

INTERNATIONAL STANDARD

ISO/IEC 14165-222

First edition
2005-05

Information technology – Fibre channel –

Part 222: Single-byte command sets-2 mapping protocol (FC-SB-2)



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INFORMATION TECHNOLOGY – FIBRE CHANNEL –

PART 222: Single-byte command sets-2 mapping protocol (FC-SB-2)

FOREWORD

- 1) ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.
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International Standard ISO/IEC 14165-222 was prepared by subcommittee 25: Inter-connection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

Introduction

FC-SB-2 describes the Fibre Channel protocol mapping for the Single-Byte Command Code Sets. The protocol is intended for use with ANSI X3.230, FC-PH, and its subsequent enhancements which specify the Fibre Channel Physical and Signalling Interface. FC-SB-2 is one of a number of Fibre Channel protocol mappings, referred to as FC-4s.

The reader should be familiar with FC-PH, Single-Byte Command Code Sets Connection (SBCON) Architecture (ANSI X3.296-1997).

Figure 1 shows the relationship of this FC-4 proposed working draft standard (highlighted rectangle) with other Fibre Channel standards and draft proposed standards.

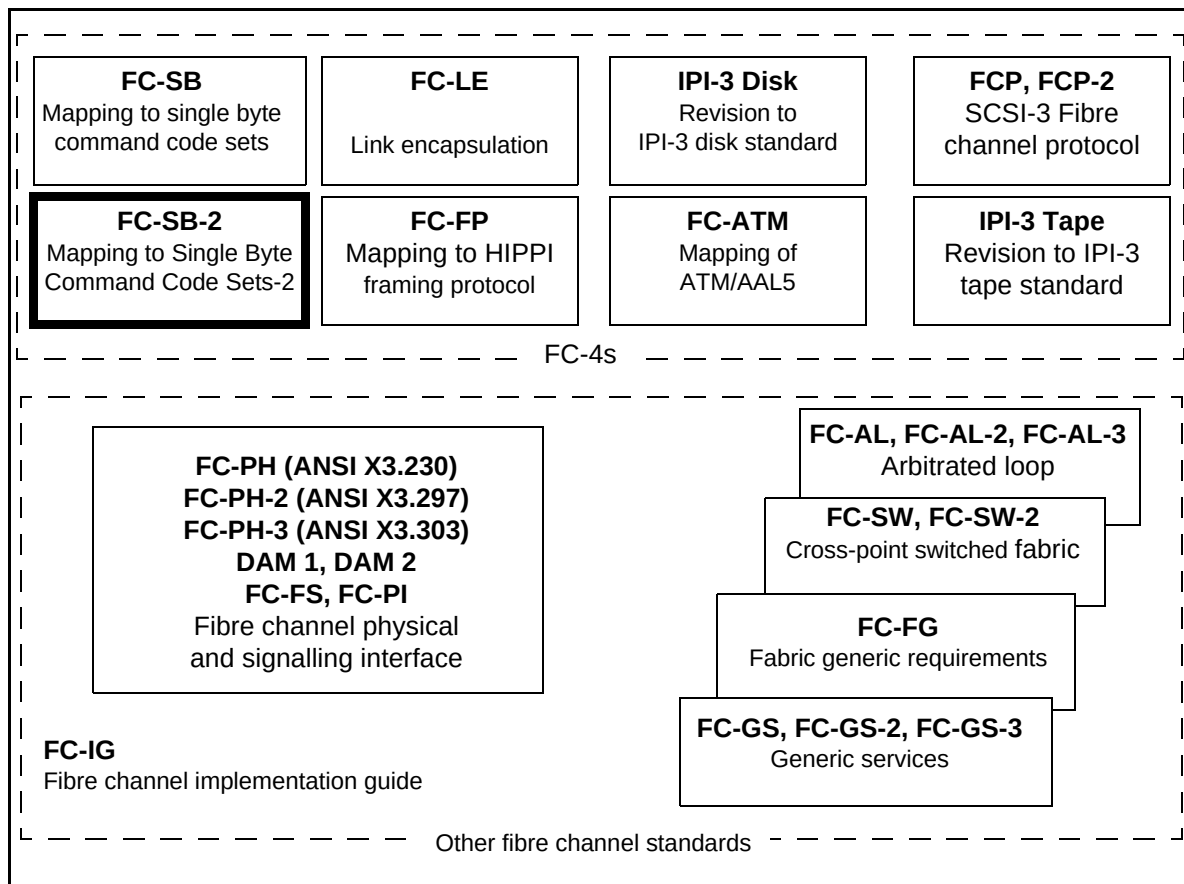


Figure 1 – Document relationship

The information presented in this document is grouped into clauses:

Clause 1, "Scope," gives a general introduction to the document.

Clause 2, "Normative references," lists the standards which are referenced in the text and which constitute provisions of this document.

Clause 3, "Definitions and conventions," describes the basic elements, acronyms, naming conventions, and terminology used in this document.

Clause 4, "Structure and concepts," provides an overview of the structure, concepts, configurations, and mechanisms used in this document and FC-PH, reference [1].

Clause 5, "FC-PH Link Control," describes how FC-2 link services, in conjunction with the link header, are used to perform SB-2 link-level and device-level functions.

Clause 6, "Link-Level functions," describes the link-level services and link-control functions required to establish and maintain the operational state of the FC-link.

Clause 7, "N_Port link initialization," describes an initialization process, in terms of the hierarchical steps (procedures), that need to be performed over the FC-link in order to establish link-level and device-level communication.

Clause 8, "SB-2 Information units," describes the SB-2 Information Unit (IU) types, and accompanying formats, that are transferred between conformant SB-2 ULPs.

Clause 9, "Device-Level functions and protocols," describes the functions and protocols to be used in the execution of I/O operations, exchange of control information, and device-level recovery.

Clause 10, "Link error detection," describes SB-2 level error detection mechanisms that are used in conjunction with FC-PH level error detection to insure the integrity of the FC-link and the data transferred.

Clause 11, "Error recovery actions," describes the SB-2 link-level and device-level recovery actions taken for FC-PH and SB-2 errors.

Annex A, "Fabric address assignment," describes a fabric address-assignment scheme which allows a channel to construct the three-byte N_Port ID of a given control unit from a configuration record which contains only a single byte entry for each control unit.

Annex B, "Correlation of exchanges of an exchange pair," describes some of the facilities available for correlation of an outbound and inbound exchange of an exchange pair.

Annex C, "LRC calculation," provides the procedure and an example of the Longitudinal Redundancy Check (LRC) calculation.

Annex D, "Status/chaining summary," summarizes the conditions controlling whether the control unit breaks or continues command chaining and when to present status to the channel.

INFORMATION TECHNOLOGY – FIBRE CHANNEL –

PART 222: Single-byte command sets-2 mapping protocol (FC-SB-2)

1 Scope

This part of ISO/IEC 14165 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 signalling 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 ANSI Fibre Channel Physical and Signaling Interface (FC-PH) architecture (ANSI X3.230-1994, reference [1]). This FC-4 Upper Level Protocol is referred to as the Fibre Channel-Single-Byte-2 Command Code Sets Mapping Protocol (or for brevity, SB-2).

2 Normative references

2.1 General information concerning references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Copies of the following documents may be obtained from ANSI: Approved ANSI standards, approved and draft international and regional standards (ISO, CEN/CENELEC) and approved foreign standards (including BSI, JIS and DIN).

2.2 Approved references

[1] ANSI X3.230-1994, *Information Technology – Fibre Channel Physical and Signaling Interface (FC-PH)*, with amendment 1, AM1-1996.

[2] ANSI X3.297-1997, *Information Technology – Fibre Channel – Physical and Signalling Interface-2 (FC-PH-2)*

[3] ANSI X3.303-1998, *Fibre Channel – Physical and Signalling Interface-3 (FC-PH-3)*

[4] ISO/IEC 14165-131:2000, *Information technology – Fibre Channel – Part 131: Switch Fabric Requirements (FC-SW)*

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

[6] ISO/IEC 9314-2:1989, *Information processing systems – Fibre Distributed Data Interface - Part 2: Token Ring – Media Access Control (FDDI-MAC)*

2.3 References under development

When drafting this document, 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 organizations, as indicated.

NOTE For more information on the current status of a document, contact the Secretariats of the relevant organisations.

[7] ANSI INCITS-230-1994/AM2-1999, *Fibre Channel-Physical and Signaling Interface (FC-PH) Amendment 2*

[8] ISO/IEC 14165-251, *Information technology – Fibre Channel – Part 251: Framing and Signaling (FC-FS)*

3 Definitions and conventions

For SB-2, the following definitions and conventions apply.

3.1 Definitions

3.1.1 channelor: an entity, typically of a host computer, which consists of one N_Port and elements which perform the functions specified by SB-2 to provide access to I/O devices by means of control units or emulated control units.

3.1.2 channel-command word (CCW): (1) A control block which contains an I/O request. (2) A structure of a specific system architecture which specifies the command to be executed along with parameters.

3.1.3 Channel image: a single ULP instance of a channel having the logical appearance of a channel.

3.1.4 Channel-path identifier (CHPID): a system-unique 8-bit value assigned to each installed channel path of a system.

NOTE See 4.4 for information regarding channel paths.

3.1.5 Channel program: A single channel-command word or a sequence of channel-command words executed sequentially that control a specific sequence of channel operations.

3.1.6 Channel-to-channel connection: A channel-to-channel (CTC) connection is an association between two channels which allows two channels to exchange IUs on an exchange pair.

A CTC connection is established through an emulated control unit provided by one of the channels. A CTC connection exists when a logical path is established between one channel and the emulated control unit provided by the other channel.

3.1.7 Connection: Between a channel and control unit, an association established 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.

A connection, once established, remains until one or both of the exchanges of the exchange pair is no longer open. Typically, an exchange pair exists for the duration of execution of an I/O operation or a chain of I/O operations.

3.1.8 Control unit: a 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.

3.1.9 Control-unit image: a single ULP instance of a control unit having the logical appearance of a control unit.

3.1.10 Device: In this document, the term device is used to refer to an I/O device such as a printer, magnetic-tape unit and direct-access-storage device. The I/O device operation is regulated by a control unit that provides the logical and buffering capabilities necessary to operate the I/O device.

3.1.11 Device Information Block (DIB): a data block present in all SB-2 information units which contains a 12-byte DIB header, a 4-byte redundancy check field, and optionally a variable length DIB data field.

NOTE See 8.3 for additional information.

3.1.12 Disconnection: see removal of a connection by closing both exchanges of an exchange pair.

3.1.13 Exchange pair: consists of two FC-PH exchanges with sequence initiative in opposite directions. The two exchanges are linked together by the SB-2 ULP.

The exchange pair carries all the communication required between ULP images during a connection. One exchange is originated by the channel and the other is originated by the corresponding control unit.

3.1.14 FC-SB-2 Channel-to-channel adapter: a channel capable of emulating a control unit which is used by a program in one system to communicate with a program of another system.

The adapter provides a fully functional 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.

3.1.15 Image: a group of related processes.

Examples of an image are a single system or a single logical partition of a system behind an N_Port.

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

3.1.17 Initiation IU: first IU of an exchange.

3.1.18 I/O operation: Execution of an I/O operation is accomplished by decoding, accepting, and executing a command by an I/O device.

One or more CCWs arranged for sequential execution form a channel program and are executed as one or more I/O operations, respectively.

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

3.1.20 SB-2 offline condition: SB-2 offline condition is recognized when a receiver transitions from the FC-PH active state to the FC-PH OLS receive state.

3.1.21 ULP process: A function executing within a channel or control unit which conforms to the Upper Level Protocol (ULP) immediately above the SB-2 service interface.

3.2 Keywords

3.2.1 mandatory: indicates items required to be implemented as defined by this standard.

3.2.2 may: indicates flexibility of choice with no implied preference.

3.2.3 model-dependent: describes an item (for example, bit, field, code value, etc.) or a behavior (for example, number of retries) which is not defined by this standard and may be vendor defined.

3.2.4 optional: 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.

3.2.5 reserved: refers 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 sender and ignored by the recipient.

3.2.6 shall: indicates a mandatory requirement.

Designers are required to implement all such requirements to ensure interoperability with other products that conform to this standard.

3.2.7 should: indicates flexibility of choice with a preferred alternative; equivalent to the phrase "it is recommended".

3.2.8 vendor-specific: A keyword describing items (for example, a bit, field, code value, etc.) that are not defined by this standard and may be vendor defined.

3.3 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:

- the first letter of each word in uppercase and the rest lowercase (for example, Exchange, Class, etc.),
- 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. (for example, N_Port),
- 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. (for example, device-level, CUE-with-busy, etc.).

All terms and words not conforming to the conventions noted above have the normal technical English meanings.

Numbered or listed items in this standard do not represent any priority unless explicitly indicated.

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.

Additional conventions applicable to this document are described in the following sections.

3.3.2 FC-PH

In order to support the SB-2 protocol, all FC-PH functions referenced in this document are required to be supported by a channel, control unit and Fabric (if present).

3.3.3 Bit numbering

All words defined by FC-PH use the convention that bit 31 is the Most Significant Bit (MSB) and bit 0 is the Least Significant Bit (LSB). (See FC-PH, reference [1].) All words defined by the SB-2 protocol use the convention that bit 0 is the MSB and bit 31 is the LSB. All bytes defined by the SB-2 protocol use the convention that bit 0 is the MSB and bit 7 is the LSB. For both FC-PH and SB-2, 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 2 gives a comparison between the FC-PH convention and the SB-2 convention.

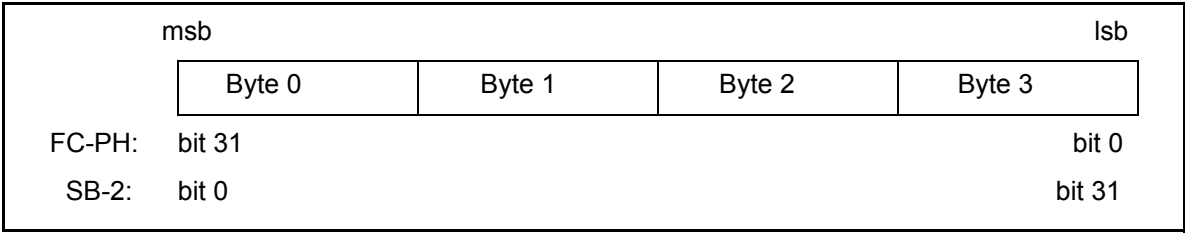


Figure 2 – FC-PH and SB-2 bit numbering conventions

3.3.4 Binary notation

Binary notation may be used to represent some fields. Single bit fields are represented using the binary values 0 and 1. 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'.

3.3.6 Abbreviations, acronyms, and symbols

Acronyms applicable to this document are listed below. See FC-PH, reference [1], for FC-PH acronyms and FC-FS, reference [8], for FC-FS acronyms. For all other acronyms, refer to the index.

ABTS	Abort Sequence FC-PH BLS
AS	Address Specific
BLS	FC-PH Basic Link Service
CC	Command Chain
CCW	Channel-Command Word
CD	Chain Data
CH	Chaining
CHPID	Channel Path Identifier

CI	Channel Initiated
CNP	CRC Not Provided
COC	Chain On Command immediate
CR	Command Retry
CRC	Cyclic Redundancy Check
CRR	Command Response Request
CTC	Channel-to-Channel
CTCA	Channel-to-Channel Adapter
DACK	Device-level Acknowledgment
DIB	Device Information Block
DU	Data chaining Update
E	End
EE	Early End
ELP	Establish Logical Path link control IU
ELS	FC-PH Extended Link Service
ES	Extended Status
FC	Fibre Channel
FC-PH	ANSI standard - FC Physical and signalling interface, reference [1]
FLOGI	F_Port Login FC-PH ELS
IU	Information Unit (See FC-PH, reference [1].)
IUI	Information Unit Identifier
LACK	Link level Acknowledgment link-control IU
LBY	Link level Busy link control IU
LIRR	Link-Incident Record Registration FC-FS ELS
LOGO	N_Port Logout FC-PH 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 FC-PH ELS Reply
PCI	Program Control Interruption
PLOGI	N_Port Login FC-PH ELS
REX	Repeat Execute
RLIR	Registered Link Incident Record FC-FS ELS
RLP	Remove Logical Path link control IU
RNID	Request Node Identification Data FC-FS ELS
RRQ	Reinstate Recovery Qualifier FC-PH ELS
RSCN	Registered State Change Notification FC-FS ELS
RV	Residual count Valid
SB-2	Single Byte protocol on FC
SCR	State Change Registration FC-FS ELS
SDC	Self-Describing Component
SLI	Suppress Length Indication
SSS	Synchronize Send Status
SYR	Synchronize Response
TIN	Test Initialization link control IU
TIR	Test Initialization Result link control IU
ULP	Upper Level Protocol

4 Structure and concepts

4.1 Introduction

This clause provides an overview of the structure, concepts, and mechanisms used in Fibre Channel (FC), FC-PH, and SB-2.

Communication over Fibre Channel takes place between a pair of N_Ports. FC-PH defines 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. For purposes of brevity, all future references to the term “control unit” assume both configurations of either a physical control unit or an emulated control unit unless stated otherwise.

SB-2 is a mapping protocol, referred to as an FC-4. An FC-4 is a mapping protocol, that maps a particular Upper Level Protocol (ULP) instance to FC-PH. The SB-2 ULP is based on the Single-Byte Command Code Set. See Bibliography 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-PH 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 SB-2 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 SB-2 overview

This clause describes the relationship between some of the SB-2 concepts and Fibre Channel concepts.

4.3.1 SB-2 instance

An SB-2 ULP instance may be either an N_Port-based SB-2 channel image, an N_Port-based SB-2 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 SB-2 protocols

Two levels of protocol are defined for SB-2:

- link-level,
- device-level.

SB-2 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 SB-2 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 a channel and one or more control units. The physical elements that make up a channel path are a channel, possibly a Fabric, one or more control units, and one or more links.

4.4.2 Channel

A channel provides the functions specified by FC-PH and SB-2 and performs their prescribed protocols. Each channel shall provide one N_Port. When the N_Port of a channel is shared by multiple related 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 3.1.6 and 4.5.6.)

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 and physical paths. The N_Port of a channel performs certain functions for all sharing channel images (for example, link synchronization and acquisition of address identifiers) and may perform functions for a single sharing channel image (for example, 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-PH.

Figure 3 shows multiple channel images which are sharing the same N_Port.

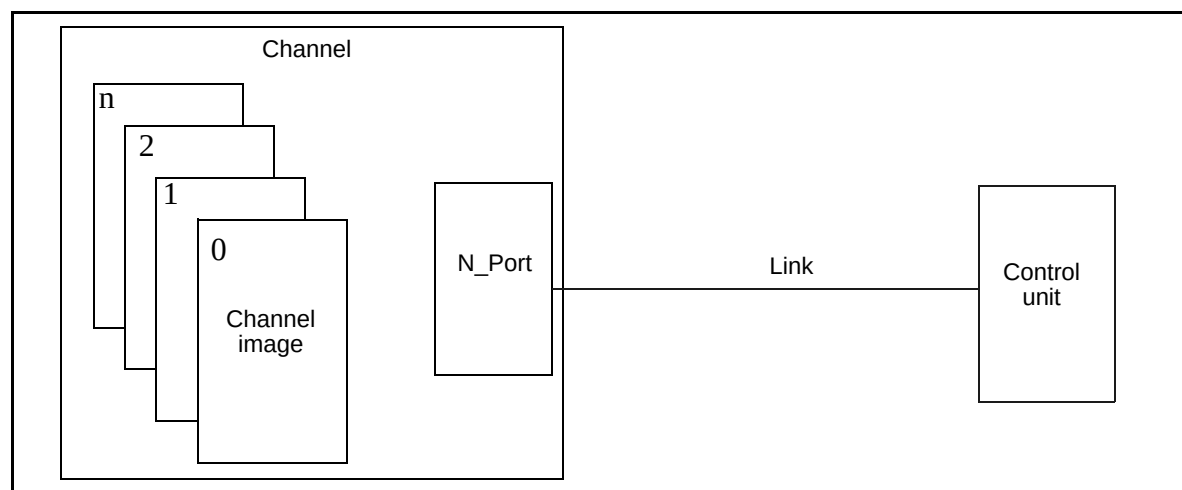


Figure 3 – Channel images

Either single or multiple channel images may exist at an N_Port. Each channel image denotes one SB-2 channel ULP instance.

NOTE Channel images represent different logical channel paths (logical channel paths or for brevity, logical 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 the N_Port provided by the channel. These common facilities which include N_Port functions and may include SB-2 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.

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

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 the 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 the 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, however, the number of logical paths that a control unit permits is model dependent.

NOTE 1 Certain ULP operating systems 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 2 A control unit may have more than one N_Port, each configured to communicate with a different channel.

NOTE 3 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 SB-2 functions and protocols. Those SB-2 functions and protocols not provided by the common facilities shall be provided by the individual images.

FC-PH and SB-2 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 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-PH.

Figure 4 shows multiple control-unit images which are common to a single N_Port.

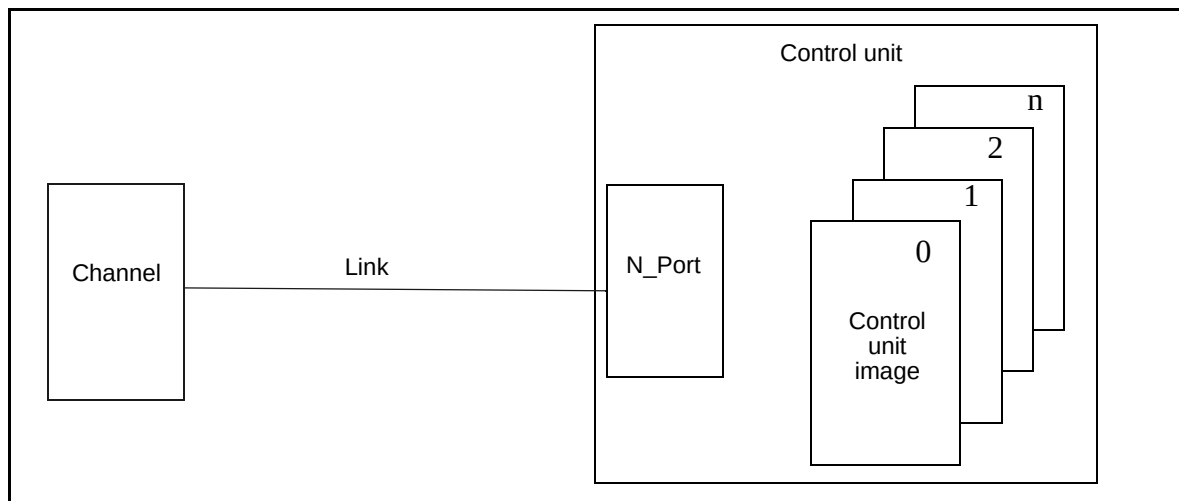


Figure 4 – Control unit images

NOTE Each control-unit image is architecturally identical, even though each image may provide a different device type); therefore, there is no change to the definition of a control unit and no need to use any term other than *control unit* in this document. 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 fully described in FC-PH, reference [1].

4.5 Channel-path configurations

4.5.1 Channel-path configuration overview

Point-to-point and fabric channel path configurations are provided.

NOTE SB-2 does not preclude NL_Port usage, however, the operation of SB-2 on a loop is not supported because not all potential problems associated with operating SB-2 on a loop have yet been considered.

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 5 shows a point-to-point configuration consisting of a single channel image and single control unit image, and Figure 6 shows a point-to-point configuration consisting of multiple channel and control unit images.

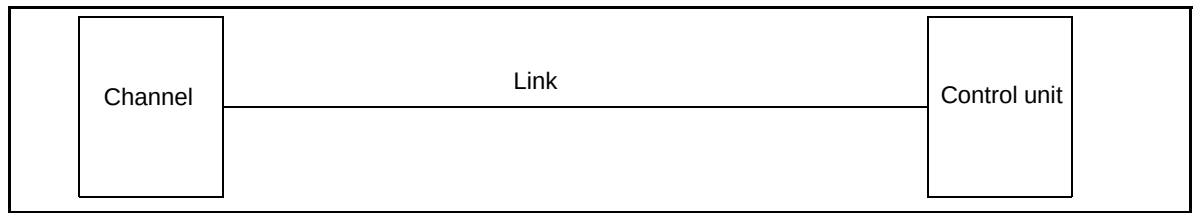


Figure 5 – Point-to-point channel-path configuration (single logical image)

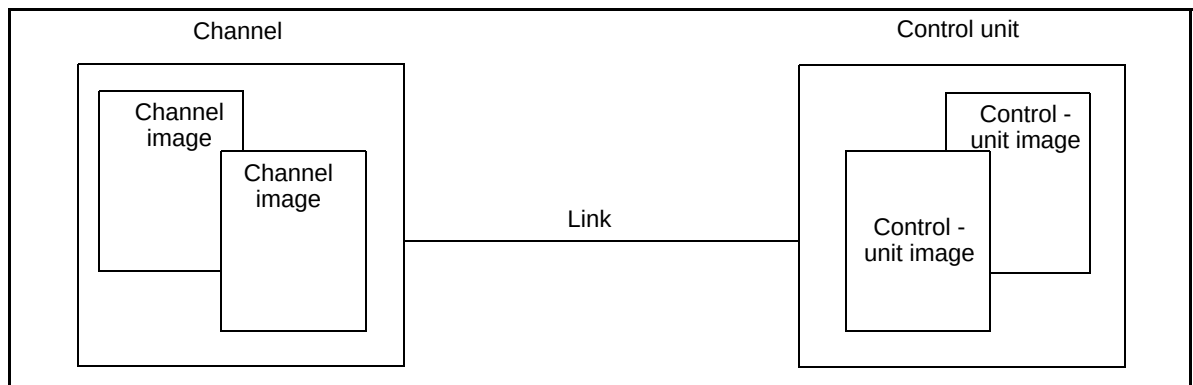


Figure 6 – Point-to-point channel-path configuration (multiple logical images)

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 a channel path configured point-to-point 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 an FC switch fabric (or for brevity Fabric) and one or more links, each of which interconnects the Fabric with one or more control-unit images, forms a fabric configuration. (See Figure 7.)

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.

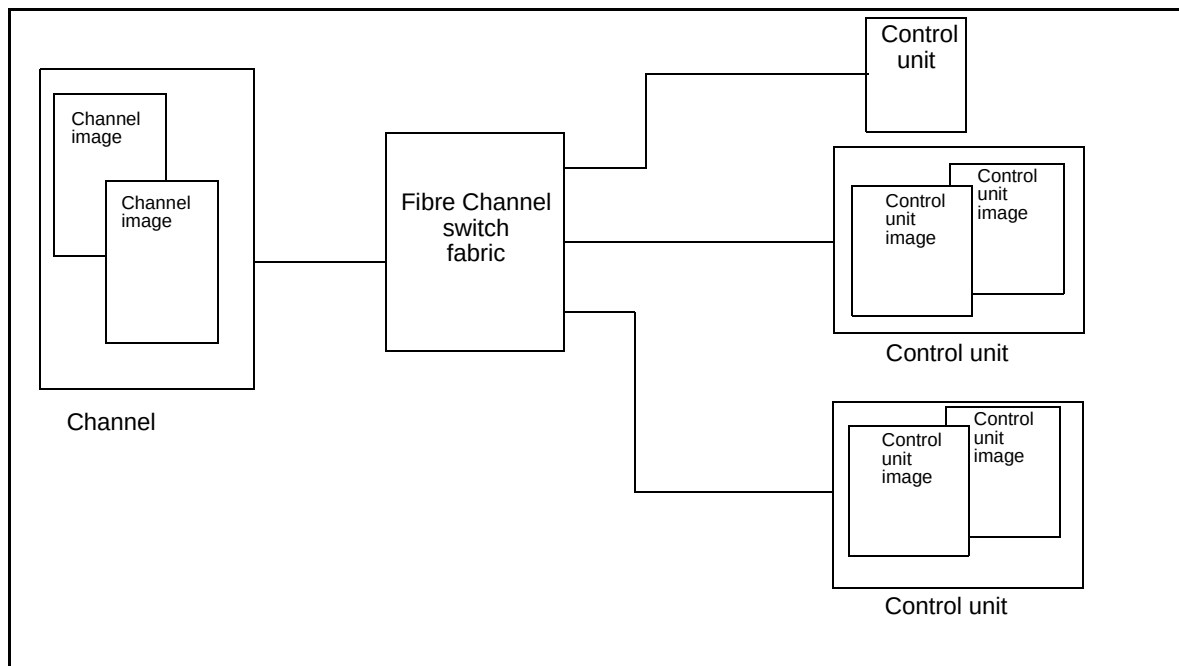


Figure 7 – Fabric channel-path configuration (multiple channel images)

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 channel path 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 FC switch fabric refer to FC-PH, reference [4]. 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 FC-SB-2 supports single-switch fabrics. It is intended to support multiple-switch fabrics, but the special issues that might occur in multiple-switch fabrics have not yet been fully considered.

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, or, for brevity, physical path, and the logical channel path, or, for brevity, 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. (For more information, see 4.5.5 below and 4.7.3.)

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 SB-2 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 logical path to each control-unit image. The number of logical paths a channel or control unit permits depends on system requirements and is model dependent.

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 CTC connection, the N_Port of the channel is also the N_Port of the emulated control unit.

Figure 8 shows a Fabric Channel-Path 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 switch.

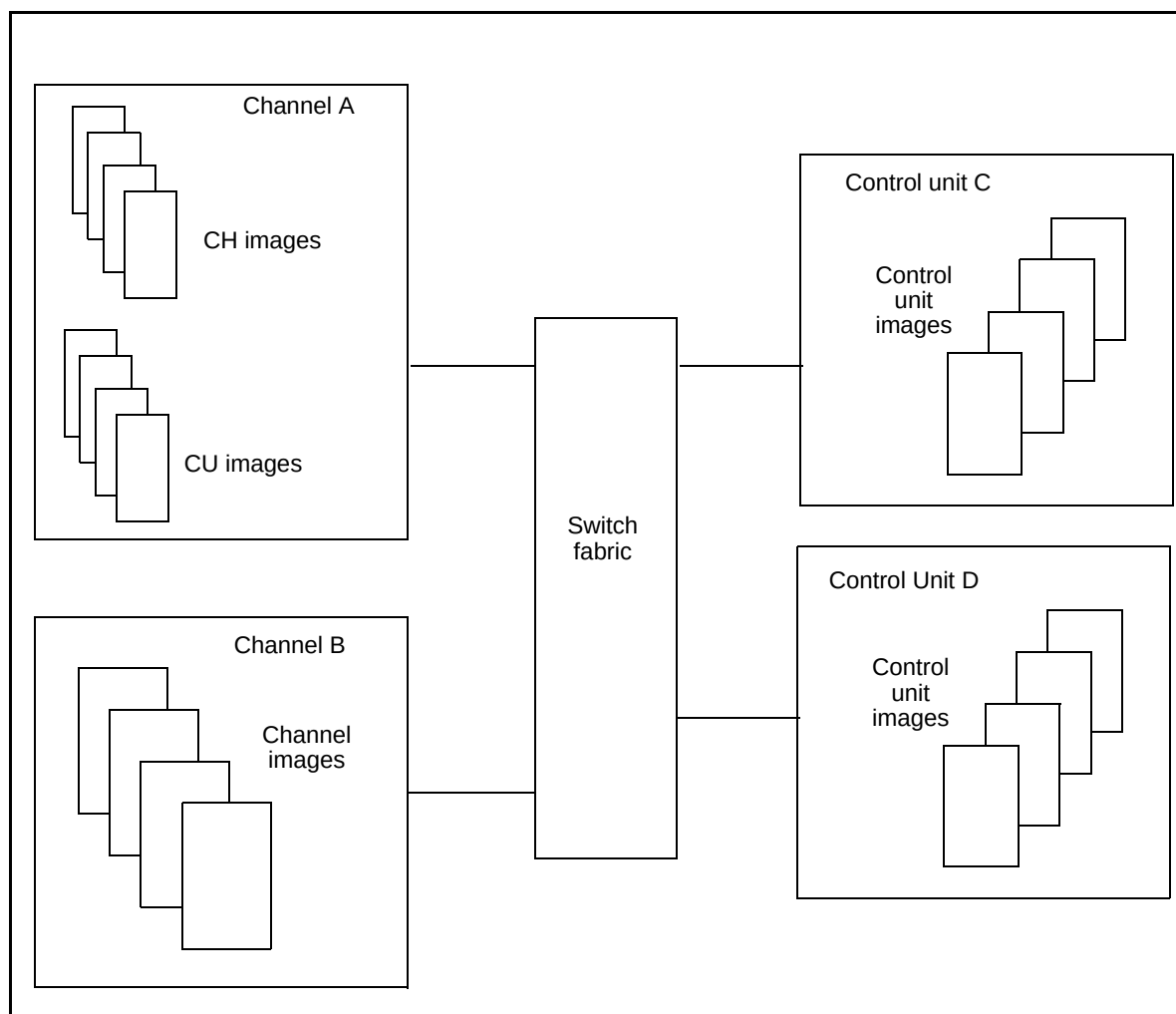


Figure 8 – Fabric channel-path configuration (multiple channel images, CTC connection)

4.5.6.2 FC-SB-2 channel-to-channel adapter

The FC-SB-2 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 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 fully functional 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. (All references to functions supported by a “control unit” apply equally to the case where a channel is emulating a control unit.)

4.6 Information transfer

SB-2 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 SB-2 are described in Figure 12. An information unit is transferred in a sequence which shall be sent as one or more FC-PH device-data frames.

4.7 Protocols

4.7.1 Protocol overview

Protocols for the SB-2 interface are classified as either link level or device level, depending on whether they are for the purpose of managing a channel path and exchanging information over that channel path or for the purpose of managing the execution of an I/O operation. The link level describes the physical characteristics of a channel path and the associated protocols required for the transmission and reception of frames. The link-level protocols for SB-2 are defined both in FC-PH and in this document. (See Clause 6.) The device level primarily relates to the protocols associated with the execution of an I/O operation for a specific device. The device level protocols for SB-2 are defined in this document and they correspond to a new FC-4 definition. These device-level protocols are similar to those of SB-CON but different in that multiplexing at the frame level and streaming of commands and data are provided. 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.

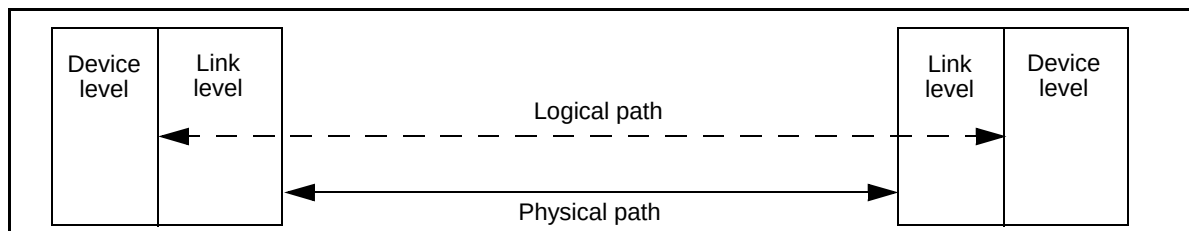


Figure 9 – Relationships among link level, device level, physical path and logical path

4.7.2 Link level

The link-level protocols described in this subclause refer to FC-PH link services and extended link-services. Additionally, SB-2 link-level functions are included.

All communications over a channel path use link-level protocols. 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-PH, reference [1] 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. Initialization, for example, is such a function. Before communication over a channel path is allowed to occur, and before an I/O operation is allowed to 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-PH, reference [1] 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 establishment of 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

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 SB-2 information units (IUs). (See Figure 12.) SB-2 information units are transferred using both link-level and device-level functions and protocols. For example, when the channel receives initiative to start an I/O operation, the device-level functions and 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 protocols provide additional information, for example, 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 and device level. Link-level addressing identifies the N_Port, which in turn identifies the physical path within the channel-path configuration to be used for communication between a channel and a control unit. (See FC-PH, reference [1], clause 18.3.) Link-level addressing also identifies the channel or control-unit images associated with an N_Port.

Device-level addressing identifies the particular device to the particular 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 particular 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-PH header, and the address identifier or the recipient of a frame is in the D_ID field of the FC-PH header. (See 5.5.3.) An N_Port that does not have an address identifier assigned is *unidentified*; an N_Port that has an ad-

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-PH, reference [1], clause 18.3 and clause 23.4.1.) 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 SB-2 header field of the IU. (See 8.4.) A channel 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 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 control-unit images are created, they share a single N_Port for each link, and therefore, the same respective address identifier. A maximum of either 256 channel images or 256 control-unit images shall share the same N_Port. 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 8.4.4.)

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 for determining the correct physical path to the required destination N_Port and, for certain IU types, for determining the appropriate image associated with that N_Port. Some IUs require only link-level addressing while others require both link-level 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 most cases device-level addressing. Device-level addressing identifies the device that is the source or destination of the information in the IU.

5 FC-PH Link Control

5.1 FC-PH Link control overview

The FC-PH 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-PH services are used to perform SB-2 link-level and device-level functions, and defines how the fields in the frame header are used to perform these functions. For a general description of FC-PH mechanisms and frame header fields which are unrelated to SB-2, see clauses 16 - 29 of FC-PH, reference [1].

5.2 Class of service

For reasons of simplicity and the need to keep protocol interlocks to a minimum, Class 3 service shall be used when sending all SB-2 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.

In certain classes of service, including Class 3, a Fabric is not required to deliver frames to a destination in the same order as they were sent by the source. If a Fabric is able to deliver frames to a destination in the same order as they were sent by the source, it indicates this capability during fabric login. The SB-2 ULP requires the Fabric to indicate support for sequential delivery during fabric login. See Clause 7 for additional information.

NOTE Since SB-2 requires the test initialization IU to be sent in Class 2, N_Ports which support SB-2 are required by FC-PH to indicate support for Class 2 at login. This also requires login to be performed using Class 2 service because login is valid only in the class of service used or a class with a higher numerical value. See FC-PH, reference [1] 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-PH link time-out error.

To prevent the loss of R_RDY primitive signals from resulting in a performance degradation or FC-PH link time-out 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, reference [8].

When either of two attached N_Ports do not support the preferred buffer-to-buffer credit reclamation procedure, 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 1 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 exchange pairs and allowing all channel programs to complete and exchange pairs 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 2 When the preferred buffer-to-buffer credit reclamation procedure is not performed, implementations should use the FC-PH 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-PH, reference [1].

NOTE 3 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 4 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 SB-2 Sequences and exchanges

5.4.1 SB-2 sequences

When receiving frames from the link, FC-PH 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 SB-2, IUs contain commands, device-level controls, link controls, and related functions. The IUs defined by SB-2 are summarized in Table 1, and the contents of SB-2 IUs conform to the general structure shown in Figure 12. The protocols for using IUs for SB-2 link-level and device-level functions are found in Clause 6 and Clause 9, respectively.

5.4.2 SB-2 exchange pairs

5.4.2.1 Exchange pair overview

IUs which a channel sends during the execution of an SB-2 link-control function or device-level function 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 an inbound exchange.

Both inbound 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 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 con-

nection 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.

5.4.2.2 Initiating exchange pairs

5.4.2.2.1 General rules for initiating exchange pairs

A channel shall initiate an exchange pair by sending an IU which opens a new exchange (or, 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.

5.4.2.2.2 Exchange pairs for link level functions

A control-unit image that initiates an exchange pair for a link-level 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:

- for another link-level function, or
- for a device-level function not associated with a specific device.

5.4.2.2.3 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:

- with the same channel image for a device-level function not associated with a specific device, or
- with the N_Port of the same channel for a link-level 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 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:

- if an exchange pair already exists for the same device on the same logical path, or
- if 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 to be closed before initiating the new exchange pair for the device on the logical path.

5.4.2.3 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 9.3.1.)

5.5 FC-PH frame header fields

5.5.1 Frame header field overview

The FC-PH 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 and destination link address fields (S_ID and D_ID), an FC-4 identification field (TYPE), an optional header control field (DF_CTL), fields which identify and control FC-PH sequences and exchanges (F_CTL, OX_ID, RX_ID, SEQ_ID, SEQ_CNT), and a parameter field whose function depends on the particular frame type. The usage of these fields for frames which are part of an IU is described below. The frame header format is described in FC-PH, reference [1], and FC-FS, reference [8]. For a definition of the settings of frame header fields in frames which contain FC-PH link-control functions, FC-PH basic link services, and FC-PH extended link services, see FC-PH, reference [1] and FC-FS, reference [8].

5.5.2 R_CTL field

The R_CTL field contains two sub-fields, the routing bits and the information field. The routing bits identify the frame payload as either FC-4 related or FC-PH related. For all frames used to send an IU, the routing bits shall be set to '0000'b to indicate that the payload contains FC-4 Device_Data.

When the routing bits are set to '0000'b and the frame is used to send an IU, the information field contains an information category field which identifies the category of the information in the payload. (See FC-PH, reference [1] for a list of information categories and their corresponding values of the information field.) All frames in an SB-2 IU shall contain the same information category. The information category of an IU depends on the contents of the IU and the conditions under which the IU is sent. Table 1 summarizes the information categories which shall be used to send each IU.

Table 1 – Information categories of SB-2 IUs

SB-2 IU name	Information category	Content
Command IU	Unsolicited command	Command DIB or command/data DIB
Solicited data IU	Solicited data	Data DIB or Status DIB
Unsolicited data IU	Unsolicited data	Status DIB
Solicited control IU	Solicited control	Link control DIB or control DIB
Unsolicited control IU	Unsolicited control	Link control DIB or control DIB

5.5.3 D_ID and S_ID fields

Each channel and control unit is assigned a unique N_Port ID during the initialization procedure. See Clause 7. When sending an IU, the D_ID field shall be set to the N_Port ID of the recipient of the frame, and the S_ID field shall be set to the N_Port ID of the sender of the frame.

5.5.4 CS_CTL

See FC-FS, reference [8].

5.5.5 TYPE field

The TYPE field identifies the FC-4 protocol which defines the frame payload. This field shall be set to hex'1B' in all frames of an IU which are sent by a channel. This field shall be set to hex'1C' in all frames of an IU which are sent to a channel.

If a channel which does not provide control-unit emulation receives an ELP IU with the TYPE field set to hex'1B', it shall send a link-level reject (LRJ) IU in response; if the channel provides control-unit emulation, the emulated control unit may send an LPE IU with the TYPE field set to hex'1C' in response. See 6.4.9 and 11.2.8, and 6.4.2 for additional information. IUs other than the ELP IU, LRJ IU, and LACK IU, which have the TYPE field set to hex'1B', are discarded by the channel and no response is sent.

5.5.6 F_CTL field

The F_CTL field controls sequences and exchanges. These bits are defined in FC-PH, reference [1]. SB-2 has the following requirement on the relative offset present bit in the F_CTL field:

Relative Offset present: The relative offset present bit shall be set to one for all IUs of information category solicited data. For all other information categories, the relative offset present bit shall be set to zero. See 7.3.2.2, 7.4.2.2, and FC-PH, reference [1], for additional information on relative offset.

For the settings of all other bits in the F_CTL field, see FC-PH, reference [1].

5.5.7 SEQ_ID

The SEQ_ID field is defined by FC-PH, reference [1].

5.5.8 DF_CTL

The DF_CTL field shall be set to zero since optional headers are not used.

5.5.9 SEQ_CNT

The SEQ_CNT field is defined by FC-PH, reference [1].

NOTE When sending IUs, the use of continuously increasing sequence count is recommended. This increases the probability that errors caused by lost frames are detected. See FC-PH, reference [1] for additional information.

5.5.10 OX_ID

The OX_ID field is defined by FC-PH, reference [1].

5.5.11 RX_ID

The RX_ID field is defined by FC-PH, reference [1].

5.5.12 Parameter field

When the information category of an IU is solicited data, the relative offset present bit is set to one and the parameter field shall contain the offset from the base address into which the data in a frame is stored. The base address for the solicited data information category is zero and refers to the first byte of the IU. When the information category of an IU is not solicited data, the relative offset present bit is set to zero and the parameter field shall be ignored by the recipient. (See 5.5.6 for information on the relative offset present bit, and see FC-PH, reference [1] for additional information about relative offset.)

5.6 Other FC-PH mechanisms

Other required FC-PH mechanisms include selected basic and extended link services. See Clause 6 for additional information.

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6 Link-Level functions

6.1 Link-level function overview

FC-PH link control, FC-PH basic link services, FC-PH extended link services, and SB-2 link control provide the means by which the elements interconnected by the physical paths are brought to and maintained in an operational state. (See Clause 5 for a description of those aspects of FC-PH link control specific to SB-2, and see FC-PH, reference [1] for general aspects of FC-PH link control, FC-PH basic link services, and FC-PH extended link services.) The functions provided by FC-PH extended link services, FC-PH basic link services, and SB-2 link control are collectively referred to as “link-level functions” in this document. Those link-level functions provided by FC-PH extended link services are referred to as “extended-link-service commands;” those link-level functions provided by FC-PH basic link services are referred to as “basic-link-service commands;” and those link-level functions provided by SB-2 link control are referred to as “SB-2 link-control functions.” The link-level functions required for SB-2 support are described in the following subclauses.

6.2 FC-PH Basic-link-services

This subclause describes the basic-link-service (BLS) commands required by SB-2. Only a brief overview of how these commands are used is provided. For additional details, see FC-PH, reference [1].

6.2.1 Abort sequence

When an exchange is to be aborted, the abort sequence (ABTS) basic-link-service shall be performed. For the conditions under which one or more exchanges are aborted, refer to Clause 11. The settings of fields in the FC-PH header of the ABTS BLS command are given in FC-PH, reference [1]. When the recipient of an ABTS BLS command accepts it, the recipient shall send a basic accept (BA_ACC) response indicating that the entire exchange is being aborted and a recovery qualifier is to be established by setting the Last_Sequence bit in the F_CTL field equal to one, the Low SEQ_CNT field equal to hex'0000', and the High SEQ_CNT field to hex'FFFF'. The recovery qualifier causes all frames for all sequences of the exchange to be discarded until the recovery qualifier is reinstated. After receiving the BA_ACC response and after waiting for an R_A_TOV time-out period, the sender of the ABTS BLS command shall send a reinstate recovery qualifier extended-link-service command to allow the OX_ID and RX_ID combination to be reused. See 6.3.4 and FC-PH, reference [1].

6.3 FC-PH Extended link services

6.3.1 F_Port login

Explicit F_Port login shall be performed by means of the F_Port login (FLOGI) extended link service during the initialization process. See Clause 7 for a definition of other aspects of explicit F_Port login specific to SB-2, and see FC-PH, reference [1] for general aspects of the explicit FLOGI extended link service.

6.3.2 N_Port login

Explicit N_Port login shall be performed by means of the N_Port login (PLOGI) extended link service during the initialization process. When an N_Port has performed N_Port login with another N_Port, that N_Port is said to be logged in with the other N_Port.

When a PLOGI ELS command is received from an N_Port with which the recipient is currently logged in, the recipient shall perform implicit N_Port logout with the source N_Port and shall consider all open exchanges with the source N_Port to be abnormally terminated before accepting the PLOGI ELS com-

mand. (See FC-PH, reference [1] clause 24.3.13 and 10.5.7 for additional information on the abnormal termination of an exchange.)

If the N_Port of a control unit completes explicit N_Port login with the N_Port of a channel at a time when one or more logical paths are indicated as being established to the channel, initiative to send a test initialization IU to that channel shall be generated. See 6.4.7 for additional information. See Clause 7 for a definition of other aspects of explicit N_Port login specific to SB-2, and see FC-PH, reference [1] for general aspects of the explicit PLOGI extended link service.

6.3.3 N_Port logout

N_Port logout may be performed either explicitly or implicitly. For the conditions under which implicit N_Port logout occurs, see FC-PH, reference [1]. When communication with the N_Port of a control unit is no longer required and no logical paths exist for which the channel is providing control-unit emulation, the N_Port of a channel shall initiate explicit N_Port logout by sending a LOGO ELS command and awaiting a response. In addition, the N_Port of a channel shall initiate explicit N_Port logout with the N_Port of a control unit if it receives an IU from the control unit and it is not configured to communicate with the control unit.

The N_Port of a control unit shall initiate explicit N_Port logout with the N_Port of a channel only if the control unit receives an IU from a channel with which the N_Port of the control unit is neither logged in nor in the process of logging in. When this occurs, the received IU shall be discarded, explicit N_Port logout shall be performed, and no further action is taken by the N_Port of the control unit.

When the N_Port of a control unit accepts a LOGO ELS command from the N_Port of a channel to which logical paths exist, it shall reset its internal indicators for the logical paths established with the channel, and perform the equivalent of a system reset for the affected logical paths. For a description of system reset, see 9.2.4. See FC-PH, reference [1] for additional information concerning the handling of open sequences and exchanges which exist at the time when explicit N_Port logout is to be performed, and see 11.2.5 for information concerning the actions of channels and control units upon implicit N_Port logout.

NOTE FC-PH, reference [1], requires that during the N_Port login procedure, other communication with the destination N_Port is neither initiated nor accepted. Therefore if a control unit has sent a PLOGI ELS to a channel and receives an IU from the channel before receiving a response to the PLOGI ELS, the received IU is discarded and no LOGO ELS is sent.

6.3.4 Reinstate recovery qualifier

The reinstate recovery qualifier (RRQ) extended link service shall be performed in order to allow reuse of the OX_ID and RX_ID of an exchange which was aborted. When the sender of an ABTS BLS command receives a BA_ACC response, it sends an RRQ ELS command after waiting an R_A_TOV timeout period. Other aspects of the Reinstate Recovery Qualifier extended link service are given in FC-PH, reference [1].

6.3.5 Registered state change notification

In a point-to-point configuration, the registered state change notification (RSCN) extended link service shall be performed in order to notify the directly-attached N_Port of an event which has affected the state of the sending channel or control unit, provided that the attached N_Port has previously registered to receive state-change notifications. (See 6.3.6.) In a fabric configuration, the RSCN ELS shall be performed in order to notify the fabric controller of an event which has affected the state of the sending N_Port. Additional aspects of the registered state change notification extended link service includ-

ing the format of the RSCN ELS command, the format of the response, and the conditions under which a fabric controller sends an RSCN ELS command are given in FC-FS, reference [8].

The N_Port of a channel or a control unit may optionally perform the RSCN extended link service when an event causes a change in existing logical paths or, for a control unit, in the ability to accept new logical paths. When the resources common to the N_Port of a channel are shared among channel images, the N_Port of that channel shall be capable of reporting a state change by performing the RSCN extended link service.

The N_Port of a channel or control unit shall perform the RSCN extended link service by sending the RSCN ELS command to the fabric controller if a Fabric is present, or to the N_Port of the attached control unit or channel if no Fabric is present. The address format byte (byte 1 of the Affected N_Port ID page of the RSCN ELS command) shall be set to zero to indicate that all three bytes of the N_Port ID are valid, and the affected N_Port ID shall be set to the N_Port ID of the sender. The sender of the RSCN ELS command shall not issue the command if it is aware that it has already signaled a condition which would cause the fabric controller, if present, to issue an RSCN ELS command on behalf of its N_Port ID.

Once the N_Port of a channel or control unit recognizes a condition for which an RSCN ELS command is sent, initiative to send an RSCN ELS command is generated. Subsequent state changes in the sender shall not create initiative to send another RSCN ELS command if the initiative to send the first RSCN ELS command has not been discharged. Once the initiative to send the first RSCN ELS command has been discharged, a subsequent state change shall create a new initiative.

Initiative to send an RSCN ELS command shall be discharged when an accept (ACC) link service reply is received in response to the RSCN ELS command.

When an RSCN ELS command is accepted, the recipient shall check each affected N_Port ID page. (See FC-FS, reference [8].) All three allowed values of the address format byte shall be supported. If an affected N_Port ID indicated in any affected N_Port ID page corresponds to an N_Port ID to which one or more logical paths are indicated as being established, initiative to send a test initialization IU to that N_Port may be generated. See 6.4.7 for additional information. If an affected N_Port ID corresponds to an N_Port ID to which no logical path is indicated as being established, initiative to send a test initialization IU shall not be generated, and no further action is needed. However, at a channel, initiative to establish logical paths may be generated if its model-dependent configuration information indicates that a new control-unit image may have become available.

NOTE Sending the RSCN ELS command is not functionally equivalent to performing the FC-PH online to offline primitive sequence protocol. (See FC-PH, reference [1] and 11.2.4.) However, the RSCN ELS command may be used by a channel or control unit to report a state change that has affected logical paths. When multiple logical images share a common N_Port, RSCN is used in place of the online to offline primitive sequence protocol to report state changes that have not affected all of the logical images.

6.3.6 State-change registration

The state-change-registration (SCR) extended link service shall be performed in order to register to receive RSCN ELS commands. General aspects of the state change registration extended link service, including the format of the SCR ELS command and response, are given in FC-FS, reference [8]. If a Fabric is present, the D_ID field in the FC-PH header of the SCR ELS command shall be set to the N_Port ID of the fabric controller. If no Fabric is present, the D_ID field shall be set to the N_Port ID of the attached channel or control unit. The registration function field in the payload of the SCR ELS command shall be set to hex'03' to request notifications to be sent for events detected by both the fabric controller and the affected N_Ports. After the SCR ELS command is accepted, registration remains in effect until N_Port logout occurs with the recipient of the SCR ELS command. Although it is possible

to clear registration for state change notifications by setting the registration function field in the SCR ELS command to hex'FF', the sender should not set the registration function field to this value.

6.3.7 Request Node-Identification Data

6.3.7.1 Request node-identification data requests and responses

The request-node-identification-data (RNID) extended link service shall be performed in order to acquire the node identification data of the recipient. General aspects of the RNID extended link service, including the format of the RNID ELS command and response, are given in FC-FS, reference [8]. When either the RNID ELS command or the RNID ACC ELS reply is sent, the node-identification data format field shall be set to hex'18'. In the RNID ACC ELS reply, the 32 byte node descriptor described below shall be returned in the specific node-identification data field. When the RNID ACC ELS is received, the common node-identification data, if present, may be ignored.

6.3.7.2 Specific node-identification data

For SB-2, the specific node-identification data is referred to as the node descriptor. A node descriptor (ND) is a 32-byte field that describes a node. The ND consists of a 1 byte flags field, a 3 byte node parameters field, and a 28 byte node-ID.

The node-ID is composed of the two parts listed below.

- a) SDC ID: The first 26 bytes of the node-ID identify the Self-Describing Component (SDC) containing the interface that determines the node. The SDC ID shall correspond to the information provided on a serial-number plate attached to the external surface of the structure containing the SDC.
- b) Interface ID (Tag): The last two bytes of the node-ID shall contain an interface identifier (ID) that uniquely identifies the physical location of the associated SDC interface.

Node-IDs with the same SDC ID shall not use the same interface ID.

Collectively, the 25 bytes of information contained in word 1, bytes 0 and 1 of word 2, bytes 1-3 of word 3, and words 4-7 of the node descriptor shall provide a vendor-specific node identifier.

A node descriptor shall have the format given in Figure 10. (See 3.3.3 for a description of the bit numbering convention used.)

Figure 10

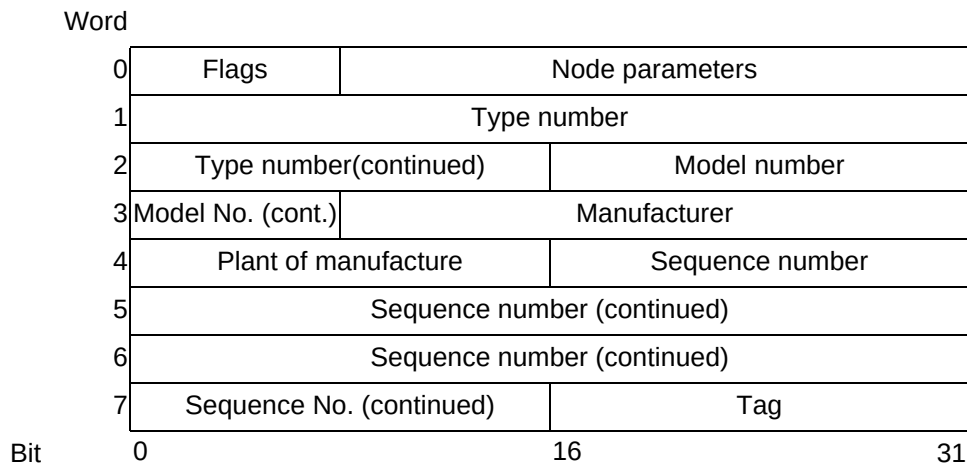


Figure 10 – Contents of the node descriptor

Flags: Byte 0 of word 0 describes the manner in which selected fields of the node descriptor are to be interpreted. The meaning of bits 0-7 is as follows:

Bits Meaning

0-2 Node-ID validity. Bits 0-2 contain a code that describes the validity of bits 3-7 of the flags field, the node parameters field, and the node-ID contained in words 1-7. The codes and their meanings are as follows:

Value Meaning

- 0 Bits 3-7 of the flags field, the node parameters field, and the node-ID are valid.
- 1 Bits 3-7 of the flags field, the node parameters field, and the node-ID are valid, however, they may not be current. This value shall be used when the SDC has obtained the requested node ID but subsequently has observed some event (such as the loss of signal on a link) which may have resulted in a configuration change. The SDC has been unable to obtain the node ID again.
- 2 Node-ID is not valid. The SDC is unable to obtain the requested node-ID. Except for the node-ID-validity field, the contents of the node descriptor shall have no meaning.

When the N_Port of a channel or control unit receives an RNID ELS command, the channel or control unit shall determine the node-ID validity and set the appropriate node-ID validity code in the flag field of the ND. If, while obtaining its node-ID, an error is detected or it is determined for some other reason that the node-descriptor information is suspect (that is, not valid), then the node-ID validity code shall be set to the value 2 in the flag field of the node descriptor being sent in the accept response.

In the accept response to the RNID ELS command, a node-ID validity code of either 0 or 2 in the flag field of the node descriptor shall be indicated. Since a node descriptor is either *valid* or *not valid*, a node-ID validity code of 1 shall never be sent in the accept response to the RNID command.

- 3 Node type. When zero, bit 3 shall specify that the node described by this node descriptor is a device-type node; when one, this bit shall specify that the node described by this node descriptor is a central-processor-complex-type (CPC-type) node.

4-7 Reserved.

Node Parameters: Bytes 1-3 of word 0 shall contain additional information about the node.

When bit 3 of the flag field is zero, indicating that this is a device-type node, the contents of bytes 1-3 of word 0 shall be as follows:

Byte Description

- 1 Bits 0-2 of byte 1 contain a code that shall specify the interface protocol type of the interface identified by the node descriptor. The codes and their meanings are as follows:

Value Meaning

0	Reserved.
1	FC-SB-2
2-6	Reserved
7	Vendor-specific

Bits 3-7 of byte 1 shall be reserved.

- 2 Class. Byte 2 of word 0 shall contain a code that specifies the class to which the device belongs. The codes and their meanings are as follows:

Value Meaning

0	Unspecified class
1	Direct access storage (DASD)
2	Magnetic tape
3	Unit record (input)
4	Unit record (output)
5	Printer
6	Communications controller
7	Terminal (full screen)
8	Terminal (line mode)
9	Reserved
10	Switch
11-255	Reserved

- 3 Byte 3 shall contain zero, except in the following case:

When code 10 is specified in the class field, indicating that this is a switch, byte 3 shall contain the area field (bits 15 - 8) of the Port address identifier of the associated switch interface.

When bit 3 of the flag field is one, indicating that this is a CPC-type node, the contents of bytes 1-3 of word 0 shall be as follows:

Byte Description

- 1 *Type.* When the class field contains a value other than 1, byte 1 of word 0 shall be reserved and set to zeros.

When the class field contains a value of 1, byte 1 of word 0 shall be defined as follows:

- Bits 0-2 contain a code that specifies the interface protocol type of the interface identified by the node descriptor. The codes and their meanings shall be as follows:

Value Meaning

0	Reserved.
1	FC-SB-2
2-6	Reserved
7	Vendor-specific

- Bits 3-7 of byte 1 shall be reserved.

- 2 *Class.* Byte 2 of word 0 shall contain a code that specifies the class to which the interface belongs. The codes and their meanings shall be as follows:

Value Meaning

0	Unspecified class
1	Channel path, not CTC capable
2-6	Reserved
7	FC-SB-2 channel-to-channel adapter (FC-SB-2 CTCA)
8	Emulated control unit support only
9-255	Reserved

- 3 *Identification.* Byte 3 of word 0 shall contain the CHPID of the channel path that contains the specified interface.

The contents of the following five fields shall correspond to the information provided on a serial-number plate attached to the external surface of the SDC. The ASCII character code used in these fields shall be ASCII/Latin 1.

Type Number: Word 1 and bytes 0-1 of word 2 shall contain the six-character (0-9) ASCII type number of the SDC. The type number shall be right justified with leading ASCII zeros if necessary.

Model Number: Bytes 2-3 of word 2 and byte 0 of word 3 shall contain, if applicable, the three-character (0-9 or uppercase A-Z) ASCII model number of the SDC. The model number shall be right justified with leading ASCII zeros if necessary.

Manufacturer: Bytes 1-3 of word 3 shall contain a three-character (0-9 or uppercase A-Z) ASCII code that identifies the manufacturer of the SDC.

Plant of Manufacture: Bytes 0-1 of word 4 shall contain a two-character (0-9 or uppercase A-Z) ASCII plant code that identifies the plant of manufacture for the SDC.

Sequence Number: Bytes 2-3 of word 4, words 5-6, and bytes 0-1 of word 7 shall contain the 12-character (0-9 or uppercase A-Z) ASCII sequence number of the SDC. The sequence number shall be right justified with leading ASCII zeros if necessary.

A serial number shall consist of the concatenation of the plant-of-manufacture designation with the sequence-number designation.

Tag: Bytes 2-3 of word 7 shall contain the physical identifier for the SDC interface that is identified by the preceding 26 bytes of the node descriptor.

6.3.8 Registered Link-Incident Record

6.3.9 Registered Link-Incident Record requests and responses

The registered link-incident record (RLIR) extended link service shall provide the means to send a link-incident record to the N_Port of a channel. General aspects of the RLIR extended link service, including the format of the RLIR ELS command and ACC reply, are given in FC-FS, reference [8]. When the RLIR ELS command is sent, the link-incident record format field shall be set to hex'18'. When the RLIR ELS command is received, the link-incident descriptor may be ignored and the common link-incident record, if present, may be ignored. The specific link-incident record field shall contain a 100 byte SB-2 specific link-incident record of the format described below.

Control units shall use the link-incident reporting procedure to report link-incidents.

6.3.9.1 SB-2 specific Link-Incident Record

The SB-2 specific link-incident record is shown in Table 2.

Table 2 – SB-2 specific Link-Incident Record

Byte	Contents		
0-3	IQ	IC	Reserved
4-35	Incident node descriptor		
36-67	Attached node descriptor		
68-99	Incident specific information		

Incident Qualifier (IQ): Byte 0 shall describe the manner in which the contents of the link-incident record shall be interpreted. The meaning of bits 0-7 is as follows:

Bits Meaning

- | | |
|---|---|
| 0 | Reserved |
| 1 | Reserved |
| 2 | Switch: When one, bit 2 shall indicate that the incident node, identified by the incident-node descriptor, is a switch node. When zero, bit 2 shall indicate that the incident node is not a switch node. |

3 Reserved

4-5 Bits 4 and 5 constitute a two-bit code which shall identify the reporting class for the link-incident. The codes and their meanings are as follows:

Value Meaning

0 Informational report: All link-incidents reported with incident-code bit 0 set to one shall use a reporting class value of zero.

1 Link degraded but operational: Link-incidents reported with incident-code bit 0 set to zero shall use reporting class 1 if the link associated with the incident node is not in a link-failure or offline state as a result of the event which generated the link-incident record.

2 Link not operational: Link-incidents reported with incident-code bit 0 set to zero shall use reporting class 2 if the link associated with the incident node is in a Link-Failure or Offline state as a result of the event which generated the link-incident record.

3 Reserved

6 Subassembly type: When one, bit 6 shall specify that the type of subassembly used for the node that is the subject of this link-incident record is laser. When zero, bit 6 shall specify that the type of subassembly used for the node that is the subject of this link-incident record is not laser.

7 FRU identification: When one, bit 7 shall specify that the incident-specific-information field is in a format that provides field-replaceable-unit (FRU) identification. When zero, bit 7 shall specify that the incident-specific-information field is vendor-specific.

Incident Code (IC): Byte 1 shall contain the incident code which describes the incident that was observed by the incident node.

Bits Meaning

0 Bit 0 of the incident code shall indicate whether the link-incident record is a primary or secondary report of the link-incident. When bit 0 is set to zero, the link-incident record shall be a primary report. When bit 0 is set to one, the link-incident record shall be a secondary report.

1-7 Bits 1-7 of the incident code shall contain a value that specifies the type of incident which was observed. The values that may be specified shall be as follows.

Value Meaning

0 Reserved

1 Implicit Incident: A condition which has been caused by an event known to have occurred within the incident node has been recognized by the incident node. The condition affects the attached link in such a way that it may cause a link-incident to be recognized by the attached node.

2 Bit-error-rate Threshold Exceeded: The number of code violation errors recognized by the incident node has exceeded a threshold. (See FC-FS, reference [8].)

- 3 FC-PH Link Failure - Loss of Signal or Synchronization: A loss of synchronization condition has been recognized by the incident node, and it persisted for more than the R_T_TOV time-out period. A loss of signal condition has been recognized by the incident node. (See FC-PH, reference [1] clause 16.4.2.)
- 4 FC-PH Link Failure - Not-Operational Primitive Sequence (NOS) Recognized: The NOS primitive sequence has been recognized by the incident node. (See FC-PH, reference [1] clause 16.5.3.2.)
- 5 FC-PH Link Failure - Primitive Sequence Time-out: The incident node has recognized either a link reset protocol time-out (See FC-PH, reference [1] clause 16.5.2.) or a time-out when timing for the appropriate response while in the NOS Receive state and after the NOS is no longer recognized. (See FC-PH, reference [1] clause 16.5.3.2.)
- 6 FC-PH Link Failure - Invalid Primitive Sequence for Port State: Either a link reset (LR) or link reset response (LRR) primitive sequence was recognized by the incident node while in the wait-for-OLS state. (See FC-PH, reference [1] clause 16.5.4.3.)

A link-incident record shall be generated and reported for an FC-PH link-failure condition only if the FC-PH link-failure condition persists for longer than SB_TOV.

7-127 Reserved

Incident-Node Descriptor: Bytes 4-35 shall contain the node descriptor of the incident node. The contents of a node descriptor are described in 6.3.7.2.

Attached-Node Descriptor: Bytes 36-67 shall contain the node descriptor of the node attached to the incident node at the time the link-incident was detected. The contents of a node descriptor are described in 6.3.7.2.

Incident-Specific Information: When bit 7 of the incident-qualifier field is set to zero, bytes 68-99 shall contain node-dependent incident information, which may provide additional information related to the incident.

When bit 7 of the incident-qualifier field is set to one, bytes 68-99 shall contain field-replaceable-unit (FRU) identification information.

When the incident-specific-information field contains FRU identification information, the format of the incident-specific information is illustrated in Table 3:

Table 3 – Incident-Specific Information

Bytes	Contents		
68 - 69	FRU flags	reserved	
70 - 81	First FRU callout (12 Bytes)		
82 - 93	Second FRU callout model-dependent information (12 Bytes)		
94 - 99	Reserved		

Byte 68 shall contain the FRU-flags field. The meaning of bits 0-7 shall be as follows:

Bits Meaning

0 Reserved.

1 Format bit; FRU-callout-field format:

Value Meaning

0 FRU-part-number format

1 FRU-code format

2-5 Reserved.

6-7 Validity code for FRU-callout fields:

Value Meaning

00 Reserved.

01 First-FRU-callout field valid; Second-FRU-callout field shall contain 12 bytes of model-dependent data.

10 First-FRU-callout and second-FRU-callout fields valid.

11 Reserved.

Byte 69 shall be reserved and set to zero.

Bytes 70-81 shall contain the first-FRU-callout identification information.

Bytes 82-93 shall contain either the second-FRU-callout identification information or 12 bytes of model-dependent information, depending on the value of bits 6-7 of the FRU-flags field.

Bytes 94-99 shall be reserved and set to zeros.

The format of a valid FRU-callout field shall depend on the value of bit 1 (format bit) of the FRU-flags field within the same link-incident record.

When the format bit is set to zero, the FRU-callout field shall be in ASCII, right justified, with either leading blanks (hex'20') or leading ASCII zeros (hex'30').

When the format bit is set to one, the FRU-callout field shall be in hexadecimal, right justified, with leading zeros (hex'00').

6.3.10 Link-Incident-Record Registration

The link-incident-record registration (LIRR) extended link service shall provide the means for the N_Port of a channel to register to receive link-incident records from a control unit. General aspects of the LIRR extended link service including the format of the LIRR ELS command and ACC response are given in FC-FS, reference [8].

The N_Port of a channel shall send an LIRR command during the initialization procedure. (See Clause 7.) The registration function field shall be set to hex'01' to indicate the "set registration-conditionally receive" function, and the link-incident-record registration type field shall be set to hex'18'. Although it is possible to clear registration for link-incident records by setting the registration function field to hex'FF', the sender shall never set the registration function field to this value.

6.4 SB-2 Link-control functions

6.4.1 SB-2 Link-control function overview

SB-2 link-control functions provide the means by which the logical paths between a channel and control-unit are established and maintained. SB-2 link-control functions also provide information about conditions on the physical and logical paths that affect the transmission or reception of information units (IUs). These functions are performed by means of control IUs containing a link-control DIB (or, link-control IUs). (See 8.12.) For brevity, a link-control IU containing a link-control DIB with a link header specifying one of the link-control functions, is referred to by the name of the link-control function specified in the link header. For example, when the link-control function is a request to establish a logical path, the link-control IU is referred to as an establish logical path IU. (See Table 4 for a list of the link-control functions.)

SB-2 link-control functions are performed primarily during initialization or when certain error conditions occur on a link.

SB-2 link-control requests shall be part of a request-response pair, followed by a link-level acknowledgment (LACK) response. The link-control IU containing the request (or, the link-control-request IU) shall be sent, opening an exchange, as an unsolicited control information category. The exchange containing the link-control-request IU shall be left open. The link-control-response IU shall be sent as a solicited control information category in a new exchange. The exchange containing the link-control-response IU shall be closed. When the sender of the link-control-request IU receives the link-control-response IU, it shall send a link-level-acknowledgment IU as a solicited control information category on the same exchange used to send the link-control-request IU. The exchange containing the link-lev-

el-acknowledgment IU shall be closed. An example of an SB-2 link-control function is a link-control-request IU sent by the channel to request the establishment of a logical path, a link-control-response IU sent by the control unit indicating whether or not the logical path was established, and a link-level-acknowledgment IU sent by the channel to close the outbound exchange.

Link-control-request IUs shall always be sent on a new exchange, that is, they shall never be sent on an existing exchange. If a link-control-request IU is received on an existing exchange, an SB-2 link-level protocol error (or, for brevity, a link-level protocol error) shall be detected.

If a channel or control unit receives an IU when any of the following apply, then the IU shall be discarded and a link-level protocol error shall be detected:

- the received IU is a link-control-response IU and no link-control-request IU was sent, or a link-control-request IU was sent and the link-control-response IU received is not an allowed response,
- the received IU is a link-control IU specifying a link-control function that is not recognized,
- the received IU has an information category other than an information category allowed for the IU,
- the received IU is a link-control IU with a link-payload byte-count field set to a value different from that described in Table 4.

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