Payoff
Fibre Channel technology combines the attributes of a channel and a network medium. This article explains how Fibre Channel works with existing interfaces, its use as a high-speed backbone in a LAN, and its messaging structure. Three topologies with guidelines for use are also explained.

Introduction
Fibre Channel is an Open Systems Interconnection (OSI) technology that provides flexibility, application layer friendliness, data integrity, and high availability. Fibre Channel technology provides a seamless application and systems interface without the need for the computer system to support the intricacies, buffering, and management of high-performance information interconnection features.

Fibre Channel Layers
Fibre Channel's Open Systems Interconnection-style layering structure is based on practical separation of the functional layers (see Exhibit 1). Fibre Channel layers include:

- **FC-0.** This is the lowest level of the Fibre Channel (FC) physical standard, covering the physical characteristics of the interface and media.

- **FC-1.** This is the middle level of the FC physical standard. It defines the 8-bit to 10-bit encoding/decoding and transmission protocol.

- **FC-2.** This is the highest level of FC physical standard, defining the rules for signaling protocol and describing transfer of frames, sequences, and exchanges.

- **FC-3.** This is the hierarchical level in the Fibre Channel standard that provides common services. Layer FC-3 is not currently used but is available for future applications, such as disk striping (i.e., multiplexing data over multiple disk drives to improve performance) or data management.

- **FC-4.** This is the hierarchical level in the Fibre Channel standard that specifies the mapping of upper layer protocols to levels below.
In contrast to 802.x transport technologies that include a physical layer that is media connection only and a medium access control (MAC) layer that is a combination of high-speed and low-speed functions, Fibre Channel offers a more practical approach by providing clean separations.

There are no sublayer physical definitions of the layers. A clean interface can be made to computer systems as well as to important peripherals such as mass storage, media storage, medical devices, process equipment, data gathering devices (e.g., real-time sensors), and other systems. The upper layer protocol is usually the systems bus or processor I/O function. This arrangement allows easy reuse of systems software drivers with a minimal update to handle the speed of Fibre Channel, which can range up to 100M bps using optical fiber. Functionally, the information form and structure look the same. Specifically, current FC-4 layers address SCSI, Intelligent Peripheral Interface 3 (IPI-3), High-Performance Parallel Interface (HIPPI), block multiplexer (MUX), Enterprise Systems Connection (ESCON), and traditional TCP/IP.

Future applications may use a streamlined form of Fibre Channel that provides tighter coupling between the Fibre Channel I/O and the native bus of the computer/processor. The technology is still developing. Clustering protocols are being developed with Direct Memory Access- to-direct memory access connections. The protocols also offer the reliability of TCP/IP and less than 25 microsecond latency, which is much better than any other serialized system with the distance reach of Fibre Channel. This level of latency is useful in distributed systems, but not in very closely coupled systems such as backplane-connected processors.

**Channel Networking**

Fibre Channel provides links to other LAN technologies by means of straightforward bridging/routing methodologies. This combination of channel and network connectivity is called [channel networking](#) and is unique to Fibre Channel.

A Fibre Channel connection may support one or more of the defined sets of application layer (FC-4s). Fibre Channel implementations may be very simple—as in only serial SCSI—or very complex, as for multiple FC-4 support. Also, the link may support one or more transmission rates.

**Chip Coding**

A combination of hardware and firmware achieves the management, link control, buffering, and feature set implementation of layers FC-2, 3, and 4. Single and multiple chip implementations are available. The complexity of this adapter board hardware depends on how many FC-4s are supported and the range of feature sets supported. Whether implementation is as a set of chips (i.e., microcontroller, memory, firmware) or a single chip, the developer can use readily available complimentary metal oxide semiconductor (CMOS) processes.

The encode/decode function (FC-1) is the interface between the parallel process and the serial process. The 8-bit to 10-bit encoding provides a balanced set of 10 bits derived from a transmitted set of bits. The conversion provides a balanced set of bits in which there is only one more 1 than 0 for each set of 10 bits. Also, there are at most five 1s or 0s sequentially between each transition from 1 to 0 or vice versa. This coding has made it very easy for chip manufacturers to build serialize and deserializer chips and hardware. In addition, all single-bit errors in a 10-bit segment are detectable.
Fibre Channel uses the 8-bit/10-bit methodology because it is easy to implement and provides an extremely balanced serial data stream for all possible data and idle inputs. The guaranteed transitions in the 8-bit/10-bit coding structure provide a multiplexed serial stream from which it is very easy to recover timing. The balanced serial data stream also reduces electromagnetic and radio frequency interference problems.

The output of the FC-1 layer is a parallel 10-bit signal. Some implementations have this layer on the physical interface chip, but most combine this functionality with the CMOS in FC-2 chips. The higher rates are in the extensions of the Fibre Channel standard; 2G bps and 4G bps are already approved for FC physical layer 2.

**Physical, Behavioral, and Logical Subsets**

The classification into physical, logical, and behavioral subsets is useful for the development of interoperability profiles. Because of the range and complexity of the Fibre Channel standard, profiles that define the physical, logical, and behavioral choices for a specific market or application are needed. Some of the first were defined and published by the Fibre Channel Systems Initiative (FCSI) and its participants (Hewlett-Packard, IBM, and Sun Microsystems) and provide the baseline for interoperable implementations by almost all of today’s hardware for serial SCSI and TCP/IP. FCSI’s goal was to create an open systems supply of interoperable pieceparts and systems.

**Message Structure Definition**

In addition, Fibre Channel defines message structure to allow disassembly and reassembly of messages from the application layer of the transmitting side to the same level at the receiving side. These are called Fibre Channel exchanges, sequences, and frames.

**Exchanges**

An exchange refers to an application layers functional communication between users. Examples are a SCSI connection or a TCP/IP session. Several exchanges can be active simultaneously.

**Sequences**

In Fibre Channel lexicon, a sequence is a related set of frames (one or more) within the context of a specific exchange. Sometimes a sequence is called the Fibre Channel information unit (though not specifically defined by the standard).

**Frame**

A frame is a set of bytes containing control (i.e., routing) and data elements. A frame is the atomic unit in Fibre Channel. Frame overhead is a fixed 36 bytes. Frames are variable from 36 bytes (control information only) to 2,112 bytes long, which allows it to be very efficient for normal-size exchanges between computers as well as to and from mass storage connections. Exhibit 2 illustrates framing, message assembly, and message disassembly.

**Fibre Channel Information Transfer**

Fibre Channel further defines classes of messages that encompass both circuit connection (class 1) and packet connection (classes 2, 3, 4). Class 2 guarantees delivery and acknowledgment, a unique feature in packetized protocol technologies that improves transfer efficiency because:
The receiver does not need to guess about delivery.

Packets cannot be dropped without notification to the sender; the receiver sends back an acknowledgment indicating that the data has been received and whether or not it has been corrupted (i.e., a CRC Check).

Many small-scale implementations use class 3 (i.e., packetized datagram-unreliable) because it is simpler to implement and relatively reliable.

Scalability and Guidelines for Use

Forms of Fibre Channel connection include point-to-point, arbitrated loop, and switched fabric (see Exhibit 3). Users should select the connection that fits their application without device-cost impact. Topologies are designed to be interconnectable and upgradable.

Fibre Channel Topologies

Point-to-Point Connections
Point-to-point links provide a dedicated high-bandwidth connection, such as the one from a disk array to a server. Some forms provide high availability, fault tolerant access for two-server/two-disk-array applications.

Fibre Channel Fabrics
In the switched fabric topology, traffic between Fibre Channel ports passes through an intermediary switch called a fabric that combines cross-bar and packet-switching capabilities. Multiple switches can be linked together to form larger fabrics.

Like other switched media (e.g. Fast Ethernet switching hubs or asynchronous transfer mode [ATM] switches), capacity in switched fabric topologies is scalable. New switch modules are added to connect additional devices and the aggregate throughput increases to accommodate the increased load.

Fibre Channel fabrics provide multicast services without requiring external frame replication servers, although the size of a multicast packet is limited to the maximum frame size of the fabric (generally 2K bytes). Available fabrics support datagram, acknowledged connectionless, and connection-oriented service classes. In the future, some fabrics will support a virtual circuit-oriented class of service, in which multiple circuits with guaranteed bandwidth can be established by a single port.

Arbitrated Loop
In the arbitrated loop topology, up to 126 nodes can be connected in a shared-media topology. Instead of a circulating token or a collision sense mechanism, a simple arbitration mechanism ensures fairness. Star topologies with passive hubs provide robustness; some hub ports may be equipped with a loop bypass circuit to ensure continued loop operation if the port is offline.
Simultaneous Multiplexed Connections

Current implementations use TwinAxcess operating at a gigabit, which has ample capacity for interconnecting disk drives that can source on the average less than 20M bytes or network connections with 10M bps and a certain number of 100M-bps LANs (Ethernet).

Low cost is the primary advantage of the arbitrated loop topology. Only half the number of transceivers are required compared with fabric connections, and no switch is required. However, because bandwidth is shared among all nodes on an individual loop, the number of devices will be limited if many have high-traffic requirements.

Fibre Channel Application Interconnection

Fibre Channel can be viewed as an application-to-application connection using a common adapter port, such as a workstation, PC, storage array, disk drive, or any other appropriate peripheral (this port is known as the N-Port in Fibre Channel lexicon) and a common interconnection technology (i.e., point-to-point, loop, or switched). Exhibit 4 illustrates simultaneous multiplexed connections among applications using Fibre Channel.

Many applications can benefit from the economies of scale of other applications, with the incremental costs being small for both the hardware and software elements. For little additional complexity, a connection can be both serial SCSI and TCP/IP. Examples include multiple video connections (being investigated by digital video and digital movie studios), clustering and disk file access, and interactive medical applications that require streaming of data from an imaging device (e.g., MRI) and simultaneously sending the data via TCP/IP to a doctor's office in the same facility.

Conclusion

Because of its unique architecture, Fibre Channel can offer the high-performance, low-cost connection required by bandwidth-intensive applications. By combining the attributes of a channel and a network, Fibre Channel enables data transfer rates that are up to 250 times faster than many network protocols. Now that computers are faster and better able to handle large amounts of data, a network interconnection is needed that can handle higher speeds. Fibre Channel is emerging as the information connection technology that enables reliability and performance at record speeds.

Author Biographies

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**Key:**

- **SCSI**: Small Computer Systems Interface
- **IPI-3**: Intelligent Peripheral Interface 3
- **HIPPI**: High Performance Parallel Interface
- **ESCON**: Enterprise System Connection
- **IP**: Internet Protocol

**Note:**
Rates are all full duplex.

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Fibre Channel Information Transfer

Frame Format

Frame Content

(Bytes)

(4)  (24)  (0-2112)  (4)  (4)

SOF  Frame Header  Data Field  CRC  EOF

Idle Words

1. Upper Layer Protocol (e.g., SCSI) Initiator
2. Information Unit (sequence)  Sequence: Unit of delivery to application
3. Segment to frames
4. 6 5 4 3 2 1 0
5. Transmit—Point-to-Point, Loop, or Switched
6. Reassembly
7. Information Unit (Sequence)
8. Upper Layer Protocol (e.g., SCSI) Target

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- Designed computer systems friendly.