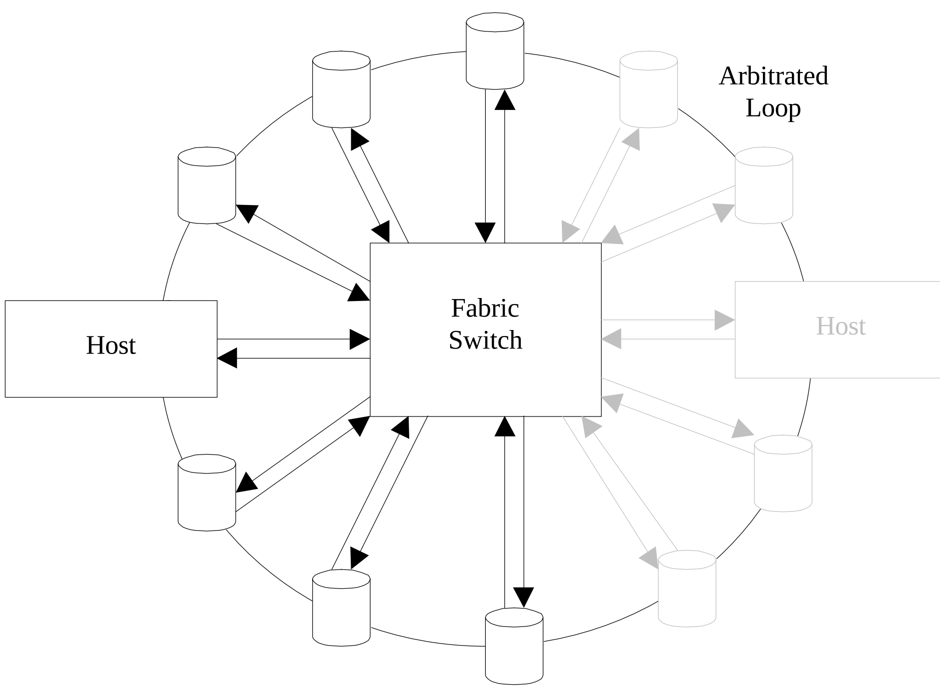

Figure 4 FC-AL with Switch Topology

Implementation of Fibre Channel involves several choices including media type (optical or copper) and topology. Application type, distance concern and cost issue are main factors, which influence decisions. Applications that utilize large bandwidth will benefit the most of the 1.0625Gigabit (Gigabaud) which is about 100MB/s provided by a single FC-AL. Cost issue will be important especially with a switch topology because of the cost of the switch. Future needs, particularly when storage is involved, have to be considered in the decision in order to make investment in Fibre Channel relevant. However, Fibre Channel does not have to be a one step process and could be done step-by-step allowing company to spread out their investments over years.

Why SCSI or Fibre Channel, Advantages and Limits of each?

The discussions around the limits of SCSI and the advantages of Fibre Channel or vice-versa are not ending today, neither tomorrow, but we can answer to the questions "Will SCSI survive or die? Will Fibre Channel dominate?" The answer is that neither standard is going to dominate or die, and the choice will depend on different factors like cost, application… In consequence, SCSI and Fibre Channel both have a foreseeable future and will continue to evolve and cohabit.

Bandwidth-Speed

Allowing for command overhead, an Ultra2 SCSI bus can sustain a data transfer around 77 MB/s before reaching saturation and an Ultra3 SCSI bus around 150MB/s of bandwidth. Similarly, Fibre Channel technology allows a sustain transfer rate of 96MB/s or 192 MB/s. Obviously, Fibre Channel provides more bandwidth than SCSI, +25% between 1 FC-AL and Ultra2, and +28% with 2 FC-AL and Ultra3. However, SCSI could compensate its bandwidth limitation by simply adding more SCSI buses. In fact, a three-bus SCSI system provides more bandwidth than a two-bus Fibre Channel system and at a lower cost. Thus, from a performance perspective, Fibre Channel has a limited advantage over SCSI.

Connectivity-Scalability

There is no question about connectivity or scalability; Fibre Channel delivers a lot more in terms of connectivity or scalability than SCSI. Fibre Channel provides up to 127 nodes on a link whereas SCSI is limited to 16. Furthermore, Fibre Channel does not suffer from termination issues like SCSI. Additionally, cabling and connections with Fibre Channel are a lot easier, and involve less impedance issues and associated data integrity problems. Fibre Channel also provides dual port capability on the devices and allows an alternate path for data. Therefore, if one port is disabled, the other port will provide continued access to data. Since SCSI only allows one port, there is no way to provide a redundant path into a device in SCSI as there is in Fibre Channel. Fibre Channel allows easy component expansion with its true hot plugging for easy addition of new devices. Large subsystems of devices can be attached to nodes on expansion modules, and expansion modules can be cascaded to connect more subsystems.

Distance-Flexibility

Increased transmission distance is another significant advantage of Fibre Channel. With SCSI, the maximum distance between devices is 25 meters whereas Fibre Channel provides greater distance flexibility, up to 10,000 meters. Indeed, Fibre Channel allows separate zones, redundant data centers, remote mirroring, and electronic vaulting. Historically, distance limitations of SCSI have precluded all off-site location for disaster recovery. Fibre Channel enables creation of this modular and scaleable storage pools.

Cost Issues

As with any new technology, Fibre Channel currently has an associated premium price but the concern is to determine its cost effectiveness. Table 3. summarizes extra cost associated with Fibre Channel vs. SCSI.

	SCSI	Fibre Channel
Host Adapter	1	3 to 6
Disk	1	+ $10 per disk
Cabinet	1	1.5 to 4
Cable	1	0.5 to 0.8

Table 3.Cost of SCSI Vs Fibre Channel

As cost go down (because of competition and economies of scale) and requirements for better scalability increase, there will be a shift from SCSI to Fibre Channel for higher end system. However, the use of SCSI will persist for years for smaller systems where scaling, distance and connectivity are not issues. In fact, over the next several years, hybrid solutions will remain a good alternative to enable companies to spread out the cost of the transition. A Fibre Channel connection to a storage subsystem, which drives are attached to a SCSI interface, can give distance, scalability, and cost advantages. These benefit more than balance the increased cost of Fibre Channel.

Summary

Today, the misconception of the demise of SCSI is over for a number of reasons: improvements of SCSI performance, cost of Fibre Channel and SCSI-specific applications. In conclusion, SCSI remains a viable and cost effective technology although Fibre Channel is a best-suited technology for some high-bandwidth applications, distance and cabling ease and server cluster RAID storage. Both technologies are viable in the future. Consequently, decision-makers have to choose with accuracy which technologies will best match their present and future needs.