FIBRE CHANNEL USE IN DATA ACQUISITION SYSTEMS

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ABSTRACT

Since becoming an ANSI standard in 1994, Fibre Channel has matured into a high-speed reliable data communication solution. Fibre Channel uses point-to-point, arbitrated loop, or switched topologies, to provide a wide range of options for data storage and high-speed data transfer applications. Unlike Gigabit Ethernet, Fibre Channel supports protocols such as HIPPI-FP, SCSI and IPI, allowing for greater flexibility when designing systems. However, the wide range of options supported in the Fibre Channel standard can be the source of misunderstanding and incompatibility.

This paper intends to clear up some of the misconceptions about Fibre Channel by presenting the current standard and discussing how Fibre Channel can be used in data acquisition systems. Since these systems often require extremely high throughput for routing data, as well as high speed data storage to long term media, solutions are not often cut and dry.

This paper will give examples of how using different layers of the Fibre Channel protocol will meet the needs of today's data acquisition requirements. It provides a brief overview of Fibre Channel technology and identifies the different types of Fibre Channel products available. It provides examples of how commercial-off-the-shelf (COTS) products can be used to build data acquisition and storage systems requiring throughputs of up to 90 Mbytes per second on a single fiber. Additionally, it shows how multiple fibers can be used to achieve much higher data rates.

KEY WORDS

Fibre Channel, Data Acquisition, Bulk Storage

INTRODUCTION

Today's data acquisition systems can require data rates between 50 and 2000 Mbytes/sec. In the past, data acquisition systems that met these requirements often used custom equipment for transferring data between chassis' or to long term storage devices. These custom products were often application specific and difficult to adapt to other applications. With the move towards COTS, system integrators are looking for a more flexible, yet standardized, means of transferring this data. Fibre Channel, among others, is providing such technology. Fibre Channel is, however, a complicated and often misunderstood medium. Data acquisition systems are moving towards using Fibre Channel due to its versatility, however, in order to realize the maximum benefit the system designer must be careful to choose the most appropriate level of service and protocol.

This paper will discuss how Fibre Channel is being used in today's data acquisition systems. It will provide a brief overview of Fibre Channel technology, characteristics of available equipment, and considerations that should be taken in designing such systems.

FIBRE CHANNEL TECHNOLOGY REVIEW

The Fibre Channel physical specification (FC-PH) was released as ANSI standard X.3230-1994 in 1994. The specification defines a technology capable of transfer rates up to 1.0625 Gbps, with payload rates of up to 100 Mbytes/sec. The physical media is commercially available in both copper and optical fiber. With long wavelength light sources and single-mode fiber, transmission distances of up to 10 km can be achieved.

There are three classes of service available for Fibre Channel:

- Class 1:Dedicated Connection – Data transferred from source to destination is guaranteed to be received in order. All transfers are acknowledged.
- Class 2:Connectionless – Data transferred from over Fibre Channel is sent in a switched packet format. Every packet (frame) received must be acknowledged.
- Class 3:Datagram, Connectionless – Data is transferred in a switched packet format, but all packets (frames) are assumed delivered correctly. There are no acknowledgement packets.

Depending on the application, each class of service is useful. Typically, Class 3 is most common. An intermixed class can be used that allows Class 1 service with interleaved Class 2/3 frames.

Figure 1 - Fibre Channel Layers shows the various protocol layers of Fibre Channel specification. Chip level Fibre Channel controllers are commercially available and handle

layers up to FC-2 (with some upper level protocol support). Software or other hardware is responsible for the upper levels of the Fibre Channel specification.

FC-4	Upper Level Protocols (SCSI 3, HIPPI, IP, IPI, ATM, FXLP, etc.)
FC-3	Login Management and Error Recovery
FC-2	Sequence Management and Flow Control
FC-1	Frame Manager (Loop, Encode/Decode, CRC, Credit Management)
FC-0	Physical Characteristics (Transmitters, Receivers, Connectors, etc.)

Figure 1 - Fibre Channel Layers

As shown in Figure 1, Fibre Channel offers many upper level protocol options that can be used to interconnect two or more systems. Among the most popular standard protocols followed are:

- SCSI 3: Used in most, if not all bulk storage applications.
- TCP/IP: Used to interconnect Fibre Channel in standard network environments.
- HIPPI: Used for high-speed (up to 100 Mbytes per second) applications.

Systran Corp developed another protocol, Fibre Channel Light Weight Protocol (FXLP). This protocol is being used in applications that require low latency.

One of the major benefits of Fibre Channel is the ability to have multiple simultaneous protocols exist on the same fiber. An example of this is a loop containing a Fibre Channel RAID, a sensor, and a signal processor. While the sensor may send data to the signal processor over Fibre Channel using FXLP or some other low latency protocol, the same hardware in the signal processor could communicate via SCSI 3 to the RAID to store the acquired data.

As mentioned earlier, flexibility is a significant reason why data acquisition systems are leaning towards Fibre Channel. Different acquisition systems require different networked topologies. Fibre Channel allows the systems integrator to choose from one of three types of topologies:

- Point-to-Point – A direct physical connection between two Fibre Channel ports. This provides dedicated bandwidth between two nodes.

- Arbitrated Loop – Fiber output of each node is daisy chained to input of adjacent node. This allows many nodes to be connected, all of them sharing the same 100 Mbyte per second bandwidth.
- Switched Fabric – Capable of sustaining multiple non-blocking point to point connections. This provides scalable bandwidth. It supports multiple, concurrent 100 Mbytes per second connections.

Arbitrated loop (known as FC-AL) is the most common method of connecting multiple (more than two) Fibre Channel components. In this topology, data is passed around the loop from node to node until it reaches its assigned destination. One drawback of arbitrated loop topologies is that a single failed node can block the entire network. This can be overcome by inserting a network transparent switch (Figure 2) between all nodes of the loop. Use of the switch allows for recovery if a node becomes unavailable. In data acquisition systems using multiple processing elements connected to sensors over Fibre Channel, transparent switches allow nodes to be taken offline without inhibiting the performance of the rest of the system.

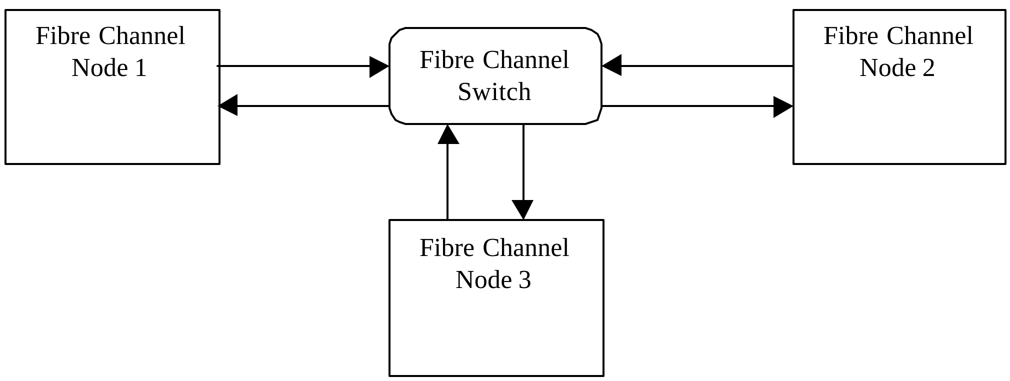
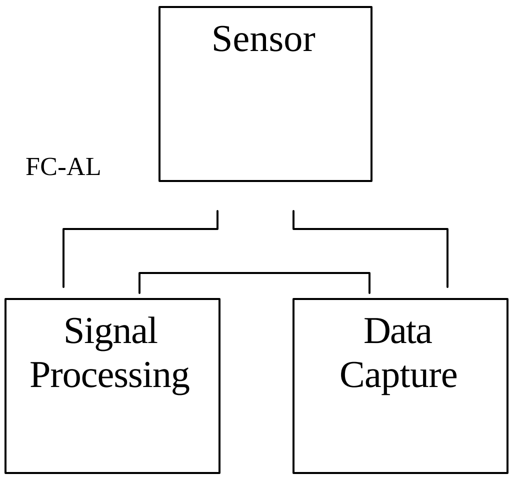


Figure 2 – Using a Fibre Channel Transparent Switch

FIBRE CHANNEL APPLICATIONS IN DATA ACQUISITION SYSTEMS

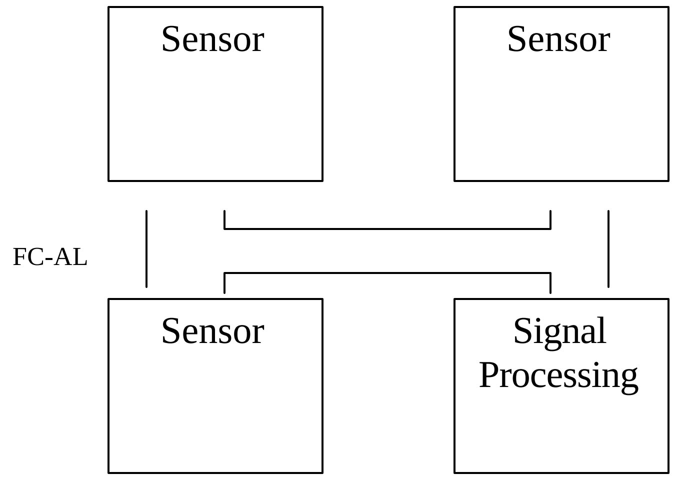
Fibre Channel has found a place in today's high-speed data acquisitions systems. Typically there are two types of systems where Fibre Channel is used: sensor to signal processing applications and long term data storage applications. Often these applications are used together in the same system, with each requiring a different type of Fibre Channel connections.

Figures 3 and 4 characterize the different way Fibre Channel is used in sensor to signal processor environments. Choosing the appropriate protocol and product is dependent on the particular topology required. In the case of Figure 3, only one open Fibre Channel exchange will exist at any one instance. This is the simplest case, requiring a Fibre Channel interface capable of maintaining only one line of communication. If there are multiple sensors transmitting data to one or more receivers (as in Figure 4) the receiving Fibre Channel hardware needs to have the ability to accept interleaved data sequences correctly or application level software needs to manage use of the Fibre Channel.



Single Sensor to Multiple Receivers

Figure 3



Multiple Sensors to Single Source

Figure 4

The Fibre Channel hardware required to perform both topologies is significantly different. With one sensor and multiple receivers, broadcast can be used to send information to all receivers at once. Even when communicating with different receivers, the data transfer is similar. The only requirements on the receive hardware is that the data can be received at the rate required, within Fibre Channel limits. On the other hand, when multiple sources are sending data to a single sink, the receiving circuitry must have the ability to handle the interleaved sequences properly. Often this means putting incoming data into random access memory, as opposed to storing it in a FIFO device. One thing common to both types of sensor applications is high throughput (up to 100Mbytes/sec) and low latency/overhead. Regardless of the topology, it is desirable to use low latency protocols to transfer data in these environments. This is the primary difference between these applications and Fibre Channel to storage device applications.

Figure 5 shows a block diagram of a Fibre Channel connection between a signal processor and RAID. It demonstrates a multiple input signal processor, capable of taking in data at 90 Mbytes per second per input channel, while simultaneously storing the data to RAID. The incoming data is sent across RACEway to the signal processor, where it is processed and buffered. Each Fibre Channel RAID interface can then read the raw buffered data from the signal processor across the RACEway and write it onto multiple RAIDs. Today’s RAID have the capability of holding 145 Gbytes of data each. Most, if not all, Fibre Channel RAIDs available today use the SCSI 3 protocol as the ULP over the Fibre Channel physical layer.

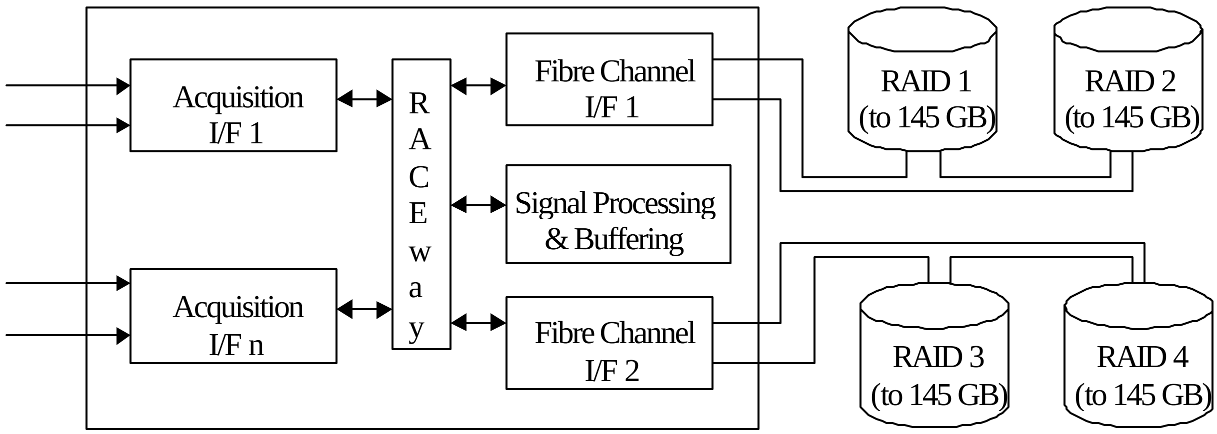


Figure 5 Data Acquisition to RAID via RACEway

CHARACTERISTICS OF COMMERCIALLY AVAILABLE EQUIPMENT

Chip Level Controllers

The chip level controller used on a Fibre Channel interface card often defines the interoperability and capability of Fibre Channel hardware. Generally, there are two types of commercially available chip level controllers for Fibre Channel. There are highly integrated controllers that do significant Fibre Channel protocol handling in hardware as well as those that perform the bare minimum necessary to meet Fibre Channel specifications. Each type of controller has its place in the hardware required for today's data acquisition systems.

The Hewlett Packard Tachyon Fibre Channel controller is an example of a highly integrated controller capable of providing all three classes of Fibre Channel operation. It also integrates low-level Fibre Channel protocols (FC-0 through FC-2) plus some hardware assisted upper level protocol support (particularly SCSI 3). If controlled by an intelligent resource, the Tachyon is capable of sustaining multiple simultaneous exchanges. The Tachyon controller is used in 80 % of Fibre Channel equipment, including most RAIDs.

Fibre Channel controllers are also available that are easier to integrate into special purpose hardware. Typically, these controllers provide only FC-0 and FC-1 support. It is up to the interface board and software to provide any other levels of Fibre Channel the application requires. The advantage of these types of controllers is the ease of integration into sensor hardware. In data acquisition applications that require nothing more than receiving data addressed to the system and passing on data addressed elsewhere, these types of controllers make ideal solutions.

The key here is that it is easy to put a lower level Fibre Channel controller into a sensor, but care should be taken in designing the overall data acquisition system. Typically, low level controllers allow data to be transferred over a fiber (or copper) connection, without sequence management and flow control. It would be difficult at best for that sensor to communicate directly with a RAID or other device containing a more integrated fiber channel controller, such as the Tachyon. On the other hand, while putting a highly integrated controller on a sensor would give more hardware compatibility, more software would be required on the sensor to control the upper level protocols and more complex chipset.

Board Level Controllers

Three are three major types of board level Fibre Channel Controllers available today:

- Non-buffered board level products – These products receive data from the Fibre Channel interface and immediately send the data to the host interface or system bus memory storage. The interface board bridges the Tachyon or other controller directly to the host bus interface. This limits the performance of the system to the loading on the system bus.
- RAM-buffered board level products – These products contain some amount of random access memory on board. Typically, throughput is limited to approximately half the RAM bandwidth (40-50 Mbytes per second). This type of interface allows for concurrent interleaved exchanges and software retransmission, with the proper software implementation.
- FIFO-buffered board level products – Unlike the previous example, these board level products use FIFOs to buffer data input from the Fibre Channel interface. They provide a higher maximum transfer rate than the RAM-buffered boards, but because of their first in first out nature do not support interleaved exchanges or frame retransmission.

Data acquisition systems that require multiple transmitting sensors to a single receiving signal processor require either RAM-buffered products or application level protocols that allow multiple interleaved sequences. As mentioned earlier, the overhead to sort the incoming sequences results in a lower achievable data rate. For the single sensor to multiple receiver scenarios, FIFO-buffering can be used to provide the maximum data rate possible.

CONCLUSIONS

Fibre Channel is quickly gaining momentum in the data acquisition world, for both sensor to signal processor and bulk storage applications. The ability for Fibre Channel to be tailored to a particular application allows system developers to choose the most appropriate means to transfer their data. If its SCSI 3 or FXLP, arbitrated loop or point-to-point, and datagram or dedicated connection, Fibre Channel can provide a solution to most data acquisition needs. By carefully designing data acquisition systems, system designers will be able to avoid some of the pitfalls associated with the different types of Fibre Channel hardware available today.