

# Fibre Channel

GIGABIT COMMUNICATIONS  
AND I/O FOR  
COMPUTER NETWORKS

Alan F. Benner

McGraw-Hill Series on Computer Communications

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# **Fibre Channel**

**Gigabit Communications and I/O  
for Computer Networks**

**Alan F. Benner**

**McGraw-Hill**

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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One of the difficult and exciting things about writing this sort of book is that much of the information is nearly outdated by the time it can be published.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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# Contents

<b>Chapter 1. Introduction</b>	<b>1</b>
1.1 Unification of LAN and Channel Technologies	2
1.2 Relative Speeds of Computer Components	4
1.3 Goals of the Fibre Channel Architecture	5
1.4 Fibre Channel Features	6
1.4.1 Goals of the Book	7
1.5 Solutions to Data Communication Problems	7
1.5.1 Clocking and Bit Synchronization	9
1.5.2 Byte- and Word-Level Synchronization	10
1.5.3 Error Detection and Error Recovery	10
1.5.4 Flow Control	11
1.5.5 Classes of Transmission Service	12
1.5.6 Flexibility	12
1.5.7 Other Issues	13
 <b>Chapter 2. Overview:</b>	
<b>Structure and Concepts</b>	<b>15</b>
2.1 FC-0 General Description	16
2.2 FC-1 General Description	18
2.3 FC-2 General Description	21
2.3.1 Physical Model: Nodes, Ports, and Topologies	22
2.3.2 Bandwidth and Communication Overhead	23
2.3.3 Building Blocks and Their Hierarchy	25
2.3.4 Link Control Frames	30
2.3.5 General Fabric Model	30
2.3.6 Classes of Service	33
2.3.7 Basic and Extended Link Service Commands	36
2.3.8 Arbitrated Loop Functions	37
2.3.9 Protocols	37
2.3.10 Segmentation and Reassembly	38
2.3.11 Error Detection and Recovery	39
2.4 FC-3 General Description	40
2.5 FC-4 General Description	41
2.5.1 IP Over Fibre Channel	42
2.5.2 SCSI Over Fibre Channel	42
 <b>Chapter 3. Example: System Initialization</b>	
<b>and Data Transfer</b>	<b>45</b>
3.1 Link Initialization	46



3.2 Loop Initialization	48
3.3 Fabric and N_Port Login	51
3.4 Initial Sequence Transmission	53
3.5 Completion of an Exchange	57
3.6 Protocol Not Covered by the Example	58
3.6.1 Error Detection and Recovery	58
3.6.2 Class 1 and Fabric Operation	59
3.6.3 Other Protocol Operations	60
<b>Chapter 4. FC-0: Physical Interface</b>	<b>61</b>
4.1 General Characteristics	61
4.2 Transmitter and Receiver	62
4.3 Intentional Transmission of Invalid Code	63
4.4 FC-0 Nomenclature and Technology Options	64
4.5 Long-Wavelength Laser Single-Mode Link	65
4.5.1 Cable Plant	67
4.5.2 Transmitter	67
4.5.3 Receiver	68
4.6 Short-Wavelength Laser Multi-Mode Fiber Links	69
4.6.1 Cable Plant	69
4.6.2 Transmitter	71
4.6.3 Receiver	71
4.7 Open Fiber Control Safety System for SW Laser Links	72
4.8 LED Multi-Mode Fiber Links	74
4.9 75 Ohm Coaxial Cable Electrical Links	75
4.10 150 Ohm Shielded Twisted Pair Electrical Links	77
<b>Chapter 5. FC-1: 8B/10B Transmission Code, Transmitters, and Receivers</b>	<b>79</b>
5.1 8B/10B Transmission Code Overview	79
5.1.1 Notation Conventions	81
5.2 Character Encoding and Decoding	82
5.3 Transmission, Reception, and Error Detection	87
5.4 Transmitter and Receiver State Descriptions	89
<b>Chapter 6. Ordered Sets, Port States, and Primitive Sequence Protocols</b>	<b>93</b>
6.1 Ordered Sets	95
6.1.1 Start of Frame Delimiters	95
6.1.2 End-of-Frame Delimiter	96
6.1.3 Primitive Signals — Idle and R_RDY	98
6.1.4 Primitive Sequences: NOS, OLS, LR, and LRR	99
6.2 Port States	102
6.2.1 Active State	104
6.2.2 Link Recovery States (LR1, LR2, and LR3)	104

6.2.3 Link Failure States (LF1 and LF2)	106
6.2.4 Offline States (OL1, OL2, and OL3)	107
6.3 Primitive Sequence Protocols	108
6.3.1 Link Recovery Protocols	108
6.3.2 Online to Offline Protocol	110
<b>Chapter 7. FC-2: Frames</b>	<b>111</b>
7.1 Frame Format	112
7.1.1 Idle and R_RDY Primitive Signals	112
7.1.2 Start of Frame Delimiter	113
7.1.3 Frame Header Fields	113
7.1.4 Optional Headers	114
7.1.5 Payload	114
7.1.6 CRC Field	114
7.1.7 End-of-Frame Delimiter	115
7.2 Frame Header Fields	115
7.2.1 Routing Control Field: R_CTL	116
7.2.2 Address Identifiers: S_ID and D_ID	119
7.2.3 Reserved Field	122
7.2.4 Data Structure Type: TYPE	123
7.2.5 Frame Control: F_CTL	123
7.2.6 Sequence ID: SEQ_ID	130
7.2.7 Data_Field Control: DF_CTL	131
7.2.8 Sequence Count: SEQ_CNT	131
7.2.9 Originator Exchange_ID: OX_ID	132
7.2.10 Responder Exchange_ID: RX_ID	133
7.2.11 Parameter	134
7.3 Data Frames and Link Control Frames	134
7.3.1 Data Frame Types and Handling	136
7.4 Link Credit Reset (LCR) Frame	138
7.5 Detailed Responses to Data and Link Control Frames	139
7.5.1 R_RDY Response	139
7.5.2 ACK Frames	139
7.5.3 F_BSY Frames	143
7.5.4 P_BSY Frames	144
7.5.5 F_RJT and P_RJT Frames	145
<b>Chapter 8. FC-2: Sequences and Exchanges</b>	<b>149</b>
8.1 Sequence Management	149
8.1.1 Sequence Initiation	150
8.1.2 Sequence Handling Validity	151
8.1.3 Sequence Count Management	152
8.1.4 Normal Sequence Completion	153
8.2 Exchange Management	155
8.2.1 Exchange Origination and X_ID Assignment	156
8.2.2 Exchange Management	157

8.2.3 Exchange Termination	158
8.3 Sequence and Exchange Status Blocks	159
8.3.1 Sequence Status Block Rules	159
8.3.2 Exchange Status Block Rules	161
<b>Chapter 9. Login and Logout Services</b>	<b>163</b>
9.1 Login and Logout Overview	163
9.2 Fabric Login	166
9.3 N_Port Login	169
9.4 Logout	171
9.5 N_Port and F_Port Service Parameters	172
9.5.1 Common Service Parameters	173
9.5.2 N_Port_Name or F_Port_Name	175
9.5.3 Node_Name or Fabric_Name	176
9.5.4 N_Port and F_Port Class Service Parameters	177
9.5.5 Vendor Version Level	179
9.6 Overview of Process Login/ Logout	180
9.7 Procedure to Estimate End-to-End Credit	183
9.7.1 Procedure Details	184
<b>Chapter 10. Classes of Service</b>	<b>187</b>
10.1 Class 1 Service	189
10.2 Class 2 Service	192
10.3 Class 3 Service	194
10.3.1 Performance and Reliability with Class 3 Service	195
10.4 Intermlx	196
<b>Chapter 11. Link Services</b>	<b>199</b>
11.1 Basic Link Service Commands	200
11.1.1 No Operation (NOP)	200
11.1.2 Remove Connection (RMC)	201
11.1.3 Basic Accept (BA_ACC)	201
11.1.4 Basic Reject (BA_RJT)	201
11.1.5 Abort Sequence (ABTS) Command	202
11.2 Extended Link Service Command Overview	203
11.2.1 Types of Extended Link Service Commands	206
11.3 Extended Link Service Replies	206
11.3.1 Link Service Reject (LS_RJT)	206
11.3.2 Accept (ACC)	207
11.4 ELS Requests: Login, Logout, and Abort Exchange	207
11.4.1 N_Port Login (PLOGI)	208
11.4.2 F_Port Login (FLOGI)	209
11.4.3 Logout (LOGO)	209
11.4.4 Abort Exchange (ABTX)	210
11.5 ELS Requests: Status Determination and Initiative Request	210
11.5.1 Read Connection Status (RCS)	210

11.5.2 Read Exchange Status Block (RES)	212
11.5.3 Read Sequence Status Block (RSS)	212
11.5.4 Request Sequence Initiative (RSI)	212
11.6 ELS Requests: Credit Determination	213
11.6.1 Establish Streaming (ESTS)	213
11.6.2 Estimate Credit (ESTC)	213
11.6.3 Advise Credit (ADVC)	213
11.7 ELS Requests: Miscellaneous Functions	214
11.7.1 Read Timeout Value (RTV)	214
11.7.2 Read Link Error Status Block (RLS)	214
11.7.3 Echo (ECHO)	216
11.7.4 Test (TEST)	216
11.7.5 Reinstate Recovery Qualifier (RRQ)	216
11.8 FC-4 Link Services	217
<b>Chapter 12. Error Detection and Recovery</b>	<b>219</b>
12.1 Timeout Periods	220
12.1.1 R_T_TOV	220
12.1.2 E_D_TOV	221
12.1.3 R_A_TOV	221
12.1.4 FC-AL Loop Timeout	222
12.2 Usage of Timeouts	223
12.2.1 Sequence Timeout	223
12.3 Link Error Detection and Recovery	226
12.3.1 Link Recovery: Secondary Effects	227
12.4 Frame Reception and Frame Validity	227
12.4.1 Detection of Missing Frames	228
12.5 Exchange and Sequence Integrity	229
12.6 Exchange Error Policies for Class 1 and Class 2	231
12.6.1 Rules Common to All Discard Policies	231
12.6.2 Abort, Discard Multiple Sequences Error Policy	232
12.6.3 Discard Multiple With Immediate Retransmission	233
12.6.4 Abort, Discard a Single Sequence Error Policy	234
12.6.5 Process with Infinite Buffering Error Policy	234
12.7 Class 3 Sequence Error Handling	235
12.8 Sequence Recovery	235
12.8.1 Error Recovery Strategy	236
12.8.2 Abort Sequence Protocol for Sequence Recovery	237
12.8.3 Sequence Retransmission for Class 1 Recovery	240
12.9 Stop Sequence Protocol Overview	242
12.10 Link Error Status Block Rules	243
<b>Chapter 13. Association Management and Other Optional Headers</b>	<b>245</b>
13.1 Expiration_Security_Header	247
13.2 Network_Header	248

13.3 Association_Header	248
13.4 Device_Header	250
<b>Chapter 14. Class 1 Connection Management</b>	<b>251</b>
14.1 Overview: Normal Procedures	252
14.1.1 Establishing a Connection	252
14.1.2 During a Connection	253
14.1.3 Removing a Connection	254
14.2 Dedicated Connection Recovery	255
14.3 Dedicated Connections over Various Topologies	255
14.3.1 Point-to-Point and Arbitrated Loop Topologies	255
14.3.2 Fabric Topology	256
14.4 Class 1 Dedicated Connection: Detailed Operation	258
14.4.1 Establishing a Connection	258
14.4.2 Unidirectional versus Bidirectional Connections	260
14.4.3 Stacked Connect-Requests	260
14.4.4 Removing a Connection	262
<b>Chapter 15. Flow Control</b>	<b>265</b>
15.1 General Strategies	265
15.2 Fibre Channel Flow Control Strategies	267
15.3 End-to-End Flow Control	268
15.3.1 Receive Buffer Allocation for EE_Credit Assignment	269
15.3.2 Events Affecting EE_Credit_CNT	270
15.3.3 Sequence Recipient Responsibilities	272
15.4 Buffer-to-Buffer Flow Control	273
15.5 Integrated Flow Control for Class 2 Service	274
<b>Chapter 16. FC-AL: Arbitrated Loop Architecture and Operations</b>	<b>277</b>
16.1 Introduction to Arbitrated Loop	277
16.1.1 Extra Functions Required for FC-AL Operation	279
16.2 AL_PA Physical Addresses	280
16.3 Primitive Signals and Primitive Sequences for AL	282
16.3.1 Primitive Signals	283
16.3.2 Primitive Sequences	285
16.4 Loop Initialization	286
16.4.1 Selecting a Temporary Loop Master	288
16.4.2 Selection of AL_PA Addresses	288
16.4.3 Building an AL_PA Address Map	290
16.5 Loop Port State Machine Operation: An Example	291
16.5.1 Initialization of the Two-Port Loop	292
16.5.2 Arbitration and Initiation of Communication	293
16.5.3 Arbitration and Access Fairness	295
16.5.4 Finishing Communications	296

16.5.5 Need for the Alternate Buffer-to-Buffer Credit	296
16.5.6 Continuing Communications	297
16.5.7 Transfer to Another Port	297
16.6 Performance and Timing	298
16.7 Summary: Advantages of Arbitrated Loop Topology	300

## **Chapter 17. FC-4: Mapping IP and SCSI over Fibre Channel** **301**

17.1 FC-4 Control over Fibre Channel Operations	302
17.2 IP over Fibre Channel	303
17.2.1 Transmission of IP and ARP Datagrams	304
17.2.2 IP Operations	306
17.3 SCSI-3 over Fibre Channel: FCP Overview	309
17.3.1 FCP Information Unit Formats	311
17.3.2 Sample I/O Operation under FCP	315

## **Chapter 18. Future Work: FC-PH-2 and Beyond** **319**

18.1 Possible FC-PH-2 Features	319
18.1.1 Process Login	320
18.1.2 Dedicated Simplex	320
18.1.3 Class 4: Fractional Bandwidth	320
18.1.4 Aliases	321
18.1.5 Multicast	321
18.1.6 Hunt Groups	321
18.1.7 Camp On	322
18.1.8 Stacked Connect-Requests	322
18.1.9 Buffered Class 1 Service	323
18.1.10 Data Compression	323
18.2 Future Directions	323
18.2.1 Upper-Level Protocol Changes	324
18.2.2 Fibre Channel Usage	325

## **Appendix A Reference Documents and Further Reading** **327**

# Figures

<b>Figure 1.1</b>	<b>Physical topology for Fibre Channel networks.</b>	<b>8</b>
<b>Figure 2.1</b>	<b>Fibre Channel structural hierarchy.</b>	<b>17</b>
<b>Figure 2.2</b>	<b>FC-0 link.</b>	<b>18</b>
<b>Figure 2.3</b>	<b>Examples of Point-to-point, Fabric, and Arbitrated Loop topologies.</b>	<b>19</b>
<b>Figure 2.4</b>	<b>Transmitter FC-1 and FC-0 data flow stages.</b>	<b>20</b>
<b>Figure 2.5</b>	<b>Receiver FC-0 and FC-1 data flow stages.</b>	<b>21</b>
<b>Figure 2.6</b>	<b>Sample Data Frame + ACK Frame transmission, for bandwidth calculation.</b>	<b>24</b>
<b>Figure 2.7</b>	<b>Building blocks for the FC-2 Frame / Sequence / Exchange hierarchy.</b>	<b>25</b>
<b>Figure 3.1</b>	<b>Physical configuration of a host-to-disk Fibre Channel Arbitrated Loop connection.</b>	<b>46</b>
<b>Figure 3.2</b>	<b>Link initialization through Ordered Set Transmissions.</b>	<b>48</b>
<b>Figure 4.1</b>	<b>Nomenclature for describing FC-0 cable plant options.</b>	<b>64</b>
<b>Figure 4.2</b>	<b>Defined cable plant technology options.</b>	<b>65</b>
<b>Figure 4.3</b>	<b>Specifications for single-mode optical fiber links.</b>	<b>66</b>
<b>Figure 4.4</b>	<b>Duplex SC connector for single- and multi-mode optical links.</b>	<b>67</b>
<b>Figure 4.5</b>	<b>Eye diagram mask for valid waveforms at the transmitter output.</b>	<b>69</b>
<b>Figure 4.6</b>	<b>Specifications for multi-mode fiber short wavelength laser and LED links.</b>	<b>70</b>
<b>Figure 4.7</b>	<b>Block diagram schematic for the OFC laser safety system.</b>	<b>73</b>
<b>Figure 4.8</b>	<b>Specifications for electrical cable links.</b>	<b>76</b>
<b>Figure 4.9</b>	<b>Transmitter eye diagram mask for coaxial cable links.</b>	<b>77</b>
<b>Figure 4.10</b>	<b>Configuration for shielded twisted pair 9-pin "D" connectors.</b>	<b>78</b>
<b>Figure 5.1</b>	<b>Sample conversion of an FC-2 byte to FC-1 Transmission Character notation.</b>	<b>82</b>

<b>Figure 5.2</b>	<b>5B/6B and 3B/4B coding conversions.</b>	<b>83</b>
<b>Figure 5.3</b>	<b>Full 8B/10B code: Valid Special Characters.</b>	<b>84</b>
<b>Figure 5.4</b>	<b>Full 8B/10B code: Valid Data Characters, 1 of 3.</b>	<b>85</b>
<b>Figure 5.5</b>	<b>Full 8B/10B code: Valid Data Characters, 2 of 3.</b>	<b>86</b>
<b>Figure 5.6</b>	<b>Full 8B/10B code: Valid Data Characters, 3 of 3.</b>	<b>87</b>
<b>Figure 5.7</b>	<b>Example logical structure of an 8B/10B encoder.</b>	<b>88</b>
<b>Figure 5.8</b>	<b>Transmission order of bits and bytes in a word.</b>	<b>88</b>
<b>Figure 5.9</b>	<b>Example logical structure of a 10B/8B decoder.</b>	<b>90</b>
<b>Figure 6.1</b>	<b>Defined Ordered Sets for Frame delimiters.</b>	<b>95</b>
<b>Figure 6.2</b>	<b>Defined Ordered Sets for Primitive Signals and Primitive Sequences.</b>	<b>100</b>
<b>Figure 6.3</b>	<b>Meanings of and responses to the Primitive Sequences.</b>	<b>101</b>
<b>Figure 6.4</b>	<b>Port state transition chart.</b>	<b>103</b>
<b>Figure 7.1</b>	<b>Frame and Frame Header formats.</b>	<b>111</b>
<b>Figure 7.2</b>	<b>Summary of the kinds of Fibre Channel Frames, 1 of 2: Data Frames.</b>	<b>117</b>
<b>Figure 7.3</b>	<b>Summary of the kinds of Fibre Channel Frames, 2 of 2: Link Control Frames.</b>	<b>118</b>
<b>Figure 7.4</b>	<b>Frame Payload formats for Data Descriptor, Unsolicited Command, and Command Status Information Categories.</b>	<b>119</b>
<b>Figure 7.5</b>	<b>Proposed S_ID/D_ID address space partitioning.</b>	<b>121</b>
<b>Figure 7.6</b>	<b>Bit definitions for Frame header F_CTL field.</b>	<b>124</b>
<b>Figure 7.7</b>	<b>Summary of F_CTL bit usage and validity in Data and Link Control Frames.</b>	<b>130</b>
<b>Figure 7.8</b>	<b>Bit definitions for Frame Header DF_CTL (Data Field Control) field.</b>	<b>132</b>
<b>Figure 7.9</b>	<b>Frame reject reason codes, 1 of 2.</b>	<b>146</b>
<b>Figure 7.10</b>	<b>Frame reject reason codes, 2 of 2.</b>	<b>147</b>
<b>Figure 8.1</b>	<b>N_Port- and Class-dependent conditions for considering Sequences as complete.</b>	<b>154</b>
<b>Figure 8.2</b>	<b>Sequence Status Block format.</b>	<b>160</b>
<b>Figure 8.3</b>	<b>Exchange Status Block format.</b>	<b>162</b>
<b>Figure 9.1</b>	<b>Pre-Login Default Service Parameters.</b>	<b>164</b>
<b>Figure 9.2</b>	<b>Frame flow during Fabric Login and N_Port Login.</b>	<b>165</b>



<b>Figure 9.3</b>	<b>Format of the N_Port Login and Fabric Login requests and their Accept replies.</b>	<b>167</b>
<b>Figure 9.4</b>	<b>Format of Logout (LOGO) Command and corresponding Accept (ACC).</b>	<b>172</b>
<b>Figure 9.5</b>	<b>LS_Command codes and Common Service Parameters for FLOGI and PLOGI Commands.</b>	<b>173</b>
<b>Figure 9.6</b>	<b>Bit field definitions for FLOGI and PLOGI Common Service Parameters</b>	<b>174</b>
<b>Figure 9.7</b>	<b>Formats of worldwide Port_Names and Node_Names.</b>	<b>176</b>
<b>Figure 9.8</b>	<b>F_Port and N_Port Class Service Parameters.</b>	<b>177</b>
<b>Figure 9.9</b>	<b>Bit field definitions for Class Service Parameters.</b>	<b>178</b>
<b>Figure 9.10</b>	<b>Multiple images are addressable behind a single Port using Process Associators.</b>	<b>181</b>
<b>Figure 9.11</b>	<b>Frames and Sequences transmitted in procedure for establishing streaming credit.</b>	<b>184</b>
<b>Figure 10.1</b>	<b>Examples of N_Port Login over a Fabric using the three Classes of service.</b>	<b>190</b>
<b>Figure 11.1</b>	<b>Basic Link Service commands.</b>	<b>200</b>
<b>Figure 11.2</b>	<b>Format of the Basic Accept to the ABTS Basic Link Service command.</b>	<b>202</b>
<b>Figure 11.3</b>	<b>Basic Reject BLS Response format, BA_RJT reason codes, and reason explanation codes.</b>	<b>203</b>
<b>Figure 11.4</b>	<b>Extended Link Service commands, with LS_Command codes and usage requirements.</b>	<b>205</b>
<b>Figure 11.5</b>	<b>Link Service Reject (LS_RJT) format and reason codes.</b>	<b>207</b>
<b>Figure 11.6</b>	<b>Link Service Reject (LS_RJT) explanation codes.</b>	<b>208</b>
<b>Figure 11.7</b>	<b>Payloads for the RCS, RES RSS, and RSI Requests.</b>	<b>211</b>
<b>Figure 11.8</b>	<b>Payloads for the RTV, RLS, ECHO, TEST, and RRQ ELS Requests and Replies.</b>	<b>215</b>
<b>Figure 12.1</b>	<b>Reply format to Read Link Error Status Block Request.</b>	<b>243</b>
<b>Figure 13.1</b>	<b>Placement of optional headers in Frame.</b>	<b>246</b>
<b>Figure 13.2</b>	<b>Summary of optional header usage.</b>	<b>246</b>
<b>Figure 13.3</b>	<b>Format of Expiration_Security_Header.</b>	<b>248</b>
<b>Figure 13.4</b>	<b>Format of Network_Header.</b>	<b>249</b>
<b>Figure 13.5</b>	<b>Format of Association_Header.</b>	<b>249</b>