Fibre Channel

GIGABIT COMMUNICATIONS AND I/O FOR COMPUTER NETWORKS

Alan F. Benner

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Preface

One of the difficult and exciting things about writing this sort of book is that much of the information is nearly outdated by the time it can be published. For example, in the months between starting and finishing this work, the definitions for double- and quadruple-speed FC-0 physical links have been approved, several field trials of the technology have been completed, and the main parts of an FC-PH-2 set of proposed extensions to the FC-PH ANSI standard functions have been defined. This rate of change makes it very difficult to decide what parts of the voluminous information on Fibre Channel to include in an overview book like this.

I have included here the Fibre Channel functions that have been generally agreed upon at the time of writing (Spring 1995). These include the functions in the FC-PH ANSI standard. I have also included several functions, such as double- and quadruple-speed links, which are not yet part of an ANSI standard, but are stable and expected to be adopted in the FC-PH-2 standard. I have not included discussion of some of the more speculative parts of FC-PH-2, such as fractional bandwidth guarantees, aliases, and compression of transmitted data. Most of these will likely be adopted, but explaining them in detail would have extended the book significantly. I have included discussions of Process Login, since it is in use for the implementing SCSI-3 over Fibre Channel, and the chapter on SCSI shows how it is used.

The other consequence of the rapidly evolving architecture definition is that certain descriptions in the book may not reflect final Fibre Channel definitions. To some extent, therefore, some errors will be inevitable, although every attempt has been made to minimize them. This book is not intended to replace the standards documents, but is intended to be an overview guide to the concepts, the structures, and the goals of the Fibre Channel architecture. A dedicated reader should be able to use it to understand most of the details of Fibre Channel before referring to the ANSI materials for authoritative information.

Determining a consistent notation in this type of work is not trivial, since the subject matter bridges both computer and communications arenas, which have traditionally used slightly different notations. For example, communications data rates are generally

measured in megabits per second, where "mega" means 10^6, while computer data is measured in megabytes, where "mega" means 2^{20}. We will freely intermix both somewhat, using "b" to represent bits, as in Gbps, and "B" to represent bytes, as in MBps. In recognition of the communications-oriented nature of the subject, the prefixes "mega (M)" and "giga (G)" will mean 10^6 and 10^9 throughout, rather than 2^{20} and 2^{30}, as is generally used in computer-related work. All numbers in the book are written in binary (b'0110 0101'), hexadecimal (x'FF FFFD'), or decimal (65,532) formats. Single bits are written as 1 or 0.

A number of common words, such Sequence, Exchange, and Connection, have specific meanings in Fibre Channel that are quite distinct from their common usage. In this book, words with specific Fibre Channel meanings are generally capitalized to distinguish them from the common usage. This capitalization generally matches the format used in the ANSI standards documents. Information provided here is in the public domain, through generally available books, articles, ANSI documents, or other reference material.

Several terms used in this book, such as ATM and HIPPI, are taken from other architectures. Any trademarks used are properties of their rightful owners. Ethernet is a trademark of the Xerox Corporation. ESCON is a trademark or registered trademark of the IBM Corporation in the United States or other countries or both. FCS is a trademark of Ancor Communications, Inc.

The book is organized as follows. The first few chapters give an overview of the features and goals for the Fibre Channel architecture, along with an example of how data is transmitted under a Fibre Channel network.

The middle chapters cover the ideas of Fibre Channel in a fair amount of detail. These include chapters on all of the Fibre Channel physical components and logical constructs, supported functions, flow control, and error recovery.

The final chapters cover configuration and operation of the Arbitrated Loop topology, mapping of Fibre Channel constructs to upper level protocols such as SCSI and the IP level of TCP/IP, and probably FC-PH-2 extensions. These chapters show how Fibre Channel fits in with currently existing software and operating system levels.

Chapter 1 introduces the Fibre Channel architecture, including the reasons for its introduction, the problems that it attempts to solve, and the features it provides.

Chapter 2 gives a overview of the entire Fibre Channel protocol, covering protocol hierarchy, physical connections, transmitters and receivers, Classes of service, performance models, switch fabric models, and error handling.

Chapter 3 provides an example of the operation of a Fibre Channel system, from power-on through initialization, login, and data transfer. This provides an overview of the basic Fibre Channel terms and functions.

Chapter 4 begins detailed description of Fibre Channel concepts. It describes the Fibre Channel physical layer, with descriptions of various options for optical and electrical cabling and connectors at the various data rates.

Chapter 5 describes the 8B/10B coding that is used for improving transmitter and receiver performance at Fibre Channel data rates and for simplifying detection of data transmission errors.

Chapters 6 describes the formats and usage of "Ordered Sets," which are forty-bit (word sized) control words used for Frame delimitation, low-level link control, and synchronization at byte and word boundaries.

Chapters 7 through 11 describe the various protocol-related control structures and functions required to initialize a Fibre Channel network, transmit and receive data, handle different Classes of service, and maintain system status during communications.

Chapter 12 describes the procedures for detecting and recovering from the transmission and reception errors that occur in any communications system.

Chapter 13 describes the optional headers available for removing out-of-date Frames, bridging between different networks, linking Exchanges together and including upper level protocol information.

Chapter 14 describes mechanisms for handling Class 1 dedicated connections, which allow dedication of full uninterrupted bandwidth between two specific ports in a switched network environment.

Chapter 15 describes the levels of flow control used to prevent multiple sources from simultaneously sending enough traffic to a single destination to overwhelm the destination's ability to handle it. This subject is given a complete chapter since it is such an important component of any data communication protocol that hopes to guarantee reliable transmission with reasonable efficiency.

Chapters 16 describes the mapping of the Fibre Channel protocol onto a ring or loop topology. Loops provide lower hardware costs than switched topologies for connecting multiple components, but

require some additional constructs and procedures for arbitrating access to the shared medium.

Chapter 17 describes the methods of mapping the IP level of TCP/IP and of mapping SCSI commands over Fibre Channel constructs, to show how the flexibility of Fibre Channel allows interleaved traffic from two very different communications and I/O protocols. Mappings are defined for far too many other already existing upper level protocols to include all of them here, but the examples given show the flavor of how they work.

Chapter 18 covers some possible future directions for Fibre Channel, including functions under development that may be included in an FC-PH-2 Fibre Channel-2 standard.

Thanks are due to a number of people. Much of what is good in this book is due to their help. All errors are of course my own. I have tried to recognize everybody who helped, and I apologize in advance to those I may have missed. Many thanks to Carl Zeitler, Ki Won Lee, Mike Yang, Dan Eisenhower, Ron Cash, Roger Weekly, Giles Frazier, Jerry Chapman, Jerry Rouse, Jonathan Thatcher, Bill George, Al Widmer, Tom McConathy, Casey Cannon, Gary Nutt, R. Bryan Cook, Paul Green, Dal Allan, Martin Sachs, Horst Truestedt, Richard Taborek, Schelto Van Doorn, and Roger Cummings, who helped during the writing. Thanks to Herman Presby, Ivan Kaminow, and Jon Sauer, for getting me involved in optical fiber networking. Thanks to Frank Kampf, Bob Stucke, Harish Sethu, Doug Joseph and Bob Cypher for helping me understand some of the many issues in computer communications. Finally, thanks also to Steve Chapman and Caroline Levine for help in putting the book together and getting the project finished.

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