



BSI Standards Publication

Information technology — Fibre channel

Part 226: Single-byte command code sets mapping protocol — 6 (FC-SB-6)

National foreword

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**Single-byte command code sets
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Foreword (This foreword is not part of American National Standard INCITS 544-2018.)

The Fibre Channel Single-Byte Command Code Sets - 6 (FC-SB-6) standard describes the Fibre Channel mapping protocol associated with the Single-Byte Command Code Sets.

This standard was developed by the INCITS Fibre Channel T11 Technical Committee (FC-TC) of Accredited Standards Committee during 2015-2016. The standards approval process started in 2016. This document includes annexes which are informative and are not considered part of the standard.

Requests for interpretation, suggestions for improvement or addenda, or defect reports are welcome. They should be sent to InterNational Committee for Information Technology Standards (INCITS), ITI, 1101 K Street, NW, Suite 610, Washington, DC 20005.

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Introduction

FC-SB-6 describes the Fibre Channel protocol mapping for the Single-Byte Command Code Sets. FC-SB-6 is one of a number of Fibre Channel protocol mappings, referred to as FC-4s.

Fibre Channel – Single-Byte Command Code Sets Mapping Protocol - 6 (FC-SB-6)

1 Scope

This standard describes a communication interface between a channel and I/O control units that utilize the Single-Byte Command Code Sets (SBCCS) as implemented in a wide range of data processing systems. It employs information formats and signaling protocols that provide a uniform means for communicating with various types of I/O control units, facilitating a high bandwidth, high performance, and long distance information exchange environment. The signaling protocols and information exchanges are defined at a layer (FC-4) to compatibly utilize the link services and other functions provided by the INCITS Fibre Channel Framing and Signaling (FC-FS-4) and the INCITS Fibre Channel Link Services (FC-LS-3) specifications. This FC-4 Upper Level Protocol is referred to as the Fibre Channel-Single-Byte-6 Command Code Sets Mapping Protocol (FC-SB-6).

This standard modifies the FC-SB-5 standard to specify enhancements and clarifications to the command-mode and transport-mode protocols to increase the efficiency and expand the capabilities of operations.

2 Normative References

2.1 Qualification and availability of references

The references listed in this clause contain provisions that, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed in this clause.

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Phone: 202-626-5737
Web: <http://www.incits.org>
E-mail: incits@itic.org

IETF Request for Comments (RFCs) may be obtained directly from the IETF web site at <http://www.ietf.org/rfc.html>.

2.2 Approved References

FC-PI-2:INCITS 404-2006, *Fibre Channel Physical Interfaces - 2 (FC-PI-2)*

FC-PI-5:INCITS 479-2011, *Fibre Channel Physical Interfaces - 5 (FC-PI-5)*

FC-PI-6:INCITS 512-2015, *Fibre Channel - Physical Interface - 6 (FC-PI-6)*

FC-PI-6P:INCITS 533-201x, *Fibre Channel - Physical Interface - 6 (FC-PI-6P)*

SBCON:ANSI X3.296-1997, *Single-Byte Command Code Sets Connection Architecture (SBCON)*

FC-SB-5:INCITS 485-2014, *Fibre Channel - Single Byte Command Code Sets - 5 (FC-SB-5)*

FCP-4:INCITS 481-2012, *Fibre Channel - Protocol - 4 (FCP-4)*

FDDI-MAC:ISO/IEC 9314-2:1989, *Fibre Distributed Data Interface - Media Access Control (FDDI-MAC)*

2.3 References Under Development

At the time of publication, the following referenced standards were still under development. For information on the current status of the document, or regarding availability, contact the relevant standards body or other organization as indicated.

FC-FS-4:INCITS Project 2238-D, *Fibre Channel - Framing and Signaling - 4 (FC-FS-4)*

FC-LS-3:INCITS Project 2237-D, *Fibre Channel - Link Services - 3 (FC-LS-3)*

FC-SW-6:INCITS Project 2220-D, *Fibre Channel - Switch Fabric - 6 (FC-SW-6)*

FC-PI-7:INCITS 543-201X, *Fibre Channel - Physical Interface - 6 (FC-PI-7)*

3 Definitions and Conventions

3.1 Overview

For this standard, the following definitions and conventions apply.

3.2 Definitions

3.2.1 channel

entity, typically of a host computer, which consists of one N_Port and elements which performs the functions specified by this standard to provide access to I/O devices by means of control units or emulated control units

3.2.2 channel-command word (CCW)

a) control block which contains a request to perform an I/O operation in command mode; or b) structure of a specific system architecture which specifies the command to be executed along with parameters

3.2.3 CCW channel program

single channel-command word or sequence of channel-command words executed sequentially that control a specific sequence of channel operations

3.2.4 CCW I/O operation

decoding, accepting, and executing a CCW by an I/O device

3.2.5 channel image

single ULP instance of a channel having the logical appearance of a channel

3.2.6 channel-path identifier (CHPID)

system-unique 8-bit value assigned to each installed channel path of a system

3.2.7 channel program

a) CCW channel program; or b) TCW channel program

3.2.8 channel-to-channel connection

association between two channels, one of which provides an emulated control unit, which allows those two channels to exchange IUs on an exchange pair

3.2.9 command mode

mode of operation that is used to perform SB-6 device-level functions that are performed using an exchange pair and to perform all FC-SB-6 link-control functions

3.2.10 connection

association between a channel and control unit established: a) after the successful transfer of IUs that constitute an exchange pair resulting in two open exchanges, one inbound and the other outbound, and both occurring between the channel and the control unit in command mode; or b) after transfer of an IU by a channel to a control unit that opens an exchange in transport mode

3.2.11 control unit

physical or emulated entity, consisting of at least one N_Port and elements which adapt the characteristics of one or more I/O devices to allow their attachment to the N_Port of a channel

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3.2.12 control-unit image

single ULP instance of a control unit having the logical appearance of a control unit

3.2.13 CRC Offset Block

list of 1-word values identifying the byte offset of each intermediate CRC word in the write transport data

3.2.14 device

equipment such as a printer, magnetic tape unit or direct-access-storage device (DASD) that is accessed by means of a control unit to allow attachment to a channel

3.2.15 device-command word (DCW)

a) control block which contains a device I/O command; or b) structure of a specific system architecture which specifies an I/O command to be executed along with parameters

3.2.16 device-level functions

protocols and functions used to perform and manage I/O operations

3.2.17 device information block (DIB)

data block present in all device-level FC-SB-6 command-mode IUs except IUs used to perform I/O operations in transport mode

3.2.18 disconnection

removal of a connection by closing one or both exchanges of an exchange pair or by closing a transport exchange

3.2.19 exchange pair

two FC-FS-4 exchanges between a channel and a control unit with sequence initiative in opposite directions that are linked together by the SB-6 ULP

3.2.20 extended CRC offset block

list of 1-word values identifying the CRC offsets and block lengths of segments of write transport data

3.2.21 Fabric

entity that interconnects Nx_Ports attached to it and is capable of routing frames by using the D_ID information in a Frame_Header (see FC-FS-4)

3.2.22 image

group of related processes behind a single N_Port (e.g. a single system or a single logical partition of a system)

3.2.23

inbound exchange

exchange of an exchange pair which originates from a control unit and that carries information to the channel

3.2.24 initiation IU

first IU of an exchange

3.2.25 I/O operation

execution of an operation specified by a CCW or a TCW

3.2.26 link-level functions

FC-FS-4 link-control mechanisms and basic-link services (BLS), FC-LS-3 extended-link services (ELS), and SB-6 link-control functions used to make operational and manage the physical and logical link between an entity acting as a channel and an entity acting as a control unit

3.2.27 mode of operation

identifies the protocols and functions of either command mode or transport mode, used by a channel and control unit to perform device-level functions.

3.2.28 N_Port

see FC-FS-4

3.2.29 N_Port_ID

see FC-FS-4

3.2.30 outbound exchange

exchange of an exchange pair which originates from a channel and that carries information from the channel to the control unit

3.2.31 persistent IU pacing

method for allowing an FC-SB-6 channel to retain a pacing credit for use at the start of execution of a channel program

3.2.32 SB-6 offline condition

condition recognized when a receiver transitions from the FC-FS-4 active state to the FC-FS-4 OLS receive state

3.2.33 transport command control block (TCCB)

variable length data structure that contains device-command words (DCWs) and associated control information that is sent from a channel to a control unit

3.2.34 transport command word (TCW)

a) control block which contains a request to perform an I/O operation in transport mode; or b) structure of a specific system architecture which specifies a TCCB to be sent from the channel to the CU

3.2.35 TCW channel program

single transport command word

3.2.36 TCW I/O operation

decoding, accepting, and executing a TCCB by an I/O device

3.2.37 transport exchange

single bi-directional exchange that carries the communication required between a channel and control unit to perform a device-level function

3.2.38 transport mode

mode of operation that is used to perform SB-6 device-level functions using transport exchanges

3.2.39 transport status block (TSB)

variable length data structure that contains status for a TCW I/O operation

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3.2.40 ULP process

function executing within a channel or control unit which conforms to the Upper Level Protocol (ULP) immediately above the SB-6 service interface

3.3 Editorial Conventions

3.3.1 English Usage Conventions

In this standard, a number of conditions, mechanisms, sequences, parameters, events, states, or similar terms that do not have their normal English meaning are printed with the following conventions:

- a) The first letter of each word in uppercase and the rest lowercase (e.g., Exchange, Class, etc.);
- b) A term consisting of multiple words, with the first letter of each word in uppercase and the rest lowercase, and each word separated from the other by an underscore (_) character. A word may consist of an acronym or abbreviation which would be printed in uppercase. (e.g., N_Port); and
- c) a term consisting of multiple words with all letters lowercase and each word separated from the other by a dash (-) character. A word may also consist of an acronym or abbreviation which would be printed in uppercase. (e.g., device-level, CUE-with-busy).

Certain words and terms used in this standard have a specific meaning beyond the normal English meaning. These words and terms are defined either in the definitions or in the text where they first appear.

Lists sequenced by lowercase or uppercase letters show no ordering relationship between the listed items. Lists sequenced by numbers show an ordering relationship between the listed items.

If a field or a control bit in a frame is specified as not meaningful, the entity which receives the frame shall not check that field or control bit.

3.3.2 FC Link Functions

In order to support the SB-6 protocol, the FC-FS-4 and FC-LS-3 functions referenced in this document are required to be supported by a channel, control unit and Fabric (if present) as specified in this document.

3.3.3 Bit Numbering

All words defined by FC-FS-4 and FC-LS-3 use the convention that bit 31 is the Most Significant Bit (MSB) and bit 0 is the Least Significant Bit (LSB). All words defined by the FC-SB-6 protocol use the convention that bit 0 is the MSB and bit 31 is the LSB. All bytes defined by FC-FS-4 and FC-LS-3 use the convention that bit 7 is the Most Significant Bit (MSB) and bit 0 is the Least Significant Bit (LSB). All bytes defined by the FC-SB-6 protocol use the convention that bit 0 is the MSB and bit 7 is the LSB. For FC-FS-4, FC-LS-3 and FC-SB-6, byte 0 is the most significant byte of a word, and byte 3 is the least significant. In all figures, tables and text of this document, the most significant bit of a binary value is shown as the left-most bit. Figure 1 gives a comparison between the FC-FS-4/FC-LS-3 convention and the FC-SB-6 convention.

Figure 1 – FC-FS-4/FC-LS-3 and FC-SB-6 Bit Numbering Conventions

MSB					LSB		
Byte 0		Byte 1		Byte 2		Byte 3	
Bit							
FC-FS-4/	31	23	15	7	0		
FC-LS-3:							
FC-SB-6:	0	8	16	24	31		

3.3.4 Binary Notation

Binary notation may be used to represent some fields. Single bit fields are represented using the binary values zero and one. For multiple bit fields, the binary value is enclosed in single quotation marks followed by the letter b. For example, a 4-byte field containing a binary value may be represented as '00000000 11111111 10011000 11111010'b.

3.3.5 Hexadecimal Notation

Hexadecimal notation may be used to represent some fields. When this is done, the value is enclosed in single quotation marks and preceded by the word hex. For example, a 4-byte field containing a binary value of '00000000 11111111 10011000 11111010'b is shown in hexadecimal format as hex'00 FF 98 FA'.

3.4 Abbreviations, Acronyms, and Symbols

Abbreviations and acronyms applicable to this standard are listed below. See FC-FS-4 and FC-LS-3 acronyms associated with those specifications. For all other acronyms, refer to the index.

ABTS	Abort Sequence BLS
AS	address specific
BLS	FC-FS-4 Basic Link Service
CC	chain command
CCW	channel-command word
CD	chain data
CH	chaining
CHPID	channel path identifier
CI	channel initiated
CNP	CRC not provided
COB	CRC Offset Block
COC	continue on command immediate
CR	command retry
CRC	cyclic redundancy check
CRR	command response request
CTC	channel-to-channel
CTCA	channel-to-channel adapter
CU	control unit
DACK	device-level acknowledgment
DCW	device command word
DIB	device information block
DU	data chaining update
E	end

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EE	early end
ELP	Establish Logical Path link-control IU
ELS	FC-LS-3 Extended Link Service
ES	extended status
FC	fibre channel
FC-FS-4	FC Framing and Signalling Interface-4 Specification
FC-LS-3	FC Link Services-3 Specification
FC-PI-6	FC Physical Interface Specification-6
FC-SB-6	Single Byte Command Code Sets Protocol-6 Specification
FLOGI	F_Port Login ELS
FQXID	Fully Qualified Exchange ID
IU	information unit (see FC-FS-4)
IUI	information unit identifier
LACK	Link Level Acknowledgment link-control IU
LBY	link level busy link-control IU
LESB	link error status block
LIRR	Link-Incident Record Registration ELS
LOGO	N_Port logout ELS
LPE	Logical Path Established link-control IU
LPR	Logical Path Removed link-control IU
LRC	longitudinal redundancy check
LRI	long record/immediate
LRJ	Link level Reject link control IU
LS_RJT	Link-Service Reject ELS Reply
PCI	program control interruption
PLOGI	N_Port Login ELS
PRLI	Process Login ELS
PRLO	Process Logout ELS
QSA	Query Security Attributes ELS
REC	Read Exchange Concise ELS
REX	repeat execute
RFCN	Registered Fabric Change Notification ELS
RLIR	Registered Link Incident Record ELS
RLP	Remove Logical Path link-control IU
RNID	Request Node Identification Data ELS
RRQ	Reinstate Recovery Qualifier ELS
RSCN	Registered State Change Notification ELS
RV	residual count valid
SCR	State Change Registration ELS
SDC	self-describing component
SLI	suppress length indication
SSS	synchronize send status
SYR	synchronize response
TCA	transport command area
TCAH	transport command area header
TCAX	transport command area extension
TCCB	transport command control block
TCH	transport command header
TCOB	Transfer CRC Offset Block command
TCW	transport command word
TIN	Test Initialization link-control IU
TINC	test initialization capability
TINCR	test initialization capability result

TIR	Test Initialization Result link-control IU
TSB	transport status block
TTE	Transfer TCA Extension command
ULP	upper level protocol

3.5 Keywords

3.5.1 mandatory: A keyword that indicates items required to be implemented as defined by this standard.

3.5.2 may: A keyword that indicates flexibility of choice with no implied preference.

3.5.3 model-dependent: A keyword describing an item (e.g. bit, field, code value, etc.) or a behavior (e.g., number of retries) that is not defined by this standard and may be vendor specific.

3.5.4 optional: A keyword that describes features that are not required to be implemented by this standard. However, if any optional feature defined by this standards is implemented, it shall be implemented as defined in this standard.

3.5.5 reserved: A keyword referring to bits, bytes, words, fields and code values that are set aside for future standardization. Their use and interpretation may be specified by future extensions to this or other standards. A reserved bit, byte, word or field shall be set to zero by the originator and ignored by the recipient.

3.5.6 shall: A keyword indicating a mandatory requirement. Designers are required to implement all such requirements to ensure interoperability with other products that conform to this standard.

3.5.7 should: A keyword indicating flexibility of choice with a preferred alternative; equivalent to the phrase “it is recommended”.

3.5.8 vendor specific: A keyword describing items (e.g., a bit, field, code value, etc.) that are not defined by this standard.

4 Structure and Concepts

4.1 Introduction

This clause provides an overview of the structure, concepts, and mechanisms used in Fibre Channel (FC), FC-FS-4, FC-LS-3 and FC-SB-6.

Communication over Fibre Channel takes place between a pair of N_Ports. FC-FS-4 and FC-LS-3 define all of the functions and protocols required to transfer information from one N_Port to another. Depending upon the configuration, the communicating N_Ports are between a channel and control unit or in the case of a channel-to-channel connection, between a channel and a channel emulating a control unit.

FC-SB-6 is a mapping protocol, referred to as an FC-4 that maps a particular upper level protocol (ULP) instance to FC-FS-4. The FC-SB-6 ULP is based on the Single-Byte Command Code Set (SBCON) and on FCP-4. See Annex E for additional information.

An N_Port supports an FC-4 mapping protocol and its associated ULP. More than one FC-4 and ULP instances of the same type or different type may be supported by the same N_Port.

4.2 FC-4 General Description

The FC-4 mapping layer uses the FC-FS-4 protocol to transfer Upper Level Protocol (ULP) information. Each FC-4 describes, through mapping rules, how ULP processes of the same ULP type interoperate. An example of an active ULP process is an FC-SB-6 I/O operation in progress at a device of a particular type such as a disk drive.

The protocols are described in terms of the elements visible in the stream of frames, sequences, and exchanges generated by a pair of communicating nodes transferring ULP information.

4.3 FC-SB-6 General Description

4.3.1 FC-SB-6 Instance

An FC-SB-6 ULP instance may be either an N_Port-based FC-SB-6 channel image, an N_Port-based SB-6 control-unit image, or an N_Port-based emulated control-unit image. Information associated with the execution of an I/O operation and the operation of a device is transferred between a channel image and control-unit image.

4.3.2 FC-SB-6 Protocols

Two levels of protocol are defined for this standard:

- a) link-level; and
- b) device-level.

FC-SB-6 protocols are classified as either link-level or device-level, depending on whether they are for the purpose of managing a logical path and exchanging information over that path or for the purpose of managing the execution of an I/O operation.

The execution of an I/O operation requires both FC-SB-6 link-level and device-level protocols at the channel and control unit. Information exchanged between a channel and control unit as a result of executing an I/O operation is transferred under the control of device-level protocols, which rely on link-level protocols for sending and receiving frames (see 4.7.2 and 4.7.3).

4.4 Channel-Path Elements

4.4.1 Overview of Channel-Path Elements

The channel path provides the communication path between two systems. The physical elements that make up a channel path are a channel, possibly a Fabric, a control unit, and one or more links.

4.4.2 Channel

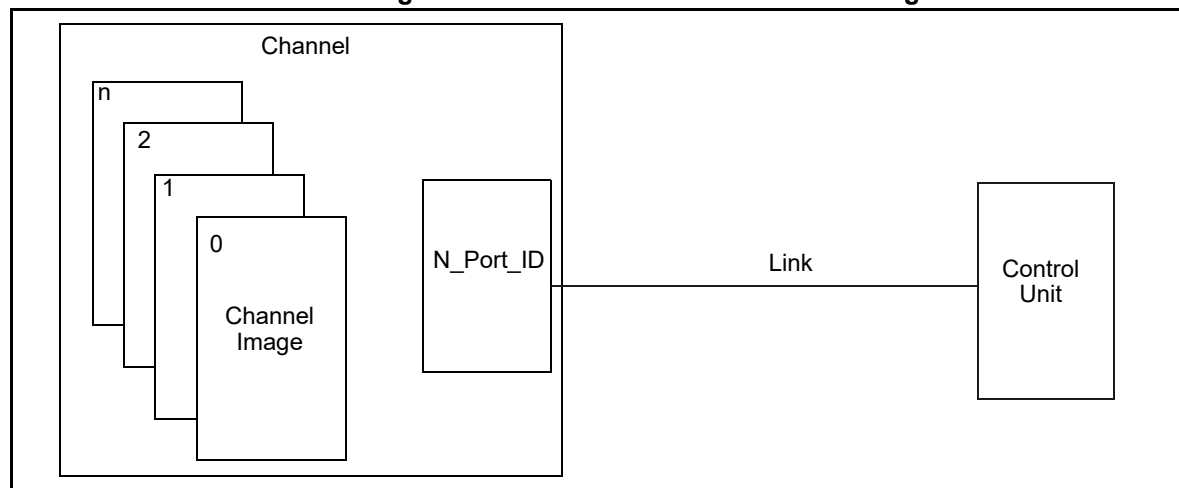
A channel provides the functions specified by FC-FS-4, FC-LS-3, and FC-SB-6, and performs their prescribed protocols. Each channel shall provide one N_Port. When the N_Port of a channel is shared by multiple processes, such as multiple operating systems, each channel path shall be logically and separately represented within the channel. This logical representation is termed a “channel image” (see 4.4.3). A channel may also be capable of providing control unit emulation (see 4.5.6.2).

4.4.3 Channel Image

A channel image has the logical appearance of a channel. Each channel image appears to be an independent channel although all channel images on a specific channel share the same N_Port_ID and physical paths. The N_Port of a channel performs certain functions for all sharing channel images (e.g., link synchronization and acquisition of address identifiers) and may perform functions for a single sharing channel image (e.g., sending frames during the performance of link-level and device-level functions). The N_Port of a channel common to multiple channel images may perform functions for multiple channel images simultaneously by multiplexing work on each function and interleaving frames for each function on the link as allowed by FC-FS-4.

Figure 2 shows multiple channel images which are sharing the same N_Port_ID.

Figure 2 – Channel Path with Channel Images



Either single or multiple channel images may exist at an N_Port. Each channel image denotes one FC-SB-6 channel ULP instance.

NOTE 1 – Channel images represent different logical channel paths even though the channel images share the same N_Port. Therefore, there is one channel per channel path.

4.4.4 Control Unit

A control unit provides the logical capability necessary to operate and control one or more devices and adapts, through the use of common facilities, the characteristics of each device to an N_Port provided by the channel. These common facilities which include N_Port functions and may include FC-SB-6 functions provide for the execution of I/O operations, indications concerning the status of the device and control unit, control of the timing of data transfer over the channel path, and certain levels of device control.

A control unit may have more than one N_Port in order to allow attachment to more than one link, each from a different channel or from a different F_Port on the same or a different Fabric. When a control-unit N_Port is attached to a link from a Fabric, the control unit and its devices may be physically accessible over that N_Port to all channels also attached to links from that Fabric.

When an N_Port on a control unit is shared among multiple channel paths, each channel path shall be logically represented separately within the control unit. This logical relationship is called the logical path (see 4.5.5). A control unit shall provide at least one logical path for each operational N_Port_ID, however, the number of logical paths that a control unit permits is model dependent.

A control unit may also be capable of supporting N_Ports that act as channel paths.

NOTE 2 – Certain ULPs have a dependency upon the existence of a single path to a control unit for a given channel for purposes of managing the I/O configuration. In order to satisfy this dependency, it is recommended that a control unit have only one N_Port which is configured to communicate with a given channel.

NOTE 3 – A control unit may have more than one N_Port, each configured to communicate with a different channel.

NOTE 4 – A control unit may be connected to more than one channel at the same time. When a control unit is connected to more than one channel at the same time, each connection may be for the same or a different device.

4.4.5 Control-Unit Image

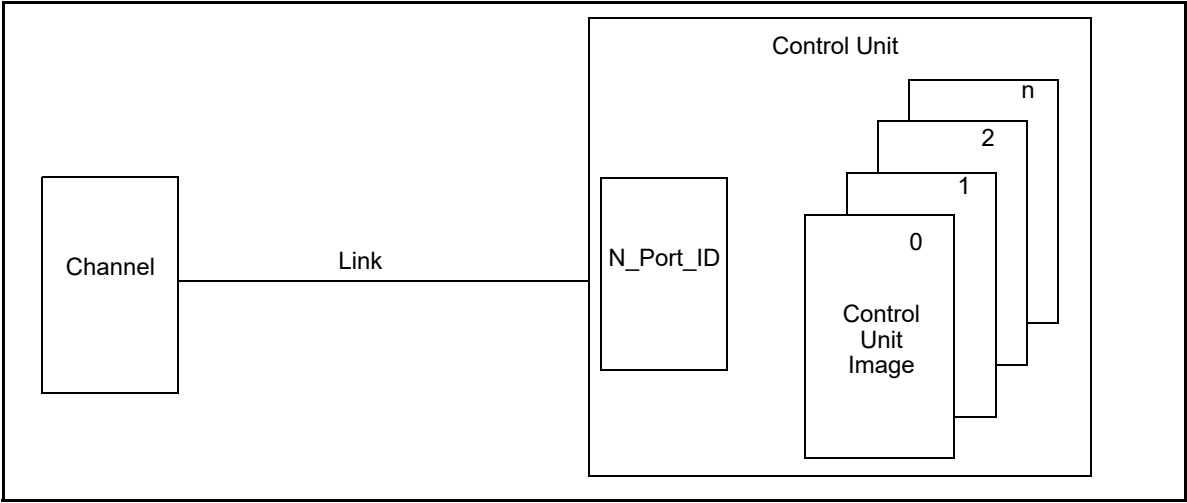
A control-unit image has the logical appearance of a control unit. Each control-unit image appears to be an independent control unit, although all control-unit images common to one control unit may share the same common facilities and N_Ports. These common facilities may provide some or all of the FC-SB-6 functions and protocols. Those FC-SB-6 functions and protocols not provided by the common facilities shall be provided by the individual images.

Up to 256 devices may be attached to each control-unit image.

FC-SB-6 protocols operate for each control-unit image independent of all other control-unit images except for resolving contention for the common facilities shared among control-unit images. The N_Port_ID of a control-unit common to multiple control-unit images may perform functions for multiple control-unit images simultaneously by multiplexing work on each function and interleaving frames for each function on the link as allowed by FC-FS-4.

Figure 3 shows multiple control-unit images which are common to a single N_Port_ID.

Figure 3 – Channel Path with Control-Unit Images



NOTE 5 – Each control-unit image is architecturally identical, even though each image may provide a different device type. The presence of multiple control-unit images becomes apparent only through the logical addresses used when logical paths are established (see 4.7.4 and 4.5.5).

4.4.6 Link

The link is as described by FC-PI-2, FC-PI-5, FC-PI-6, FC-PI-6P, FC-PI-7 and FC-FS-4.

4.5 Channel-Path Configurations

4.5.1 Channel-Path Configuration Overview

Support for point-to-point configuration and Fabric configuration is provided.

4.5.2 Point-to-Point Configuration

A channel path that consists of a single link interconnecting one or more control-unit images to one or more channel images forms a point-to-point configuration. A point-to-point configuration shall be permitted between a channel and control unit only when a single control unit is defined on the channel path or when multiple control-unit images all share the same N_Port. Figure 4 shows a point-to-point configuration consisting of a single channel image and single control-unit image, and figure 5 shows a point-to-point configuration consisting of multiple channel images and control-unit images.

Figure 4 – Point-to-Point Channel-Path Configuration (Single Logical Image)

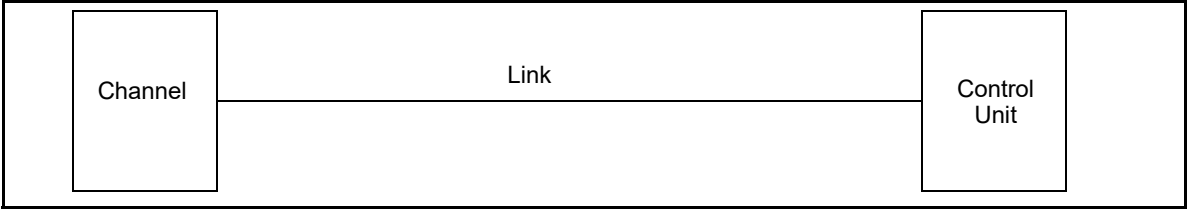
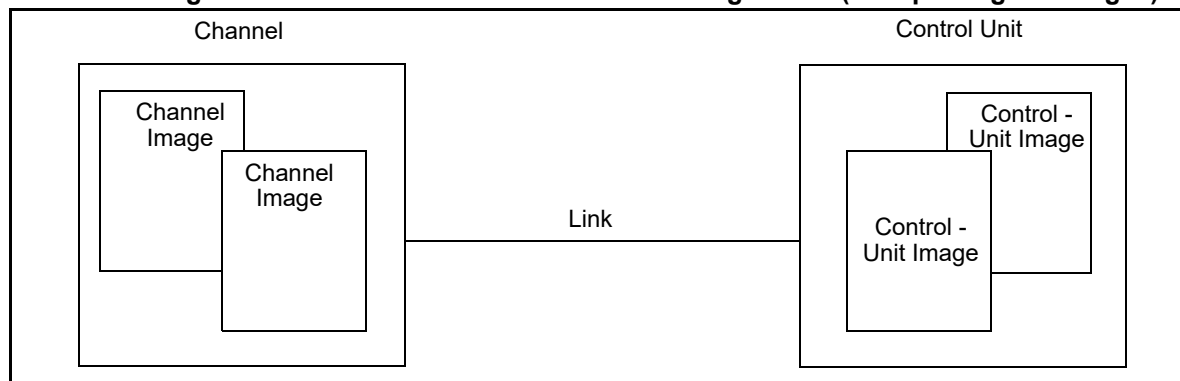


Figure 5 – Point-to-Point Channel-Path Configuration (Multiple Logical Images)

The channel N_Port and the control-unit N_Port resolve contention among the logical images for access to the link.

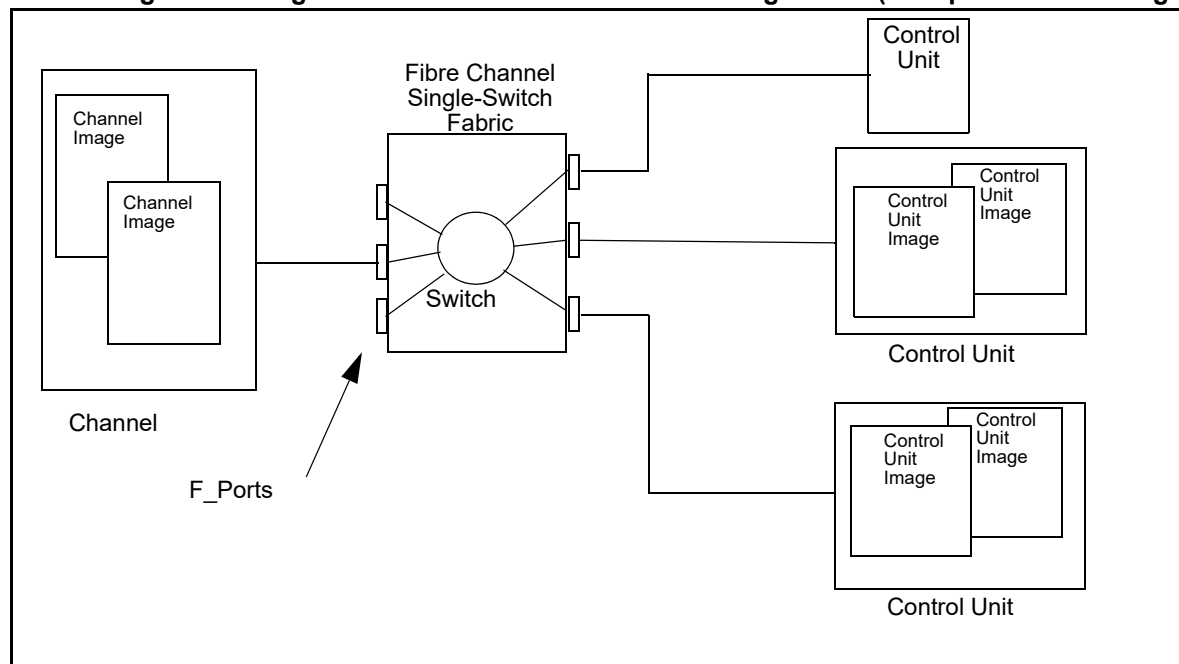
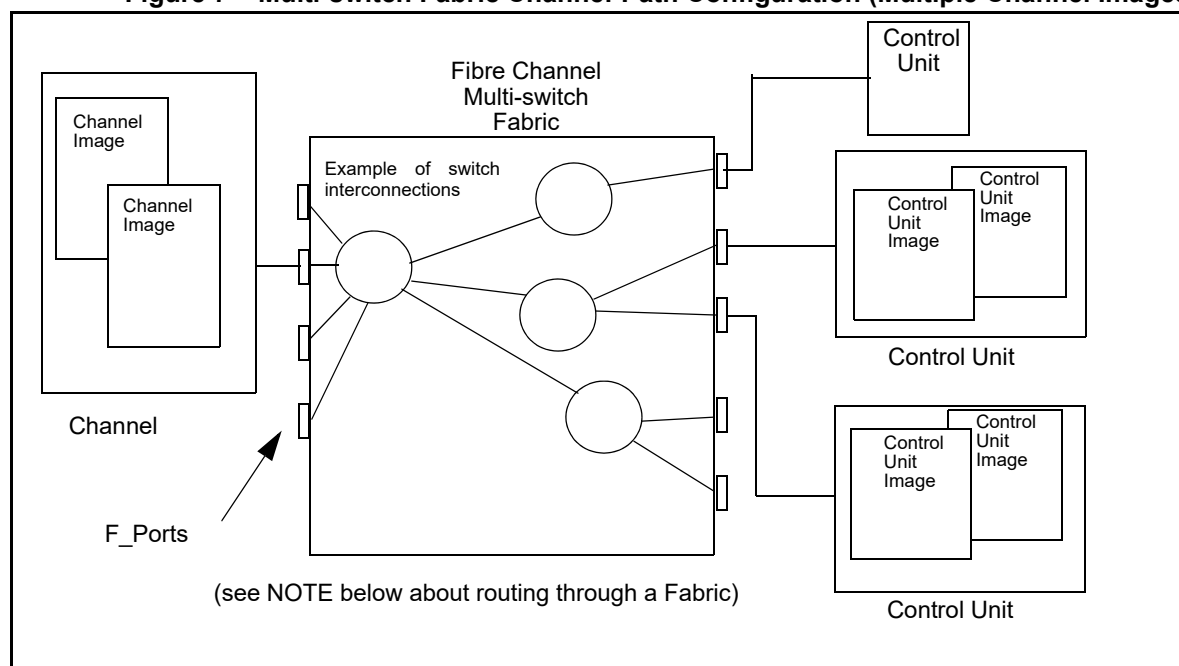
A maximum of one link shall be attached to the channel in a point-to-point channel-path configuration. The maximum number of control-unit images that shall be addressed over the link is 256; therefore, the maximum number of devices that shall be addressed over point-to-point channel path configuration is equal to 256 control-unit images times 256 devices per control-unit image, or 65536.

4.5.3 Fabric Configuration

A channel path that consists of one link which interconnects one or more channel images with a Fabric and one or more links, each of which interconnects the Fabric with one or more control-unit images, forms a Fabric configuration.

Multiple channel images and multiple control-unit images may share the resources of the FC links and the Fabric, such that multiplexed I/O operations may be performed.

There are two types of Fabric configurations: single-switch and multi-switch. In a single-switch Fabric configuration, all channels and control units are attached to a single switch (see figure 6). In a multi-switch Fabric configuration, channels and control units are attached to multiple, interconnected switches (see figure 7).

Figure 6 – Single-switch Fabric Channel-Path Configuration (Multiple Channel Images)**Figure 7 – Multi-switch Fabric Channel-Path Configuration (Multiple Channel Images)**

Channels and control units may be attached to the links from the Fabric in any combination, depending on configuration requirements and depending on available resources in the Fabric. Sharing a control unit through a Fabric means that communication with the control unit may take place over one N_Port in the case where the control unit has only one link to the Fabric or over multiple N_Ports in the case where a control unit has more than one link to the Fabric.

A maximum of one link shall be attached to the channel in a Fabric configuration. The same control unit and device addressing capability exists as for the point-to-point configuration, however the attachment flexibility is

greatly increased with a Fabric through the capability to use the 24 bit N_Port address, to access multiple control units.

For a detailed description of the Fabric refer to FC-SW-6. The N_Port of the channel or control unit attaches to an F_Port of the Fabric. The F_Port is required to support at least Class 2 and Class 3 service.

NOTE 6 – This standard does not limit the number of switches in a Fabric but some implementations may limit the number of switches in the route between an N_Port of any channel and an N_Port of any control unit due to configuration management considerations.

4.5.4 Physical Path

The communication path between a channel and a control unit is composed of two different parts, the physical channel path (physical path) and the logical channel path (logical path). The physical path is the link, or the interconnection of two or more links by a Fabric, that provides the physical transmission path between a channel and a control unit. The logical path is the relationship that exists between a channel and a control unit for device-level communication during execution of an I/O operation and presentation of status.

4.5.5 Logical Path

A logical path is the relationship established between a channel image and control-unit image which identifies a communication path over which device-level information may be transferred and to which certain device-level allegiances may be associated. The logical path is established as part of the channel and control unit initialization procedures by the exchange of FC-SB-6 link-control IUs.

When the logical path is established, device-level communication is allowed on that logical path. All device-level protocols depend upon the existence and identity of logical paths. Device-level protocols are executed over an established logical path by means of the exchange of information units between the channel and the control unit. When a logical path is not established, only link-level communication is permitted.

A logical path is identified within a channel or control unit by the combination of a 24-bit N_Port address identifier assigned to the channel, a 24-bit N_Port address identifier assigned to the control unit, an 8-bit logical address assigned to the channel image establishing the logical path, and an 8-bit logical address assigned to the control-unit image to which the logical path is being established. Both the channel and the control unit recognize a logical path by the same combination of addresses. The two 24-bit address identifiers define the N_Ports to which the images are associated, and the two 8-bit logical addresses identify the images for which the logical path exists.

A channel image may have one or more logical paths to each control-unit image. The number of logical paths a channel or control unit permits depends on system requirements and model capabilities.

Even though multiple logical paths may be associated with the same N_Port on the control unit the channel paths represented by these logical paths are treated as if each were associated with a separate N_Port interface; each logical path represents a logical relationship to a channel.

Allegiances, I/O operations, system resets, and path groups for a particular system are identified by means of the logical path established by the channel for that system. To a control unit, each logical path represents a different channel path or logical subdivision of a channel path.

When multiple control-unit images are provided, their presence is apparent only through associated logical paths.

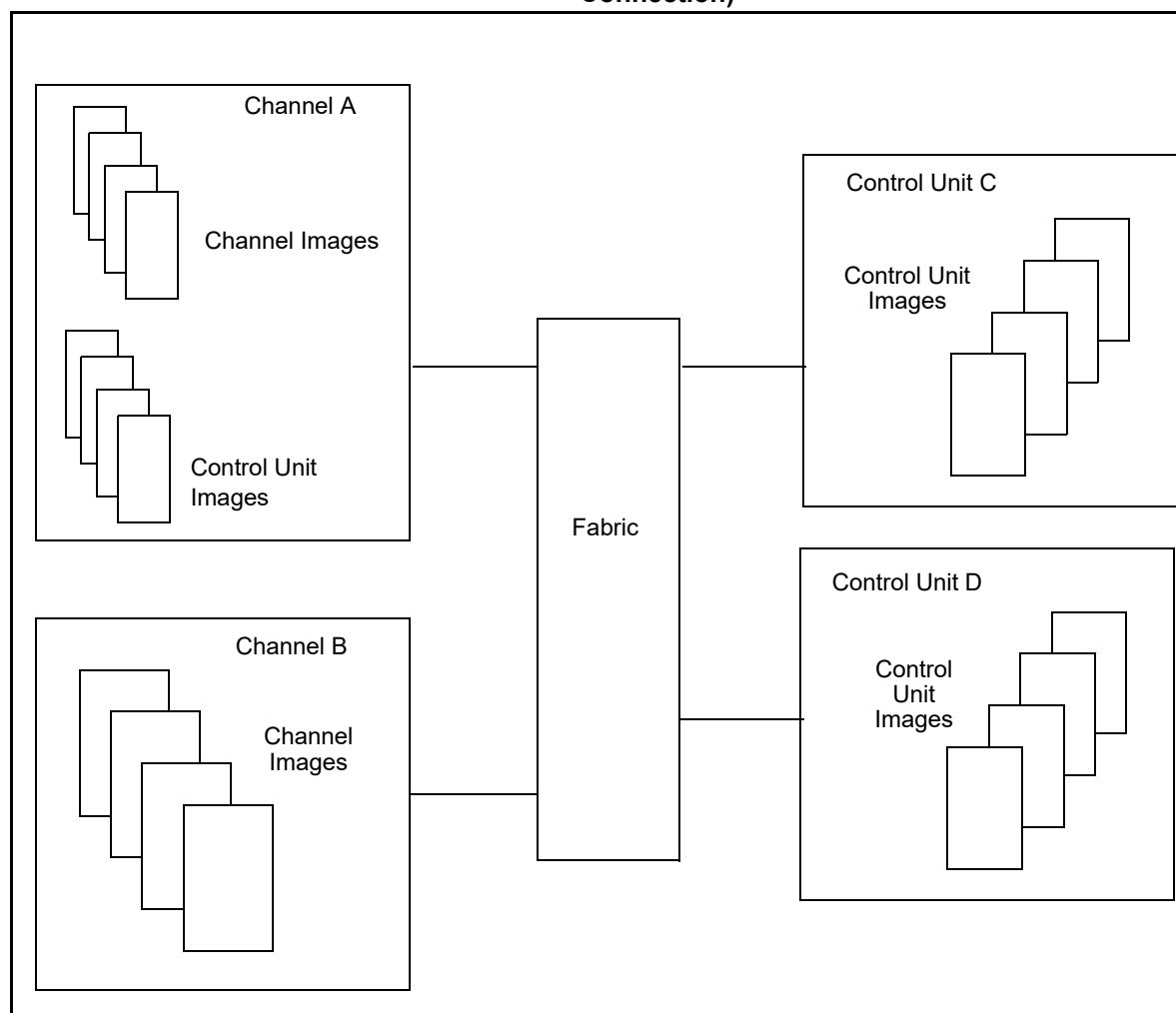
4.5.6 Channel-to-Channel Communication

4.5.6.1 Channel-to-Channel Communication Overview

A channel supporting channel-to-channel communication shall be able to accept a request to establish one or more logical paths and shall be able to provide all of the functions of a control-unit image on logical paths on which communication is to take place. In addition to providing all of the functions required of a channel for other logical paths, a channel supporting channel-to-channel communication shall provide all of the functions required of a control unit on a logical path for which it has accepted an Establish Logical Path (ELP) IU (see 6.4.2). When a channel supports channel-to-channel communication, the N_Port of the channel is also the N_Port of the emulated control unit.

Figure 8 shows a Fabric configuration in which a control-unit image of one channel, referred to as “channel A” is communicating with another channel, referred to as “channel B.” In the configuration shown, one or more of the control-unit images of channel A has accepted a request from channel B to establish a logical path, and the control-unit image within channel A is providing all of the functions required of a control unit on the logical path to a corresponding channel image of channel B. Both channel A and channel B may also have established logical paths with other control units attached to the Fabric.

Figure 8 – Fabric Channel-Path Configuration (Multiple Channel Images, Channel-to-Channel Connection)



4.5.6.2 FC-SB-6 Channel-to-Channel Adapter

A FC-SB-6 channel-to-channel adapter is a channel capable of emulating a control unit and is used by a program in one system to communicate with a program of another system. The FC-SB-6 channel-to-channel adapter provides the data path and synchronization for a data transfer between two channels; however, in so doing, it presents a view as though it were a control unit including support of requests for logical paths and all of the functions of a control-unit image (or images) on logical paths over which communication is to occur.

4.6 Information Transfer

FC-SB-6 information is transferred on an FC link in FC-4 information units. An information unit is a collection of data that is organized according to a particular structure depending on the function being performed or the data content. The types and structures of the IUs defined for this standard are described in 8.3. An information unit is transferred in a sequence which shall be sent as one or more FC-FS-4 device-data frames.

4.7 Protocols

4.7.1 Protocol Overview

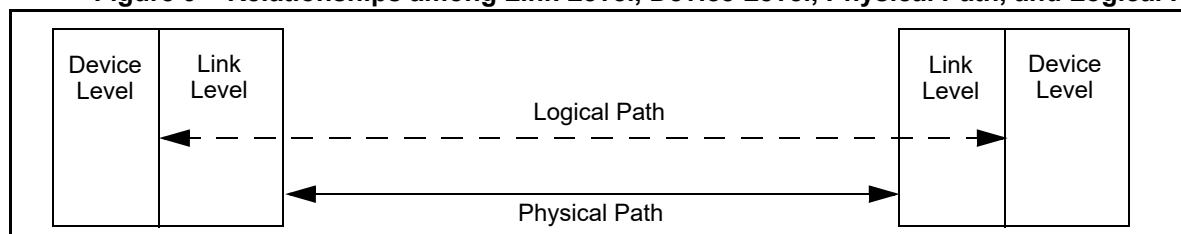
The link-level protocols describe the physical characteristics of a channel path and the associated protocols required for the transmission and reception of frames. The link-level protocols for this standard are defined in FC-FS-4, FC-LS-3, and in clause 6. The device-level protocols are associated with the execution of an I/O operation for a specific device. The device-level protocols for FC-SB-6 are defined in this standard and provide multiplexing at the frame level, streaming of commands and data, and the transport of multiple I/O commands in a single IU. The frame level multiplexing provided is based on Fibre Channel protocols. This multiplexing allows for multiple simultaneous exchanges, each concurrently transferring information, between a channel and control unit over the same N_Port to different devices.

The presence of multiple channel images or multiple control-unit images only becomes apparent through the logical paths that are established. All device-level protocols depend on the existence of and identity of these logical paths. When the logical path is known, the particular logical images for which the link-level and device-level facilities are dedicated at any one time is also known.

The execution of an I/O operation requires link-level and device-level protocols to be present in both the channel and the control unit. Information exchanged between a channel and control unit as a result of executing an I/O operation is transferred under the control of the device-level protocols with the aid of the link-level protocols for sending and receiving frames. The failure to satisfy protocols at either level results in an error being recognized.

Figure 9 shows the relationship between the link level, device level, physical path, and logical path.

Figure 9 – Relationships among Link Level, Device Level, Physical Path, and Logical Path



4.7.2 Link Level Protocol

Link-level protocols refer to FC-FS-4 Basic Link Services (BLS), FC-LS-3 Extended Link Services (ELS) and FC-SB-6 link-level functions.

Link-level protocols are used to establish and maintain the physical and logical paths in order to provide for transmission and reception of frames and primitive sequences. They include functions such as acquiring address identifiers, establishing frame credit, generating the basic frame structure, coordinating the protocols for frame transmission, and checking the integrity of information sent in frames (see FC-FS-4, FC-LS-3 and clause 6).

Certain functions require the exchange of information between the channel and control unit at the link level. These functions are performed by means of link-level protocols (e.g., initialization). Before communication over a channel path is allowed to occur, and before an I/O operation may be executed, some form of initialization shall be completed according to the requirements of the system and according to the specifications of the architectural definition (see FC-LS-3 for link initialization and login definitions).

Once the N_Port of a channel has performed initialization procedures for a control unit, including logging in and establishing a logical path to a control-unit image, that control-unit image is considered operational and capable of executing I/O operations over that channel path.

4.7.3 Device Level Protocols

Device-level protocols allow for transfer of information specifically related to an I/O operation, transfer of status of a device or control unit, and recovery when errors are detected by the channel or the control unit.

The types of device-level information transferred between a channel and control unit that use device-level protocols are: commands, data, control information, and status. Commands are provided by the channel program being executed. Data is the information associated with the command being executed that is to be transferred to or from the device. Control information includes functions that manage the transfer of data between the channel and control unit and functions that manage execution of the I/O operation. Status describes the results of the completion of an I/O operation (successful or unsuccessful) or provides information not associated with an I/O operation that is to be reported to the channel.

Device-level information is transferred between a channel and a control unit in FC-SB-6 information units (see 8.3). FC-SB-6 information units are transferred using link-level functions, device-level functions, link-level protocols and device-level protocols (e.g., when the channel receives initiative to start an I/O operation in command mode, the device-level functions and device-level protocols obtain the command and other parameters from the current CCW and insert them into the appropriate fields within a command IU). When the command IU is ready for transmission, link-level functions and link-level protocols provide additional information (e.g., address identifiers and exchange ID in the frame header) and then coordinate the actual transmission of the frame on the channel path.

4.7.4 Addressing

Two levels of addressing are used for the link-level and device-level structure. All control units and channels use both levels of addressing. Link-level addressing identifies the N_Port, which identifies the physical path within the channel-path configuration to be used for communication between a channel and a control unit. Link-level addressing also identifies the channel images or control-unit images associated with an N_Port (see FC-FS-4).

Device-level addressing identifies the device to the channel or control unit, once the physical path, as designated by the link-level addressing, has been determined.

Link-level addressing is considered to be the first level of addressing because it determines the N_Port, physical path, and the sharing logical image; device-level addressing is considered to be the second level of addressing because it determines the device once the N_Port and logical image are determined. Both levels of addressing have specific address assignment requirements.

Link-level addressing requires each N_Port to be assigned a 24-bit address, called the address identifier. The address identifier of the sender of a frame is in the S_ID field in the FC-FS-4 header, and the address identifier of the recipient of a frame is in the D_ID field of the FC-FS-4 header (see 5.5.3). An N_Port that does not have an address identifier assigned is *unidentified*; an N_Port that has an address identifier assigned is *identified*. The assignment of an address identifier to an N_Port occurs when the N_Port performs initialization and the required login procedure (see FC-LS-3). When an unidentified N_Port performs initialization, it acquires its address identifier through the procedures defined for the login process.

Link-level addressing also requires that each channel and control-unit image be assigned an 8-bit address, called the logical address. The logical addresses of the sender and receiver of an IU are in the FC-SB-6 header field of the IU (see 8.4). A channel image or control-unit image is assigned a logical address when it is created. A logical address shall be unique at a channel or control unit N_Port_ID but need not be unique on a channel path. The assignment of logical addresses and the method by which this assignment is performed are model dependent.

When either multiple channel images or multiple control-unit images are created, they share a single N_Port_ID for each link, and therefore, the same respective address identifier. A maximum of 256 channel images and 256 control-unit images shall share the same N_Port_ID. The combination of the address identifier and the logical address determines the image to which the device-level addressing applies.

Device-level addressing depends on the assignment of an 8-bit address, called the device address, to every device. A device address shall be unique on a logical path on a control unit but need not be unique on a channel path because the resultant combination of the N_Port address identifier, control-unit logical address, and the device address uniquely identifies a device on a channel path. The assignment of device addresses and the method by which this assignment is performed are model dependent (see 8.4.5).

Control units that attach to more than one link provide an N_Port per link, with each N_Port having an assigned address identifier.

All IUs sent on a channel path rely on link-level addressing information to determine the correct physical path to the destination N_Port_ID and, for certain IU types, to determine the image associated with that N_Port_ID. Some IUs require only link-level addressing while others require both link-level addressing and device-level addressing. An IU sent to perform a link-level protocol requires only link-level addressing, and an IU sent to perform a device-level protocol requires link-level addressing and in some cases device-level addressing. Device-level addressing identifies the device that is the source or destination of the information in the IU. For device-level protocols that does not use device-level addressing, the protocol relies on the fully qualified exchange identifier (FQXID) associated with the exchange to identify the logical path and device. The FQXID is provided in the FC-FS-4 header and is composed of the source port identifier, the destination port identifier, the OX_ID field value, and the RX_ID field value (see FC-FS-4).

5 FC-FS-4 Link Control

5.1 FC-FS-4 Link Control Overview

FC-FS-4 provides services which support the transfer of data between N_Ports in frames which consist of a frame header and a payload. This clause describes how FC-FS-4 services are used to perform FC-SB-6 link-level functions and device-level functions, and defines how the fields in the frame header are used to perform these functions. For a general description mechanisms and frame header fields which are unrelated to this standard, see FC-FS-4.

5.2 Class of Service

Class 3 service shall be used when sending all FC-SB-6 IUs except for the test initialization IU (see 6.4.7). Class 2 service shall be used when sending the test initialization IU because the N_Port receiving the test initialization IU may be in a non-operational state. When this is the case, Class 2 provides the means for the Fabric to provide timely notification of this fact, thereby avoiding costly timeouts and retry operations.

The FC-SB-6 ULP requires the Fabric to indicate support for sequential delivery during Fabric login (see clause 7).

NOTE 7 – Since this standard requires the test initialization IU to be sent in Class 2, N_Ports which support this standard are required to indicate support for Class 2 at login. See FC-LS-3 for additional information.

5.3 Buffer-to-Buffer Credit Reclamation

During operation over extended periods of time, errors may occur which result in the loss of one or more R_RDY primitive signals. The loss of R_RDY primitive signals affects the available buffer-to-buffer credit at an N_Port and as a result, may affect that N_Port's ability to send frames and maintain optimum performance. Designs should be tolerant of the loss of some R_RDY primitive signals for short periods of time but also shall be capable of taking some action to offset the cumulative effect of errors over longer periods of time. The cumulative loss of R_RDY primitive signals over long periods of time may result in a reduction in available buffer-to-buffer credit to a point where performance is significantly affected or, in the extreme case where the available buffer-to-buffer credit goes to zero, the inability to send a frame, and an FC-FS-4 link timeout error.

To prevent the loss of R_RDY primitive signals from resulting in a performance degradation or FC-FS-4 link timeout error, N_Ports shall perform a model-dependent buffer-to-buffer credit reclamation procedure which reinitializes the available buffer-to-buffer credit at both ends of the link. The preferred reclamation procedure is specified in FC-FS-4.

When the preferred buffer-to-buffer credit reclamation procedure is not supported, an alternative procedure shall be performed periodically at model-dependent time intervals. The time interval of the model-dependent procedure should be as large as possible provided that buffer-to-buffer credit reclamation is performed before the loss of R_RDY primitive signals results in a performance degradation. To minimize the number of IUs lost as a result of buffer-to-buffer credit reclamation, the buffer-to-buffer reclamation procedure is not initiated when open exchanges exist, and an effort is made to quiesce the link before the procedure is performed.

NOTE 8 – When the preferred buffer-to-buffer credit reclamation procedure is not performed, the channel may quiesce the link before performing buffer-to-buffer credit reclamation by not initiating new exchanges and allowing all channel programs to complete and all exchanges to end. Control units may quiesce the link by completing all channel programs which are in process and by returning control unit busy status to new commands or control functions other than a system reset or purge path. Since efforts made to quiesce the link

do not guarantee that no IUs are lost, occasional errors resulting from buffer-to-buffer credit reclamation should be expected.

NOTE 9 – When the preferred buffer-to-buffer credit reclamation procedure is not performed, implementations should use the FC-FS-4 link reset primitive sequence protocol to provide buffer-to-buffer credit reclamation. In addition, it is preferred that data queued in receive and transmit buffers before the protocol is initiated as well as data received into buffers during the time when the protocol is being performed be preserved and processed normally when the protocol is completed. For additional information on the link reset primitive sequence protocol, see FC-FS-4.

NOTE 10 – When the preferred buffer-to-buffer credit reclamation procedure is not performed, the suggested default time interval between the performance of each buffer-to-buffer credit reclamation procedure is approximately 24 hours. A means should be provided to adjust the time interval and randomly vary the time interval by up to 10% so that reclamation does not occur at predictable time intervals such as the same time each day. For Fabric configurations, a means should be provided which minimizes the probability of simultaneous buffer-to-buffer credit reclamation by a large number of N_Ports because of the system performance impact which results. The means used to avoid simultaneous buffer-to-buffer credit reclamation is model-dependent but may include the use of a slightly different time interval by each N_Port or by causing the time interval of each N_Port to begin at a different time.

NOTE 11 – When the preferred buffer-to-buffer credit reclamation procedure is not performed, unnecessary execution of an alternative buffer-to-buffer credit reclamation procedure should be avoided. An implementation should defer buffer credit reclamation for a model-dependent time interval after performing a procedure such as login or link initialization which initializes the available buffer-to-buffer credit. In a point to point configuration, only one of the N_Ports is required to initiate the buffer-to-buffer credit reclamation procedure because the procedure initializes the available buffer-to-buffer credit at both ends of the link. F_Ports are not required to perform the procedure since performance of buffer reclamation by the attached N_Port reinitializes the available buffer-to-buffer credit at both the N_Port and the attached F_Port.

5.4 FC-SB-6 Sequences and Exchanges

5.4.1 FC-SB-6 Sequences

When receiving frames from the link, FC-FS-4 provides a mechanism which assembles sub-blocks of data contained in the payloads of one or more frames into a single data block called a sequence. Each FC-4 defines the contents of the sequences which are used for ULP functions. When the contents and usage of a sequence are defined by a ULP, it is referred to as an information unit (IU). For this standard, IUs contain commands, device-level controls, link controls, and related functions. The IUs defined by this standard are summarized in Table 1, and the contents of FC-SB-6 IUs conform to the general structures in 8.3. The protocols for using IUs for FC-SB-6 link-level functions and device-level functions are found in clause 6 and clause 9, respectively.

5.4.2 FC-SB-6 Exchanges

An exchange pair consisting of two unidirectional exchanges, one used by the channel to send IUs and one used by the control unit to send IUs, are required for all FC-SB-6 link-control functions and for all FC-SB-6 device-level functions that are executed in command mode. A single bi-directional exchange, referred to as a transport exchange, is required for all device-level functions executed in transport mode. Exchange pairs and transport exchanges are described in the following sections.

5.4.2.1 FC-SB-6 Exchange Pairs

IUs which a channel sends during the execution of an FC-SB-6 link-control function or the execution of an FC-SB-6 device-level function in command mode are restricted to one exchange, and IUs which a channel receives during the operation are restricted to a different exchange. The exchange on which the channel sends IUs is referred to as the outbound exchange, and the exchange on which the channel receives IUs is referred to as the inbound exchange.

Inbound exchanges and outbound exchanges shall transfer IUs in a single direction. When both an outbound exchange and an inbound exchange simultaneously exist between a channel and a control unit for the execution of the same link-level function or device-level function, an exchange pair is said to exist, and the control unit is said to be connected to the channel. A channel program which is executed in a single connection uses only one exchange pair. If the connection is removed by the closing of the exchanges during the channel program, a new exchange pair shall be required to complete the channel program.

5.4.2.1.1 General Rules for Initiating Exchange Pairs

A channel shall initiate an exchange pair by sending an initiation IU as an unsolicited command or unsolicited control information category. A control unit shall initiate an exchange pair by sending an initiation IU as an unsolicited control or unsolicited data information category (see Table 1).

5.4.2.1.2 Exchange Pairs for FC-SB-6 Link Control Functions

A control-unit image that initiates an exchange pair for an FC-SB-6 link-control function shall wait for a response to the initiation IU before it initiates another exchange pair with the N_Port of the same channel if the exchange pair to be initiated is:

- a) for another FC-SB-6 link-control function, or
- b) for a device-level function not associated with a specific device.

5.4.2.1.3 Exchange Pairs for Device-Level Functions

A control-unit image that initiates an exchange pair for a device-level function not associated with a specific device shall wait for a response to the initiation IU before it initiates another exchange pair if the exchange pair to be initiated is:

- a) with the same channel image for a device-level function not associated with a specific device;
or
- b) with the N_Port of the same channel for an FC-SB-6 link-control function.

A channel or control unit may initiate multiple exchange pairs, each for a different device or for the same device provided that there is no more than one exchange pair or transport exchange for a specific device on a logical path. A new exchange pair for a specific device on a logical path shall not be initiated when any of the following conditions apply:

- a) an exchange pair or transport exchange already exists for the same device on the same logical path; or
- b) the channel or control unit initiating the new exchange pair has initiated another exchange pair for the same device on the same logical path and not received a response.

If either of the above conditions apply, the channel or control unit shall wait for the existing exchange pair or transport exchange to be closed before initiating the new exchange pair for the device on the logical path.

5.4.2.1.4 Exchange Pair Processing

In order to avoid errors caused by lost IUs or by the inability to send an IU, sufficient resources should be held in reserve in order to support new exchange pairs for unexpected events. If an IU initiating a new exchange pair is received, sufficient resources should be available to properly receive the IU and to initiate a new exchange in response. If an unexpected event requiring a new exchange pair to be initiated occurs, resources should be available for supporting the new exchange pair.

After a channel or control unit has closed one of the exchanges of an exchange pair for a device on a logical path, an abnormal condition may result in the recognition of a valid initiation IU for the same device on the same logical path before the other exchange of the previous exchange pair has been closed. When this occurs and the initiation IU is not a purge path IU, the IU may be accepted and held until both exchanges of the previous exchange pair have been closed or a link-busy condition may be recognized (see 6.4.10 and 9.5.1).

5.4.2.2 FC-SB-6 Transport Exchanges

IUs which a channel and control unit send during the execution of an FC-SB-6 device-level function that is performed in transport mode are restricted to a single, bi-directional exchange referred to as a transport exchange. Transport exchanges are not used to execute link-level functions.

5.4.2.2.1 General Rules for Initiating a Transport Exchange

A channel shall open a transport exchange by sending a transport-command IU as an Initiation IU. A control unit shall not open a transport exchange (see table 1).

5.4.2.2.2 Transport Exchanges for Device-Level Functions

A channel may open multiple transport exchanges, each for a different device or for the same device on different logical paths. A new transport exchange may be opened for a specific device on a logical path when a transport exchange already exists for that device and logical path only to perform an interrogate operation (see 9.3.3.2); otherwise, the channel shall not open a new transport exchange to a device and logical path when a transport exchange or exchange pair is open for that device and logical path. When a transport exchange or exchange pair is open for a device and logical path, the channel shall wait for the existing transport exchange or exchange pair to be closed before initiating the new transport exchange for the device on the logical path.

5.5 FC Frame Header Fields

5.5.1 Frame Header Field Overview

The FC frame header identifies the source and destination of a frame, the exchange and sequence to which a frame belongs, the order in which a frame was sent, and the type of information in the frame payload. The frame header consists of a frame routing field (R_CTL), source link address field and destination link address field (S_ID and D_ID), an FC-4 identification field (TYPE), an optional header control field (DF_CTL), fields which identify and control FC-FS-4 sequences and exchanges (F_CTL, OX_ID, RX_ID, SEQ_ID, SEQ_CNT), and a parameter field whose function depends on the frame type. The usage of these fields for frames which are part of an IU is described in 5.5. The frame header format is described in FC-FS-4. For a definition of the settings of frame header fields in frames which contain FC link-control functions and BLSSs, see FC-FS-4. For a definition of FC ELSSs, see FC-LS-3.