Fibre Channel and Serial FPDP in I/O Applications

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Overview

Fibre Channel and Serial FPDP, known variously as Simplex Link™ and FibreXtreme® (trademarks of Systran™ Corporation), are often candidate technologies for use in high-speed data-acquisition systems. While both use the same underlying physical and link layer technology, each has its own unique characteristics so their compatibility is limited.

This white paper explains the relationship between Fibre Channel and Serial FPDP. It compares and contrasts the two and provides guidance as to the appropriate technology choice based on the specific requirements of high-speed data-acquisition systems.

Fibre Channel

Fibre Channel (FC), embodied in a family of ANSI specifications starting with FC-PH (ANSI X3.230), is a generalized transport mechanism for various upper-level protocols such as SCSI and IP. The base specification defines a five-layer hierarchy as listed below.

0. FC-0: Physical layer
1 FC-1: Serial data encoding
2. FC-2: Framing and signaling
3. FC-3: Common port services
4. FC-4: Upper Layer Protocol (ULP) mappings

FC-PH (ANSI X3.230) defines FC-0, FC-1 and FC-2. Part of this definition includes myriad basic and extended link services and associated exchanges. FC-PH currently specifies link speeds of 1.0625 Gbaud or 2.125 Gbaud. Specifications are in development for 10 Gbaud with a road map indicating a release due shortly.

The FC-3 layer includes common services for multiple Fibre Channel ports attached to a single node. Features including multicast, striping, and hunt groups are included in this layer, but the specification is still under development.

There are separate FC-4 specifications for each of the Upper Layer Protocols (ULPs) although certain information about specific ULPs is called out in FC-PH (mainly type codes). By far the most common ULP is SCSI over Fibre Channel (also known as "SCSI Fibre Channel Protocol" – FCP). Other, less common ULPs include HIPPI (FC-FP) and link encapsulation for protocols such as TCP/IP (FC-LE).

An important feature of Fibre Channel is that multiple ULPs can coexist on the fibre simultaneously. For example, raw sensor data can be collected using a lightweight protocol such as Systran's FXLP while processed data is simultaneously sent to a RAID using FCP on the same arbitrated loop.

A related specification, FC-AL (ANSI X3.272), defines the Fibre Channel arbitrated loop topology, and is a non-conflicting enhancement to FC-PH. It fits roughly between FC-1 and FC-2. Fibre Channel switches and fabrics are specified in FC-SW and FC-FG, respectively. Loops, switches, and fabrics are mentioned, because most devices that are considered "true Fibre Channel" devices can be used in any of these environments.

Fibre Channel topologies include point-to-point, arbitrated loop, and switch fabric. Arbitrated loop, the most common topology, can support up to 127 devices which share the loop. Arbitration is for the entire loop – that is, the loop segments are not independently used – thereby limiting the aggregate bandwidth to that of an individual link. Fabrics are switches that use in-band signaling to establish connections between communicating nodes. The aggregate bandwidth of a fabric-connected system can be many times the bandwidth of a single link. When using arbitrated loops and fabrics, Fibre Channel operates as a network with individual nodes randomly addressing other nodes.

Serial FPDP

Serial FPDP, originally developed by Systran Corporation in its Simplex Link and FibreXtreme products, is defined in the VITA 17.1 specification. It is a serial encapsulation of the Front Panel Data Port (FPDP) protocol (VITA 17).

Serial FPDP uses the physical interfaces and data encoding in Fibre Channel's FC-0 and FC-1, and it uses many of the same framing concepts and ordered sets of FC-2. However, this is where the similarity ends. The actual framing structure of Serial FPDP is not generally compatible with FC-PH, and none of the link service exchanges apply. While Serial FPDP is layered on FC-0, FC-1 and some of FC-2, it is not defined as an FC-4 ULP by Fibre Channel.

Link speeds of 1.0625 Gbaud and 2.5 Gbaud are specified for Serial FPDP. The former speed is standard 1 Gbaud Fibre Channel, while the latter is twice the Gigabit Ethernet rate.

Serial FPDP is basically a point-to-point, simplex protocol designed to transfer data from a sender to a receiver. The connection between a sender and a receiver is established and remains in effect for

relatively lengthy periods of time. Establishing a new connection requires external communication and cooperation among endpoints.

While its native mode is point-to-point, other Serial FPDP topologies are supported. Chained and single master (sender) ring topologies are used for broadcast from a single sender to multiple receivers. The multiple master ring topology allows for multiple sender/receiver sets as long as a given sender has a direct path to its receivers with no intervening senders.

Serial FPDP versus Fibre Channel

The current maximum rate specification for Fibre Channel is 2 Gbaud, whereas Serial FPDP works up to 2.5 Gbaud. Undoubtedly, both standards will evolve, but since both use the same underlying technology, wide differences will not be likely. For consistency, subsequent comparisons are made using the mature 1 Gbaud standard. It is nonetheless important to consider that Serial FPDP currently enjoys the higher link-speed position.

Serial FPDP substantially reduces latency compared to true Fibre Channel devices. It also slightly improves link efficiency. The stripped down and modified protocol encapsulates the data and the FPDP control signals within the same frames on the fibre, and allows for simplified generation and processing of these frames. As a result, Serial FPDP can be used on 1 Gbaud links to transfer data at up to 105 MB/s with reported latencies below ten microseconds.

It is worthwhile to consider how this latency is measured, and whether that measurement is sensible in a particular application. The sub-ten microsecond number is measured from the fetch of a data element from the sender's memory to the delivery of that data element at the receiver's memory. However, additional time may also be required to initiate the block transfer at the sender and recognize its reception at the receiver. The size of the DMA block could then become the limiting factor in determining observed latency.

Still, the low-overhead of the Serial FPDP protocol will generally yield smaller latencies than Fibre Channel. Most ULPs on Fibre Channel involve more overhead and handshaking than Serial FPDP. Latencies using Fibre Channel would be measured in the tens to hundreds of microseconds for equivalent situations.

While the latency of Serial FPDP is lower than that of Fibre Channel, the throughput is only marginally higher. On a 1 Gbaud fibre, the theoretical limit of Serial FPDP is 105 MB/s compared the 103 MB/s of Fibre Channel. Sustained transfer rates over 102 MB/s to a RAID, including all SCSI overheads, have been demonstrated using Fibre Channel.

Fibre Channel is complex and requires a substantial amount of embedded intelligence to implement and control. By contrast, Serial FPDP is easily implemented in an FPGA and can be controlled with relatively simple state machines.

In systems with multiple devices, Serial FPDP essentially provides static and long-lasting connections between devices. By contrast, Fibre Channel connectivity is established dynamically using simple addressing.

Data broadcasting is a Serial FPDP feature that can provide a significant improvement in effective bandwidth. While broadcast mode for Fibre Channel on an arbitrated loop is defined, it is not widely implemented. Also, under certain specialized conditions, Serial FPDP's multiple master ring topology allows multiple, non-interfering broadcast sets which can further increase the system's effective bandwidth.

Fibre Channel has an advantage in storage applications including Storage Area Networks (SANs). Storage devices such as RAIDs and tape drives are widely available with Fibre Channel interfaces but do not exist for Serial FPDP. Similarly, host bus adapters (HBA) can be obtained from many manufacturers in a variety of form factors, while the selection of Serial FPDP HBAs is very limited.

Compatibility

Due to the differences between Fibre Channel and Serial FPDP framing, Serial FPDP devices can only be connected to other Serial FPDP devices. Serial FPDP cannot be run on a Fibre Channel arbitrated loop or fabric.

Serial FPDP is, however, compatible with some Fibre Channel switches that use out-of-band switching control. Many Fibre Channel analyzers cannot decode the framing structure of Serial FPDP.

The inability of Serial FPDP to co-exist with other protocols and devices on the same fibre is arguably its primary drawback. Additionally, Serial FPDP does not meet the FC-PH Fiber Channel standard up through level 2. By this somewhat circular definition, Serial FPDP devices are not true Fibre Channel devices. However, they benefit from much of the Fibre Channel technology and availability of components.

Which One to Use?

Often a system architect is faced with deciding which one to use – Serial FPDP or a true Fibre Channel device. A system can, of course, use both technologies, but it must use separate cabling. The table below lists some of the relevant characteristics of Serial FPDP versus true Fibre Channel.

	True Fibre Channel	Serial FPDP
Fastest Link Specified	2 Gbaud	2.5 Gbaud
Max Data Rate (1Gbaud)	103 MB/s	105 MB/s
1.0625 Gbaud	103.3 MB/s	105 MB/s
2.125 Gbaud	206.6 MB/s	210 MB/s
2.5 Gbaud	N/A	247 MB/s
Latency	100s of microcesonds	<10s microcesonds
Broadcast	No	Yes
Availability Wide	Wide	Narrow
Uniform Node Access Yes	Yes	No
Multi-protocol	Yes	No
Easily Reconfigured	Yes	No
Simplicity of Interface	More Complex	Less Complex
Software Complexity	More Complex	Less Complex
Minimum Controller	Microprocessor	State Machine

Serial FPDP is, essentially, an FPDP replacement without the distance limitations and with simpler cabling. It is often used for transmitting data from a sensor to a processor. Its strengths are that it has lower latency, it is easier to achieve its maximum rate, and it is easier to implement in hardware than true Fibre Channel.
For a custom board design, Serial FPDP is easier to implement and requires much less software overhead than true Fibre Channel. In fact, in a simple dedicated sensor application, it is possible to control Serial FPDP with a state machine instead of a processor.

Ease and efficiency of configuring the sensor-to-processor links may also be a consideration.
Fibre Channel, with its network-like architecture, accommodates dynamic interconnection schemes. Basically, any node on an arbitrated loop or a fabric can communicate with any other node in either direction at any time, with no specialized setup or out-of-band signaling. Serial FPDP, on the other hand, requires more setup and subsystem cooperation to reconfigure. The subsystem cooperation often implies an additional control path for complex systems.

If the same data needs to be sent to multiple destinations, broadcasting may be desired. Serial FPDP supports broadcast mode while most Fibre Channel devices do not. Figure 1 shows a typical system using serial FPDP to broadcast data from a sensor to both a processing subsystem and a recording subsystem. With the system shown in Figure 1, Ethernet is used as an out-of-band path for configuring the system, such as which device is the one transmitting. If the role of each device on the Serial FPDP ring is fixed, the Ethernet connection is not necessary.

Another consideration is whether there is a need for true Fibre Channel anywhere else in the system. For example, a Fibre Channel RAID, JBOD (Just a Bunch of Disks) or tape drive may be desirable for storage. Also, Fibre Channel can be a good candidate for getting data into a workstation either directly from the acquisition source or from the RAID. It is also possible to use Fibre Channel as a status and control interface to the system rather than adding an additional path (Ethernet in Figure 1).

If there is a requirement for a true Fibre Channel device in the system, the next question is whether it could share the fibre with the sensor subsystem. Specifically, do the data flows enable the bandwidth of the fibre to be shared between the sensor and the storage device? The example in Figure 2 shows a system that uses only Fibre Channel to make the connections between the sensor subsystem, the processing

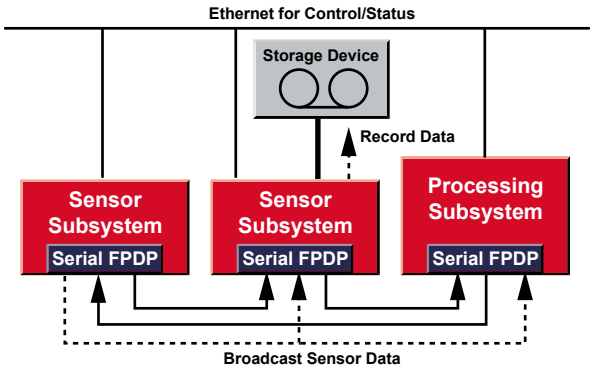

Figure 1 Application using Serial FPDP for the sensor data. Serial FPDP copy mode is used to efficiently broadcast data from the sensor to both the recording and processing subsystems. An additional connection (shown here as Ethernet) must be used for unit synchronization and control.

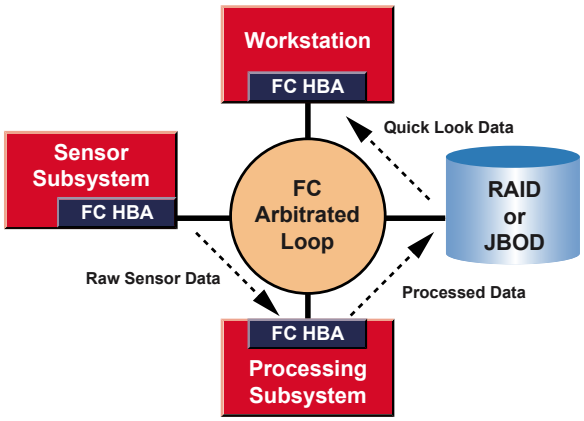

Figure 2 Application using all Fibre Channel connections between subsystems. In this example, three simultaneous data flows are occurring. Since the arbitrated loop bandwidth is shared by all devices, the combined rate of all data flows cannot exceed the 1 Gb/s limit of the fibre.

subsystem, a RAID, and a workstation. All of these devices are connected on an arbitrated loop, so they must share the bandwidth of the fibre.

The data flows in Figure 2 are depicted as simultaneous, but they are actually time-multiplexed on the loop using low-level protocols embedded in the Fibre Channel HBAs. The arbitration protocol is orderly and efficient so that almost all of the bandwidth of the loop is usable. Each subsystem simply addresses Fibre Channel devices much like devices on a multi-master bus.

Assuming that the aggregate bandwidth can be accommodated by the loop, the next consideration is whether the latency requirements can be met. Latencies below ten microseconds are possible with Serial FPDP, while typical latencies for Fibre Channel would be measured in tens to hundreds of microseconds depending on the FC-4 protocol and exchange sizes used. The time-multiplexing of the loop may also contribute to the worst-case latency and require sufficient buffering to accommodate times, up to several milliseconds, when the loop is in use for a different data flow.

Fibre Channel and Serial FPDP can be used in the same system if they use separate cabling. Figure 3 shows a system that employs both technologies. Inexpensive JBODs and RAIDs and the wide availability of Fibre Channel HBAs make Fibre Channel an excellent choice for connection to the workstation and storage device. On the other hand, the low latency and broadcast capability of Serial FPDP recommend it for the sensor data flows.

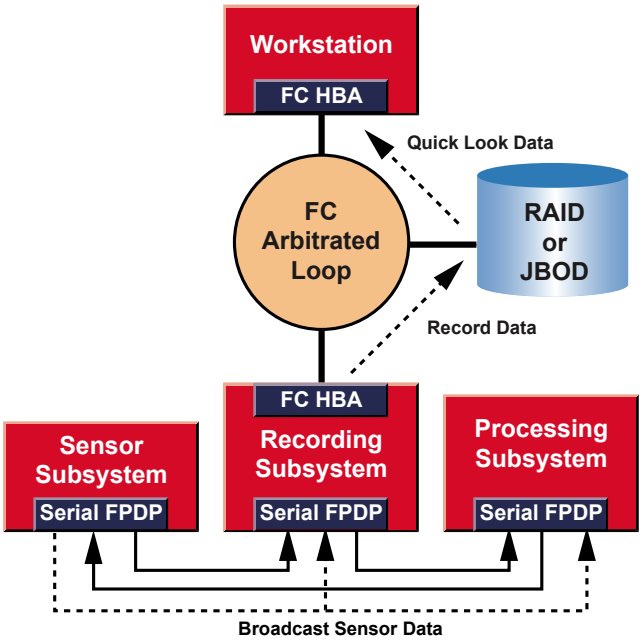

Figure 3 Application using both Serial FPDP and Fibre Channel. Serial FPDP, with its low latency and broadcast mode, is used for the sensor data. Fibre Channel provides the connection to a standard RAID, which can also be easily accessed by the workstation.

Summary

Serial FPDP and Fibre Channel each have its strengths and weaknesses. Serial FPDP is not compatible with Fibre Channel, in the sense that Serial FPDP cannot coexist on the same fibre with other Fibre Channel protocols. A system can, of course, contain both technologies. Architecture, performance, and cost considerations must be weighed to choose the appropriate combination in a given system.

NOTE: The Mercury RACE++® Series MYRIAD™-4030 I/O carrier can be equipped with Serial FPDP and/or Fibre Channel PMC interfaces. The RACE++ Series MYRIAD-4010 I/O carrier accommodates up to two J-Style Fibre Channel interfaces. Additionally, Mercury's RINOJ daughtercard supports Serial FPDP and can be used on MCJ6 and MCJ9 motherboards. Mercury also provides sensor I/O XMC modules for the PowerStream® 7000 system.

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