

INTERNATIONAL STANDARD

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First edition
2005-02

Information technology – Small computer system interface (SCSI) –

Part 222: Fibre Channel Protocol for SCSI, Second Version (FCP-2)



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**INFORMATION TECHNOLOGY –
SMALL COMPUTER SYSTEM INTERFACE –
PART 222: Fibre Channel Protocol for SCSI,
Second Version (FCP-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 14776-222 was prepared by subcommittee 25: Inter-connection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

INTRODUCTION

This International Standard defines a Fibre Channel mapping layer (FC-4) that uses the services defined by NCITS Project 1311D, Fibre Channel Framing and Signaling Interface (FC-FS) to transmit SCSI command, data and status information between a SCSI initiator and a SCSI target. The use of this standard enables the transmission of standard SCSI command formats, the transmission of standard SCSI data and parameter strings, and the receipt of SCSI status and sense information across the Fibre Channel using only the standard Fibre Channel frame and sequence formats. The Fibre Channel protocol operates with Fibre Channel Classes of Service 1, 2 and 3 and operates across Fibre Channel fabrics and arbitrated loops.

The Small Computer System Interface (SCSI) command set is widely used and applicable to a wide variety of device types. The transmission of SCSI command set information across Fibre Channel links allows the large body of SCSI application and driver software to be successfully used in the high performance Fibre Channel environment.

This standard describes the protocol for transmitting SCSI commands, data, and status using Fibre Channel FC-FS Exchanges and Information Units. Fibre Channel is a high speed serial architecture that allows either optical or electrical connections at data rates from 265 Mbits up to 4 Gbits per second. The topologies supported by Fibre Channel include point-to-point, fabric switched and arbitrated loop. All Fibre Channel connections use the same standard frame format and standard hierarchy of transmission units to transmit the Information Units that carry SCSI information.

This standard is divided into 12 clauses and comprises 6 Annexes:

Clause	Subject
1	Scope
2	Normative references
3	Definitions, abbreviations and conventions
4	Overview of the protocol for transmitting SCSI information over Fibre Channel
5	Information Units used to transfer SCSI commands, data and status across a Fibre Channel connection
6	Basic Link Services and Extended Link Services used by the protocol for transmitting SCSI information over Fibre Channel
7	FC-GS-3 Name Server objects defined for FCP-2
8	FCP FC-4 Link Service definitions for the protocol for transmitting SCSI information over Fibre Channel
9	Details of the Information Unit formats
10	SCSI management features for Fibre Channel, including the SCSI mode pages used by the protocol for transmitting SCSI information over Fibre Channel
11	Timers used for FCP-2 error recovery algorithms
12	Error recovery algorithms for FCP-2
Annex A	Relationship between the services defined by SAM-2 and the corresponding functions defined by this standard
Annex B	Examples of the protocol for transmitting SCSI information over Fibre Channel
Annex C	Examples of the FCP-2 error recovery mechanisms
Annex D	Techniques for discovering SCSI device capabilities over Fibre Channel
Annex E	Examples of the content of ELSS used during FCP-2 recovery operations
Annex F	Mechanism to support bidirectional SCSI data transfer using SCSI commands

Fibre channel Protocol-2 (FCP-2) is part of the SCSI family of standards developed by T10 to facilitate the use of the SCSI command sets for many different types of devices across many different types of physical interconnects. The architectural model for the family of standards is ISO/IEC 14776-412, Information technology – SCSI Architecture Model-2 (SAM-2).

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INFORMATION TECHNOLOGY – SMALL COMPUTER SYSTEM INTERFACE –

PART 222: Fibre Channel Protocol for SCSI, Second Version (FCP-2)

1 Scope

This part of ISO/IEC 14776 defines a second version of the SCSI Fibre Channel Protocol (FCP). This part of ISO/IEC 14776 is a mapping protocol for applying the SCSI command set to Fibre Channel. It defines how the Fibre Channel services and the defined Information Units (IUs) are used to perform the services defined by the SCSI-3 Architecture Model – 2 (SAM-2). This second version includes additions and clarifications to the first version, removes information that is now contained in other standards, and describes additional error recovery capabilities for the Fibre Channel protocol.

2 Normative 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.

2.1 International standards

ISO/IEC 14165-122, Information technology – Fibre Channel – Part 122: Arbitrated loop-2 (FC-AL-2)¹

ISO/IEC 14776-412, Information technology – Small Computer System Interface (SCSI) – Part 412: Architecture Model-2 (SAM-2)¹

ISO/IEC 14776-452, Information technology – Small Computer System Interface (SCSI) – Part 452: Primary commands-2 (SPC-2)¹

2.2 International Standards under development

ISO/IEC 14776-221, Information technology – Small Computer System Interface (SCSI) – Part 221: Protocol for SCSI (FCP)

ISO/IEC 14776-312, Information technology – Small Computer System Interface (SCSI) – Part 312: Primary commands-2 (SPC-2)

2.3 Other references

NOTE Copies of NCITS Technical Reports are available for purchase from Global Engineering Documents. For further information, contact Global Engineering Documents at ++1 800-854-7179 (telephone) or ++1 303-792-2181 (telephone) or by mail at 15 Inverness Way East, Englewood, CO 80122-5704, USA.

NCITS TR-19:1998, Fibre Channel Private Loop, SCSI Direct Attach (FC-PLDA) (Technical Report)

NCITS TR-20:1998, Fibre Channel Fabric Loop Attachment (FC-FLA) (Technical Report)

NCITS TR-24:1999, Fibre Channel – Tape Technical Report (FC-TAPE)

¹ To be published.

3 Definitions, abbreviations and conventions

3.1 Definitions

3.1.1

access controls

Mechanisms allowing a managing application client to control the set of initiators that have access to a target. The access control is enforced by the target. See SPC-3.

3.1.2

access controls data

Information sent to the target by the managing application client that is used by the target to control the set of initiators that have access to the target. See SPC-3.

3.1.3

access controls enrollment state

A state established in the target by the managing application client. The state governs the behavior of the target in controlling the set of initiators that have access to the target. See SPC-3.

3.1.4

acknowledged class

Any class of service that acknowledges transfers. Acknowledged classes of service include Class 1, Class 2, and Class 4 service. See FC-FS.

3.1.5

address identifier

An address value used to identify source (S_ID) or destination (D_ID) of a frame. See FC-FS.

3.1.6

application client

An object that is the source of SCSI commands. [SAM-2]

3.1.7

application client buffer offset

Offset in bytes from the beginning of the application client's buffer (data-in or data-out) to the location for the transfer of the first byte of a data delivery service request.

3.1.8

autosense data

Sense data (see 3.1.51) that is returned in the FCP_RSP IU payload.

3.1.9

command

A request describing a unit of work to be performed by a device server. [SAM-2]

3.1.10

command descriptor block

A structure used to communicate a command from an application client to a device server. [SAM-2, modified]

3.1.11

data buffer size

Upper limit on the extent of the data (data-in or data-out) to be transferred by the SCSI command. See Sam-2.

3.1.12

data in delivery service

A confirmed service used by the device server to request the transfer of data to the application client. See SAM-2.

3.1.13**data out delivery service**

A confirmed service used by the device server to request the transfer of data from the application client. See SAM-2.

3.1.14**data overlay**

The use of random buffer access capability where data is transmitted using the same application client buffer offset more than one time during the set of delivery actions performed by a single command. See SAM-2.

3.1.15**Destination_Identifier**

The address identifier used to indicate the destination of the transmitted frame. See FC-FS.

3.1.16**device server**

An object within the logical unit that executes SCSI tasks and enforces the rules for task management. [SAM-2, modified]

3.1.17**discard**

The term used in FC-FS to describe removing a frame or sequence from the destination buffer without making use of the frame or sequence and without notifying upper layers of the receipt of the frame or sequence. See FC-FS.

3.1.18**Exchange**

The basic mechanism which transfers information consisting of one or more related non-concurrent Sequences which may flow in the same or opposite directions. The Exchange is identified by an Originator Exchange_ID (OX_ID) and a Responder Exchange_Identifier (RX_ID). See FC-FS.

3.1.19**Execute Command service**

A peer-to-peer, confirmed service requested by the application client to perform a SCSI Command. See SAM-2.

3.1.20**FCP Exchange**

A SCSI I/O Operation for the Fibre Channel FC-2 layer. The SCSI I/O Operation for Fibre Channel is contained in a Fibre Channel Exchange. See FC-FS and 4.1.

3.1.21**FCP I/O operation**

A SCSI I/O Operation for the Fibre Channel FC-4 layer, as defined in this standard.

3.1.22**FCP_Port**

An N_Port or NL_Port that supports the SCSI Fibre Channel Protocol.

3.1.23**fully qualified exchange identifier**

A set of addresses and values used to uniquely identify an FCP I/O operation. See 5.1.

3.1.24**image pair**

The originating and responding processes related by a Process Login operation. For the Fibre Channel protocol, the image pair is composed of one initiator and one target. See FC-FS.

3.1.25**I_T nexus loss**

A condition resulting from the events defined by SAM-3 in which the SCSI device performs the operations described in SAM-3 and this standard.

3.1.26**I_T nexus loss event**

A SCSI transport protocol specific event that triggers I_T nexus loss as described in SAM-3.

3.1.27**Information Unit**

An organized collection of data specified by the Fibre Channel protocol to be transferred as a single Sequence by the Fibre Channel service interface. See FC-FS.

3.1.28**initiator**

A SCSI device containing application clients that originate device service requests and task management functions to be processed by a target SCSI device. In this standard, the word “initiator” also refers to an FCP_Port using the Fibre Channel protocol to perform the SCSI initiator functions defined by SAM-2.

3.1.29**initiator identifier**

Address a target uses to identify the initiator device. See SAM-2.

3.1.30**interconnect tenancy**

The period of time that an FCP device owns or may access a shared Fibre Channel link such as an FC-AL loop. See 10.2.1.

3.1.31**logical unit**

A target resident entity that implements a device model and processes SCSI commands sent by an application client. [SAM-2, modified]

3.1.32**logical unit number**

An encoded 64-bit identifier for a logical unit. [SAM-2, modified]

3.1.33**loop initialization primitive**

A primitive used in Fibre Channel arbitrated loops to start loop initialization. See FC-AL-2.

3.1.34**Name_Identifier**

A 64-bit identifier, with a 60-bit value preceded with a 4 bit Network_Address_Authority Identifier, used to identify entities in Fibre Channel such as N_Port, Node, F_Port, or Fabric. See FC-FS.

3.1.35**Name Server**

A Fibre Channel service accessed through a well-known address identifier that uses the Common Transfer (CT) protocol as defined in FC-GS-3 to allow a client to determine the address identifier and properties of devices attached to a Fibre Channel switching fabric. See FC-GS-3.

3.1.36**Node_Name**

A Name_Identifier associated with a Node. See FC-FS.

3.1.37**NL_Port**

An N_Port that contains arbitrated loop functions associated with the Fibre Channel arbitrated loop topology. See FC-AL-2.

3.1.38**N_Port**

A hardware entity that supports the FC-FS FC-2 layer. It may act as an Originator, a Responder, or both. See FC-FS.

3.1.39**Originator**

The logical function associated with an N_Port responsible for originating an Exchange. See FC-FS.

3.1.40**Originator Exchange Identifier**

An identifier assigned by an Originator to identify an Exchange (see 3.1.50). See FC-FS.

3.1.41**Port Identifier**

An address identifier, assigned to an N_Port or NL_Port during implicit or explicit Fabric Login. See FC-GS-3.

3.1.42**Port (N_Port) Login (PLOGI)**

The Fibre Channel Extended Link Service (ELS) that exchanges identification and operation parameters between an originating N_Port and a responding N_Port. See FC-FS.

3.1.43**Port_Name**

A Name_Identifier associated with an N_Port or an NL_Port.

3.1.44**private loop**

A loop operating with no attached fabric loop ports. See FC-PLDA.

3.1.45**public loop**

A loop operating with an attached fabric loop port. See FC-FLA.

3.1.46**random buffer access**

The occurrence of device server data transfer requests that request data transfers to or from segments of the application client's buffer with an arbitrary offset and extent. See SAM-2.

3.1.47**recovery abort**

An FC-FS protocol that recovers FCP_Port resources by terminating the Exchange and FCP I/O operation. See 12.3.

3.1.48**request byte count**

The number of bytes to be moved by a data delivery service request. See SAM-2.

3.1.49**Responder**

The logical function in an N_Port responsible for supporting the Exchange initiated by the Originator in another N_Port. See FC-FS.

3.1.50**Responder Exchange Identifier**

An identifier assigned by a Responder to identify an Exchange and meaningful only to the Responder. See FC-FS.

3.1.51**sense data**

Data returned to an application client as a result of an autosense operation, asynchronous event report, or REQUEST SENSE command. See SPC-2.

3.1.52**Sequence**

A set of one or more Data frames with a common Sequence_ID (SEQ_ID), transmitted unidirectionally from one N_Port to another N_Port with a corresponding response, if applicable, transmitted in response to each Data frame. See FC-FS.

3.1.53**Source Identifier**

The address identifier used to indicate the source port of the transmitted frame. See FC-FS.

3.1.54**SCSI device**

A device that originates or services SCSI commands. [SAM-2, modified]

3.1.55**SCSI I/O operation**

An operation defined by a SCSI command, a series of linked SCSI commands or a task management function. See SAM-2.

3.1.56**status**

A single byte returned by the device server to the application client to indicate the completion and completion state of a command. See SAM-2.

3.1.57**tag**

The initiator-specified component of a task identifier that uniquely identifies one task among the several tasks coming from an initiator to a logical unit. The fully qualified exchange identifier performs the function of the SCSI tag in this standard. See 5.1 and SAM-2.

3.1.58**target**

A SCSI device that receives SCSI commands and directs such commands to one or more logical units for execution. In this standard, the word "target" also refers to an FCP_Port using the Fibre Channel protocol to perform the SCSI target functions defined by SAM-2.

3.1.59**target identifier**

Address of up to 64-bits that identifies a target. See SAM-2.

3.1.60**task**

An object within the logical unit representing the work associated with a command or group of linked commands. [SAM-2]

3.1.61**task attribute**

The queuing specification for a task (SIMPLE, ORDERED, HEAD OF QUEUE, ACA). See SAM-2.

3.1.62**task identifier**

The information uniquely identifying a task. See SAM-2.

3.1.63**task management function**

A peer-to-peer confirmed service provided by a task manager that may be invoked by an application client to affect the execution of one or more tasks. [SAM-2, modified]

3.1.64**Worldwide_Name**

A Name_Identifier which is worldwide unique, and represented by a 64-bit unsigned binary value. (FC-FS)

3.2 Abbreviations

CRN	Command Reference Number (See 9.1.2.2.)
D_ID	Destination_Identifier (See FC-FS.)
ELS	Extended Link Service (See FC-FS.)
FC	Fibre Channel (See FC-FS.)
FC-AL-2	Fibre Channel Arbitrated Loop - 2
FC-FLA	Fibre Channel Fabric Loop Attachment
FC-FS	Fibre Channel Framing and Signaling Interface
FC-GS-3	Fibre Channel Generic Services - 3
FC-PLDA	Fibre Channel Private Loop, SCSI Direct Attach
FC-TAPE	Fibre Channel - Tape Technical Report
FCP	Fibre Channel Protocol for SCSI
	Also: referring both to FCP and to this standard
FCP-2	This standard (Fibre Channel Protocol for SCSI, second version.)
FC-4	Fibre Channel Layer 4 mapping layer. (See FC-FS.)
FLOGI	Fabric Login Extended Link Service. (See FC-FS.)
FQXID	fully qualified exchange identifier
ID	identifier
IU	Information Unit (See FC-FS.)
LIFA	loop initialization fabric assigned, a step of the loop initialization sequence (See FC-AL-2.)
LIHA	loop initialization hard assigned, a step of the loop initialization sequence (See FC-AL-2.)
LIP	loop initialization primitive (See FC-AL-2.)
LIPA	loop initialization previously assigned, a step of the loop initialization sequence (See FC-AL-2.)

LISA	loop initialization soft assigned, a step of the loop initialization sequence (See FC-AL-2.)
LISM	loop initialization select master, a step of the loop initialization sequence (see FC-AL-2.)
LOGO	Log Out Extended Link Service (See FC-FS.)
NA	Not Applicable
OX_ID	Originator Exchange Identifier (See FC-FS.)
PLOGI	Port (N_Port) Login Extended Link Service (See FC-FS.)
RX_ID	Responder Exchange Identifier (See FC-FS.)
SAM-2	ISO/IEC 14776-412, <i>SCSI Architecture Model - 2</i> (See 2.3.)
SAM-3	ISO/IEC 14776-413, <i>SCSI Architecture Model - 3</i> (See 2.3.)
SCSI	Small Computer System Interface, any revision.
SCSI-3	Small Computer System Interface-3, the SCSI architecture specified by SAM-2 and extended by the companion standards referenced in SAM-2.
S_ID	Source_Identifier (See FC-FS.)
SPC-2	ISO/IEC 14776-312, <i>SCSI Primary Commands - 2</i> (See 2.3.)
ULP	upper layer protocol (See FC-FS.)

3.3 Keywords

3.3.1

expected

A keyword used to describe the behavior of the hardware or software in the design models assumed by this standard. Other hardware and software design models may also be implemented.

3.3.2

invalid

A keyword used to describe an illegal or unsupported bit, byte, word, field or code value. Receipt of an invalid bit, byte, word, field or code value shall be reported as error.

3.3.3

ignored

A keyword used to describe a bit, byte, word, field or code value that shall not be examined by the receiving SCSI device. The bit, byte, word, field or code value has no meaning in the specified context.

3.3.4

mandatory

A keyword indicating an item that is required to be implemented as defined in this standard.

3.3.5

may

A keyword that indicates flexibility of choice with no implied preference (equivalent to “may or may not”).

3.3.6

may not

A keyword that indicates flexibility of choice with no implied preference (equivalent to “may or may not”).

3.3.7

obsolete

A keyword indicating that an item was defined in a prior SCSI standard but has been removed from this standard.

3.3.8

optional

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

3.3.9

reserved

A keyword referring to bits, bytes, words, fields and code values that are set aside for future standardization. A reserved bit, byte, word or field shall be set to zero, or in accordance with a future extension to this standard. Recipients are not required to check reserved bits, bytes, words or fields for zero values. Receipt of reserved code values in defined fields shall be reported as an error.

3.3.10

restricted

A keyword referring to bits, bytes, words, and fields that are set aside for use in other SCSI standards. A restricted bit, byte, word, or field shall be treated as a reserved bit, byte, word or field for the purposes of the requirements defined in this standard.

3.3.11

shall

A keyword indicating a mandatory requirement. Designers are required to implement all such mandatory requirements to ensure interoperability with other products that conform to this standard. This standard prescribes no specific response by a component if it receives information that violates a mandatory behavior.

3.3.12

should

A keyword indicating flexibility of choice with a strongly preferred alternative; equivalent to the phrase "it is strongly recommended".

3.4 Editorial conventions

Certain words and terms used in this standard have a specific meaning beyond the normal English meaning. These words and terms are defined either in 3.1 or in the body of the standard where they first appear. Names of commands, statuses, task management functions, task attributes, Information Units, sense keys, additional sense codes, and additional sense code qualifiers are in all uppercase (e.g., REQUEST SENSE). Lowercase is used for words having the normal English meaning.

The names of fields are in small uppercase (e.g., ALLOCATION LENGTH). When a field name is a concatenation of acronyms, uppercase letters may be used for readability (e.g., NORMACA). Normal case is used when the contents of a field are being discussed. Fields containing only one bit are usually referred to as the NAME bit instead of the NAME field. Where fields defined in another standard are referenced in this standard, the capitalization conventions of the originating standard are used.

Numbers that are not immediately followed by lower-case b or h are decimal values.

Numbers immediately followed by lower-case b (0101b) are binary values.

Numbers or upper case letters immediately followed by lower-case h (FA23h) are hexadecimal values.

In all of the figures, tables, and text of this standard, the most significant bit of a binary quantity is shown on the left side. Bit order and byte order are as specified in FC-FS.

The ISO convention of numbering is used (i.e., the thousands and higher multiples are separated by a space). A comma is used as the decimal point. A comparison of the American and ISO conventions is shown below:

ISO	American
0,6	0.6
1 000	1,000
1 323 462,9	1,323,462.9

Lists sequenced by letters (e.g., a-red, b-blue, c-green) show no ordering relationship between the listed items. Numbered lists (e.g., 1-red, 2-blue, 3-green) show an ordering relationship between the listed items.

If a conflict arises between text, tables, or figures, the order of precedence to resolve the conflicts is text; then tables; and finally figures. Exceptions to this convention are indicated in the appropriate subclauses. Not all tables or figures are fully described in the text. Tables show data format and values. Notes do not constitute any requirements for implementors.

4 General

4.1 Structure and concepts

Fibre Channel (FC) is logically a point-to-point serial data channel. The architecture has been designed so that it may be implemented with high performance hardware that requires little real-time software management. The Fibre Channel Physical layer (FC-2 layer) described by FC-FS performs those functions required to transfer data from one N_Port or NL_Port to another. In this standard, N_Ports and NL_Ports capable of supporting Fibre Channel protocol transactions are collectively referred to as FCP_Ports. The FC-2 layer may be treated as a very powerful delivery service with information grouping and several defined classes of service.

A switching fabric allows communication among more than two FCP_Ports.

Fibre Channel Arbitrated Loop (FC-AL) is an alternative multiple port topology that allows communication between two ports on the loop or between a port on the loop and a port on a switching fabric attached to the loop.

An FC-4 mapping layer uses the services provided by FC-FS to execute the steps required to perform the functions defined by the FC-4. The protocol is described in terms of the stream of FC IUs and Exchanges generated by a pair of FCP_Ports that support the FC-4.

The detailed implementation that supports that stream is not defined, although Originator and Responder FCP_Ports are assumed to have a common service interface, for use by all FC-4s, that is similar in characteristics to the service interface defined in FC-FS. The requirements for the service interface for SCSI are contained in SAM-2.

Four kinds of functional management are defined by this standard.

Device Management

Task Management

Process Login/Logout Management

Link Management

The Fibre Channel protocol device and task management protocols define the mapping of the SCSI functions defined in SAM-2 to the Fibre Channel interface defined by FC-FS. Link control is performed by standard FC-FS protocols. The task management functions defined by SAM-2 are mapped as described in 4.8 of this standard. The I/O Operation defined by SAM-2 is mapped into a Fibre Channel Exchange. A Fibre

Channel Exchange carrying information for a SCSI I/O Operation is an FCP Exchange. The request and response primitives of an I/O Operation are mapped into Information Units (IUs) as shown in table 1.

Table 1 - SCSI and Fibre Channel protocol functions

SCSI function	FCP equivalent
I/O operation	Exchange
Protocol Service Request and Response	Sequence
Send SCSI Command Request	Unsolicited command IU (FCP_CMND)
Data delivery request	Data descriptor IU (FCP_XFER_RDY)
Data delivery action	Solicited data IU (FCP_DATA)
Send Command Complete Response	Command status IU (FCP_RSP)
REQ/ACK for Command Complete	Confirmation IU (FCP_CONF)

The number of Exchanges that may simultaneously be open between an initiator FCP_Port and a target FCP_Port is defined by the FC-FS implementation. The architectural limit for this value is 65 535. The maximum number of active Sequences that may simultaneously be open between an initiator FCP_Port and a target FCP_Port is restricted by the allowable range of values of the Sequence ID to 256, as defined in FC-FS. To allow task management Exchanges to be originated, a certain number of extra Exchange IDs and at least one extra Sequence_ID should always be available.

4.2 Device management

An application client begins an FCP I/O operation when it invokes an Execute Command remote procedure call. (See SAM-2). The Execute Command call conveys a single request or a list of linked requests from the application client to the FCP service delivery subsystem. Each request contains all the information necessary for the execution of one SCSI command, including the local storage address and characteristics of data to be transferred by the command. The Fibre Channel protocol then performs the following actions using FC-FS services to perform the SCSI command. The execution of the individual steps of the protocol is consistent with the SCSI architectural model as defined by SAM-2.

The FCP_Port that is the initiator for the command starts an Exchange by sending an unsolicited command IU containing the FCP_CMND IU payload, including some command controls, addressing information, and the SCSI command descriptor block (CDB). The FCP_CMND IU payload is the Send SCSI Command protocol service request (see SAM-2) and starts the FCP I/O operation. The Exchange that is started is identified by its fully qualified exchange identifier (FQXID) during the remainder of the FCP I/O operation and is used only for the IUs associated with that FCP I/O operation. See 5.1.

When the device server for the command has completed the interpretation of the command, has determined that write data transfer is required, and is prepared to request the data delivery service, it sends a data descriptor IU containing the FCP_XFER_RDY IU payload to the initiator to indicate which portion of the data is to be transferred. The FCP_Port that is the initiator then transmits a solicited data IU to the target containing the FCP_DATA IU payload requested by the FCP_XFER_RDY IU. The FCP_XFER_RDY IU and

FCP_DATA IU payloads constitute the Receive Data-Out protocol service request and Data-Out Received service confirmation described in SAM-2. Data delivery requests containing FCP_XFER_RDY IU and returning FCP_DATA IU payloads continue until the data transfer requested by the SCSI command is complete. One FCP_DATA IU shall follow each FCP_XFER_RDY IU. If the system has mechanisms outside the scope of this standard for controlling the data transfer length, the transmission of the initial FCP_XFER_RDY IU may be disabled. See 10.2.10.

When the device server for the command has completed the interpretation of the command and has determined that read data transfer is required, the FCP_Port that is the target transmits a solicited data IU to the initiator containing the FCP_DATA IU payload. The FCP_DATA IU constitutes the Send Data-In protocol service request described in SAM-2. Data deliveries containing FCP_DATA IU payloads continue until all data described by the SCSI command is transferred.

After all the data has been transferred, the device server transmits the Send Command Complete protocol service response (described in SAM-2) by requesting the transmission of an IU containing the FCP_RSP IU payload. That payload contains the SCSI status and, if the SCSI status is CHECK CONDITION, the autosense data describing the condition. The FCP_RSP IU indicates completion of the SCSI command. If no command linking, error recovery, or confirmed completion is requested, the FCP_RSP IU is the final sequence of the Exchange. The device server determines whether additional linked commands are to be performed in the FCP I/O Operation. If this is the last or only command executed in the FCP I/O operation, the FCP I/O operation and the Exchange are terminated. If an FCP protocol error occurred during execution of the command, the FCP_RSP IU payload carries the FCP Response information instead of the SCSI status and autosense data.

When the command is completed, returned information is used to prepare and return the Command Complete Received protocol service confirmation to the application client that requested the operation. The returned status indicates whether or not the command was successful. The successful completion of the command indicates that the SCSI device performed the requested operations with the transferred data and that the information was successfully transferred to or from the initiator. Status other than successful completion indicates that either SCSI sense data or warnings about unexpected FCP behaviors are being provided. In this case, the sense data or warning is interpreted to determine whether the desired operation was successfully completed. The device server can optionally request a protocol service indication that confirms delivery of the FCP_RSP IU payload, as described in 4.4.

If the command is linked to another command, the FCP_RSP IU payload shall contain the proper status (i.e., INTERMEDIATE or INTERMEDIATE CONDITION MET) indicating that another command shall be executed. The target shall present the FCP_RSP using the IU that allows command linking, I5 (see 5.4). The initiator shall continue the same Exchange with an FCP_CMND IU, beginning the next SCSI command. All SCSI commands linked in the FCP I/O operation except the last are executed in the manner described above. SAM-2 defines the cases that interrupt and terminate a series of linked commands. In those cases, the FCP_RSP IU of the last command in the set of linked commands shall be transmitted using the IU that does not allow command linking, I4.

The number of FCP I/O operations that may be active at one time depends on the queuing capabilities of the FCP device. If command queueing resources are unavailable in the target when a command is received, the target returns TASK SET FULL status or BUSY status in the FCP_RSP IU as specified by SAM-2.

The Fibre Channel protocol takes full advantage of the multiplexing and shared bandwidth capabilities provided by various Fibre Channel classes of service. The protocol is designed to operate with any class of service and to provide options for reliable error detection and error recovery independent of the class of service.

SCSI allows the initiator function in any FCP_Port and the target function in any FCP_Port. For FCP I/O operations between a host and a peripheral subsystem, the host typically takes on the initiator role and the peripheral subsystem typically takes on the target role. For host to host communications, either one of the communicating pair may take on the initiator role. For device to device communications, typically used to

implement extended copy and other third-party operations, the initiator role is adopted by the managing FCP device.

The Fibre Channel protocol implements Asynchronous Event Reporting (see SAM-2) using the Asynchronous Event Notification (AEN) model in SPC-2. The AEN model reports asynchronous events by requiring that the peripheral FCP device take on the initiator role to deliver the asynchronous event sense data to the host, which acts as a target using the processor device model for the duration of the AEN reporting process.

4.3 Precise delivery of SCSI commands

In applications where SCSI communications between an application client and a device server are stateless, verification of the delivery and execution of SCSI commands is often not critical. Any changes in execution sequence caused by link failures or switch latencies are not important and the recovery and retry mechanisms may be executed while other activities are continued by the application client and the device server.

SAM-2 defines a mechanism to assure ordering of commands. If the initiator transmits a single command and waits for GOOD status before transmitting the next command, the commands are guaranteed to be executed in order.

This standard defines a second optional mechanism called precise delivery to assure ordering of commands. This may be used by any FCP device, but may be useful for devices performing ordered command queuing where device state is preserved from one command to the next. An application client may determine if a device server supports the precise delivery function by using the MODE SENSE and MODE SELECT commands to examine and set the enable precise delivery checking (EPDC) bit in the Fibre Channel Logical Unit Control page. See 10.3.

Precise delivery of SCSI commands uses the COMMAND REFERENCE NUMBER field in the FCP_CMND IU.

For each device server having the EPDC bit set to one, the application client places a one byte unsigned integer in the COMMAND REFERENCE NUMBER field of each command requiring precise delivery. The integer shall start at the reset value of one and shall be incremented by one for each command requiring precise delivery for that device server. Separate increment counters are maintained for each I_T_L nexus (i.e., each initiator maintains a separate counter for each device server using precise delivery). After the number of precisely delivered commands causes the integer to increment to 255, the integer wraps back to a value of one. The value of zero is reserved and shall be used for those commands that do not require precise delivery and for task management functions.

The following rules specify how the application client and device server use the CRN to determine that each command requiring precise delivery has been properly received and executed.

- a) See tables 4 and 5 for the actions that cause the CRN to be transmitted by the initiator to be set to one and the CRN expected by the device server to be set to one.
- b) The CRN shall be equal to one for the first FCP_CMND IU requiring precise delivery between the application client and device server and shall be incremented by one for each subsequent command requiring precise delivery.
- c) The CRN shall wrap from 255 to one (i.e. a value of zero in the CRN field is not valid for an Exchange using precise delivery).
- d) The initiator shall not transmit the same CRN again until delivery of the first FCP_CMND IU transmitted with that CRN has been confirmed by receipt of an FCP_XFER_RDY IU, an FCP_DATA IU, an FCP_RSP IU, an ACK, or a response to an REC.

- e) The device server shall not accept a command with a nonzero CRN into the dormant or enabled state until after all commands with a previous CRN have been received by the device server. The commands shall be assumed to be received in the order of increasing CRN, highest CRN last. The order of execution of the commands shall be managed by the normal task set management algorithms.
- f) The device server shall accept any valid command with a CRN of zero into the dormant or enabled state regardless of whether or not all commands with a nonzero CRN have been received. The order of execution of the commands shall be managed by the normal task set management algorithms. See SAM-2.
- g) Task management functions shall have the CRN set to zero and shall not be tested for precise delivery by the device server.

Any command may use a CRN of zero if precise delivery is not required for that command. For example, commands such as INQUIRY, TEST UNIT READY, REPORT LUNS and MODE SENSE/SELECT used for booting and initialization may use a CRN of zero.

4.4 Confirmed completion of FCP I/O Operations

Some FCP devices require an acknowledgment of successful delivery of FCP_RSP information. Such an acknowledgment is provided by the confirmed completion function, optionally implemented by FCP-2 devices. PRLI parameters are used to determine that confirmed completion is accepted by an initiator and may be requested by a target communicating with that initiator.

A target may invoke the confirmed completion function by setting the FCP_CONF_REQ bit to one in the FCP_RSP IU. Upon receiving the request in the FCP_RSP IU, the initiator shall transmit an FCP_CONF IU to the target, indicating to the target that the FCP_RSP IU has been received by the initiator.

The confirmed completion function allows the retry of unsuccessful notifications of errors and confirms that the initiator and the target both agree upon the state of a state dependent device. Retry mechanisms for unsuccessful transmission of FCP_RSP IUs and FCP_CONF IUs are defined in this standard.

Confirmed completion shall not be requested for FCP_RSP IUs responding to task management requests.

If confirmed completion is not enabled, the FCP_CONF IU shall not be requested by the FCP_RSP IU.

If command linking is being performed, the target shall not request confirmed completion for an FCP_RSP IU containing INTERMEDIATE status. The target may request confirmed completion

- a) when providing the FCP_RSP IU for the last command of the set of linked commands, or
- b) when providing the FCP_RSP IU for a command that terminates linking because of an error or CHECK CONDITION status.

Confirmed completion may assist initiators and targets in many environments. Particular examples include:

- a) The confirmed completion function may be used to confirm that an initiator has received an FCP_RSP IU reporting a SCSI CHECK CONDITION status, together with accompanying autosense data. Upon receiving the FCP_CONF IU, the target may discard its copy of the autosense data.
- b) The confirmed completion function may be used to confirm that a queued SCSI command has been completed and that the completion information has been successfully transferred to the initiator. That allows subsequent queued state dependent operations to be performed, since the FCP_CONF IU confirms that the FCP_RSP IU has been received by the initiator.

- c) The confirmed completion function may be used to confirm that an initiator has received the FCP_RSP IU for targets that require state dependent synchronization with initiators.

4.5 Retransmission of unsuccessfully transmitted data

Error detection and data retransmission algorithms are defined by clause 12.

The Read Exchange Concise (REC) Extended Link Service may be used by any initiator to determine the state of an ongoing Exchange. See 6.5. Those targets that do not support REC indicate that by performing a Link Service Reject (LS_RJT). See 8.3.

If an error is identified by any of the mechanisms defined by clause 12 and if the data retransmission capability is supported by both the initiator and target as indicated by the PRLI bits, the initiator may request retransmission using the Sequence Retransmission Request (SRR) FCP FC-4 Link Service Request. See 8.2. If the data retransmission capability is supported by both the initiator and the target, as indicated by the PRLI bits, both devices shall support REC.

4.6 Task retry identification

Task retry identification optionally provides an additional optional mechanism for relating commands that are being retried to the requests that are sensing the requirement for recovery (REC) and performing the recovery (SRR). The particular case that has been identified as a problem is related to the recovery procedure diagrammed in figure C.7. It is possible that initiators may re-use OX_ID values rapidly enough to create an ambiguous situation where the status being preserved in the target for possible retransmission and the new command being presented to the target may have the same OX_ID values. When recovery of a transmission failure for the new command is attempted, the target instead indicates that the recovery is related to the previous command's status and the initiator is provided status for the completed command. That information is mistakenly interpreted as status for the failed command. Many small variations on this scenario may exist.

Devices that agree to perform recovery and that may create such ambiguous cases should support task retry identification. If both devices agree to support task retry identification, a task retry identifier is provided in the PARAMETER field of each FCP_CMND IU frame. The Link Services associated with retransmission of IUs (REC and SRR) each contain the same task retry identifier, unambiguously relating them to the particular command. If the devices do not agree to support task retry identification, the PARAMETER field is zero for both the FCP_CMND IU frame and the REC and SRR frames.

4.7 Discovery of FCP capabilities

A number of Fibre Channel protocol capabilities require the knowledge and agreement of both the target and the initiator that such capabilities may or shall be used. Table 2 provides references to the discovery process for each of the Fibre Channel protocol capabilities.

Table 2 - Discovery of FCP-2 capabilities

Capability	Discovery mechanism	Reference
Initiator	Process Login	6.3.4
Target	Process Login	6.3.4
Initiator accepts data overlay	Process Login	6.3.4
Target performs data overlay	MODE SENSE command	10.2.8
Initiator generates FCP_CONF IU	Process Login	6.3.4
Target requests FCP_CONF IU	Process Login	6.3.4
Initiator performs REC	None required, Process Login allowed	4.5
Target accepts REC	LS_RJT if REC not accepted	4.5
Initiator performs SRR	Process Login	6.3.4
Target accepts SRR	Process Login	6.3.4
Initiator provides CRN	MODE SENSE command	4.3
Target accepts CRN	MODE SENSE command	10.3
Task Retry Identification	Process Login	6.3.4

4.8 Task management

An application client requests a task management function to control explicitly the execution of one or more FCP I/O Operations. See 9.1.2.4.

Some SCSI task management functions are mapped into FC-FS link services and others are mapped into control bits in the FCP_CMND IU. Task management functions that use the FCP_CMND IU are transmitted as the first IU in a new Exchange. A task management function that uses the FCP_CMND IU ends with an

FCP_RSP IU that indicates the completion status of the function. The FCP_CDB field in FCP_CMND IUs that perform task management functions is ignored. The mappings are explained in table 3.

Table 3 - Task management functions, SAM-2 to FCP

SAM-2 function	FCP equivalent	Optional / Mandatory
TARGET RESET	FCP_CMND TARGET RESET	Mandatory
ABORT TASK	FCP recovery abort¹	Mandatory
ABORT TASK SET	FCP_CMND ABORT TASK SET	Mandatory
CLEAR TASK SET	FCP_CMND CLEAR TASK SET	Mandatory
CLEAR ACA	FCP_CMND CLEAR ACA	Optional²
LOGICAL UNIT RESET	FCP_CMND LOGICAL UNIT RESET	Mandatory
Notes: 1) FC-FS basic link services are used to perform the ABORT TASK function. 2) CLEAR ACA is mandatory if Automatic Contingent Alliance is used.		

FC-FS basic link services and extended link services are used to perform the ABORT TASK function, to recover Exchange resources, and to re-establish other initial conditions. FC-FS basic link services and extended link services may be used for additional control and management activities not listed in table 2. See 9.1.3.

4.9 Clearing effects of task management, FCP, FC-FS, and FC-AL-2 actions

Tables 4 and 5 summarize the FCP target objects that are cleared as a result of Fibre Channel Link actions and SCSI operations, respectively. A 'Y' in the corresponding column of either table indicates the object is cleared to its default, saved, or initial value within the device upon successful completion of the specified action. The clearing actions are applicable only to Sequences and Exchanges associated with Fibre Channel protocol actions. Sequences and Exchanges associated with other actions follow rules specified in FC-FS or other relevant protocol standards. An 'N' in the corresponding column indicates the object is not affected by the specified action. A '-' in the column indicates that the action is not applicable. Rows indicating an effect for all initiator ports have the specified effect on all ports, regardless of the link that attaches the initiator port to the target.

Table 4 - Clearing effects of link related functions

Target object	FC link action affecting target object					
	Target Power Cycle	Reset LIP(y,x) ²	LOGO ⁵ , PLOGI	PRLI ⁴ , PRLO ⁵	TPRLO ³	ABTS (Exchange)
PLOGI parameters						
For all logged-in initiator ports	Y	Y	N	N	N	N
Only for initiator port associated with the action	-	-	Y	N	N	N
Open FCP Sequences Terminated						
For all initiator ports with open FCP Sequences	Y	Y	N	N	Y	N
Only for initiator port associated with the action	-	-	Y	Y	-	N
Only for FCP Sequences associated with Aborted FCP Exchanges	-	-	-	-	-	Y
Login BB_Credit_CNT						
For all Logged-In L_Ports	Y	Y	-	N	N	N
For transmitting L_Port only	-	-	Y			
Hard Address Acquisition Attempted	Y ¹	Y ¹	N	N	N	N
PRLI parameters cleared						
For all logged-in initiator ports	Y	Y	N	N	N	N
Only for N_Port or L_Port associated with the action	-	-	Y	Y	N	N
CRN (Command Reference Number) (set to one)						
For all initiator ports	Y	Y	N	N	Y	N
Only for initiator port associated with the action	-	-	Y	Y	-	N
NOTES:						
1 If the NL_Port has an AL_PA different than its hard address and the NL_Port experiences a power cycle or recognizes LIP(AL_PD,AL_PS), the NL_Port shall relinquish its current AL_PA and attempt to acquire its hard address.						
2 This is also known as LIP(AL_PD,AL_PS). If the destination recognizes a selective hard reset LIP where the AL_PD matches the AL_PA of the receiving NL_Port, the receiving NL_Port shall perform the behavior described in this column.						
3 For TPRLO (Third Party Process Logout), actions listed shall be performed when the GLOBAL bit is set to one. If the GLOBAL bit is set to zero, then the actions listed under PRLI/PRLO shall be performed for the designated initiator. See FC-FS.						
4 The Target shall clear the object only if ESTABLISH IMAGE PAIR is set to one and if the referenced image pair is FCP type. See 6.2.						
5 LOGO and PRLO may be either implicit or explicit. Implicit LOGO and PRLO are specified in FC-FS and FC-FLA.						

Table 5 - Clearing effects of initiator actions

Target object	Initiator action affecting target object			
	TARGET RESET	LOGICAL UNIT RESET ^{2, 3}	CLEAR TASK SET ²	ABORT TASK SET ²
PLOGI parameters For all logged-in initiator ports Only for initiator port associated with the action	N N	N N	N N	N N
Open FCP Sequences Terminated For all initiator ports with open FCP Sequences Only for initiator port associated with the action Only for FCP Sequences associated with Aborted FCP Exchanges	Y ¹ - -	Y ¹ - -	Y ¹ - -	N Y ¹ -
Login BB_Credit_CNT For all Logged-In L_Ports For transmitting L_Port only	N	N	N	N
Hard Address Acquisition Attempted	N	N	N	N
PRLI parameters cleared For all logged-in initiator ports Only for N_Port or L_Port associated with the action	N N	N N	N N	N N
CRN (Command Reference Number) (set to one) For all initiator ports Only for initiator port associated with the action	Y -	Y -	Y -	N Y
NOTES: 1 Exchanges are cleared internally within the target, but open FCP Sequences shall be individually aborted by the initiator via the recovery abort protocol that also has the effect of aborting the associated FCP Exchange. See 12.3. 2 For multiple-LUN targets, CLEAR TASK SET, ABORT TASK SET, and LOGICAL UNIT RESET affect only the addressed LUN. 3 A definition of the LOGICAL UNIT RESET Task Management function is contained in the SAM-2 standard.				

4.10 I_T nexus loss notification events

An FCP_Port shall deliver an I_T nexus loss notification (see SAM-3) for the following:

- Sending or receiving LOGO (explicit or implicit);
- Sending or receiving PRLO (explicit or implicit);
- Receiving TPRLO;
- Sending TPRLO with a Third Party Originator N_Port_ID (see FC-FS) that matches the N_Port_ID of the sending FCP_Port; or
- Sending TPRLO with the GLOBAL bit set to one to a target port that has an I_T nexus with the sending initiator port.

4.11 Transport Reset notification events

An NL_Port shall deliver a Transport Reset notification (see SAM-3) for a Reset LIP(y,x) FC link event if the AL_PD matches the AL_PA of the receiving NL_Port.

4.12 Port login/logout

The N_Port Login (PLOGI) extended link service is optionally used to establish the Fibre Channel operating parameters between any two Fibre Channel ports, including FCP_Ports.

If a target receives a PLOGI request and it finds there are not enough login resources to complete the login, the target responds to the PLOGI with LS_RJT and reason code “unable to perform command request” and reason explanation “insufficient resources to support Login” as defined by FC-FS. By means outside the scope of this standard, the target may select another initiator and release some login resources by performing an explicit logout of the other initiator, freeing resources for a future PLOGI.

4.13 Process login/logout

The Process Login (PRLI) extended link service is optionally used to establish the FCP operating relationships between two FCP_Ports. Implicit PRLI/PRLO parameters may be defined for FCP_Ports. Such definitions are outside the scope of this standard.

4.14 Link management

FC-FS allows management protocols above the FC-FS interface to perform link data functions. The standard FC-FS primitive sequences, link management protocols, and basic and extended link services are used as required by FCP devices. Implicit login functions are allowed.

5 Fibre Channel protocol overview

5.1 FCP addressing and Exchange identification

The address of each FCP_Port is defined by its address identifier as described in FC-FS. Each FCP I/O operation is identified by the FCP I/O operation's fully qualified exchange identifier (FQXID). The FQXID is composed of the initiator address identifier, the target address identifier, the OX_ID and the RX_ID. Other definitions of FQXID are outside the scope of this standard. The method used to identify FCP I/O operations internal to the application client and the device server is not defined by this standard.

Addressability of logical units uses the logical unit number provided in the FCP_CMND IU. Subsequent identification of the FCP I/O operation and the Exchange which carries the protocol interactions for the FCP I/O operation uses the FQXID. FCP devices do not use the Process_Associator.

The target uses the OX_ID, and, if it has been assigned, the RX_ID to perform error recovery and task management functions. The task retry identifier is used as a supplemental task identifier if task retry identification is supported and enabled.

5.2 SCSI third-party device identifier for the Fibre Channel protocol

The SCSI RESERVE commands that use the 64-bit THIRD-PARTY DEVICE ID defined by SPC-2 shall use the FCP third-party device id format defined in table 6 to identify the specified third-party target.

Table 6 - FCP third-party device id format

Bit	7	6	5	4	3	2	1	0
Byte								
0	RESERVED							
1–3	(MSB)	FCP_PORT IDENTIFIER						(LSB)
4–7	RESERVED							

FCP_PORT IDENTIFIER:

The FCP_PORT IDENTIFIER field defines the address identifier of the target that shall be used by the target for third-party addressing.

5.3 Use of World Wide Names

As specified in FC-FS, each Fibre Channel node and each Fibre Channel port shall have a Worldwide_Name. The Worldwide_Name shall be a unique name using one of the formats defined by FC-FS and its extensions. Each target and its associated logical units has knowledge of the Port_Name of each initiator through the Fibre Channel login process. As a result, the relationship between address identifier of the initiator and a persistent reservation for a logical unit may be adjusted as defined in SPC-2 during those reconfiguration events that may change the address identifier of the initiator. If a target receives a PRLI or a PLOGI from an initiator FCP_Port with a previously known Worldwide_Name but with a changed initiator identifier, the device server shall assign the new initiator identifier to the existing registration and reservation to the initiator port having the same Worldwide_Name.

Each logical unit shall be able to present a Worldwide_Name through the INQUIRY command vital product data device identification page as defined by SPC-2. For devices compliant with this standard and having a LUN 0, the Worldwide_Name of the logical unit having a LUN of 0 may be the same as the Node_Name of the target. The Worldwide_Name for the port shall be different from the Worldwide_Name for the node.

5.4 FCP Information Units (IUs)

The IUs used by the Fibre Channel protocol and their characteristics are shown in table 7 for IUs sent to targets, and in table 8 for IUs sent to initiators. Each IU shall be contained in a single Sequence. Each Sequence carrying an FCP IU shall contain only one IU. Examples of typical Fibre Channel protocol operations using these IUs are included in Annex B.

Table 7 - FCP Information Units (IUs) sent to targets

IU	SCSI-3 primitive	Data block		F/M/L	SI	M/O
		CAT	Content			
T1	Command / Task Mgmt Rqst	6	FCP_CMND	F	T	M
T2	Command request	6	FCP_CMND	F	H	O
T3	Command request (Linked)	6	FCP_CMND	M	T	O
T4	Command request (Linked)	6	FCP_CMND	M	H	O
T6	Data Out action	1	FCP_DATA	M	T	M
T12	Confirm	3	none	L	T	O
Notes: T5, T7, T8, T9, T10, and T11 are obsolete. T2 and T4 are only permitted when transfer ready IUs are disabled. See Table 9. T3 and T4 are only permitted for linked SCSI commands. T2 and T4 allow optional sequence streaming during Write operations. T12 is only permitted in response to an I5 frame requesting the confirmed completion protocol. See Table 8. Key: IU Information Unit identifier CAT Information category of Device_Data frames carrying the data block (see FC-FS) CONTENT Contents (payload) of data block F/M/L First/Middle/Last Sequence of Exchange (FC-FS) F First M Middle L Last SI Sequence Initiative: Held or Transferred (FC-FS) H Held T Transferred M/O Mandatory/Optional Sequence M Mandatory O Optional						

Table 8 - FCP Information Units (IUs) sent to initiators

IU	SCSI-3 primitive	Data block		F/M/L	SI	M/O																										
		CAT	Content																													
I1	Data delivery request	5	FCP_XFER_RDY (Write)	M	T	M																										
I3	Data In action	1	FCP_DATA	M	H	M																										
I4	Command/Task Mgmt Response	7	FCP_RSP	L	T	M																										
I5	Response (Linked or confirm request)	7	FCP_RSP	M	T	O																										
Notes: I2, I6, and I7 are obsolete. I5 is permitted for linked SCSI commands or to request the confirm completion protocol. I3 allows optional sequence streaming to I3, I4, or I5. Key: <table><tr><td>IU</td><td>Information Unit identifier</td></tr><tr><td>CAT</td><td>Information category of Device_Data frames carrying the data block (FC-FS)</td></tr><tr><td>CONTENT</td><td>Contents (payload) of data block</td></tr><tr><td>F/M/L</td><td>First/Middle/Last Sequence of Exchange (FC-FS)</td></tr><tr><td>F</td><td>First</td></tr><tr><td>M</td><td>Middle</td></tr><tr><td>L</td><td>Last</td></tr><tr><td>SI</td><td>Sequence Initiative: Held or Transferred (FC-FS)</td></tr><tr><td>H</td><td>Held</td></tr><tr><td>T</td><td>Transferred</td></tr><tr><td>M/O</td><td>Mandatory/Optional Sequence</td></tr><tr><td>M</td><td>Mandatory</td></tr><tr><td>O</td><td>Optional</td></tr></table>							IU	Information Unit identifier	CAT	Information category of Device_Data frames carrying the data block (FC-FS)	CONTENT	Contents (payload) of data block	F/M/L	First/Middle/Last Sequence of Exchange (FC-FS)	F	First	M	Middle	L	Last	SI	Sequence Initiative: Held or Transferred (FC-FS)	H	Held	T	Transferred	M/O	Mandatory/Optional Sequence	M	Mandatory	O	Optional
IU	Information Unit identifier																															
CAT	Information category of Device_Data frames carrying the data block (FC-FS)																															
CONTENT	Contents (payload) of data block																															
F/M/L	First/Middle/Last Sequence of Exchange (FC-FS)																															
F	First																															
M	Middle																															
L	Last																															
SI	Sequence Initiative: Held or Transferred (FC-FS)																															
H	Held																															
T	Transferred																															
M/O	Mandatory/Optional Sequence																															
M	Mandatory																															
O	Optional																															

5.5 Fibre Channel protocol standard formats

The Fibre Channel protocol requires only the standard FC-2 services as described in FC-FS. FC-FS provides an informative outline of the FC_PH_SEQUENCE.request used by the Fibre Channel protocol to provide all the information to manage the protocol. No additional capabilities are required to transmit the required FCP IUs. Corresponding FC_PH_SEQUENCE.indication information is provided to the Sequence Recipient to properly type and categorize the received IUs. Classes of service that provide end-to-end acknowledgement, including Class 1 and Class 2 service, provide the FC_PH_SEQUENCE.confirmation primitive that may be used to assist in management of the Fibre Channel protocol. The use of the FC_PH_SEQUENCE_TAG.indication primitive may be required by the Sequence Initiator.

5.6 FC-FS mappings to SCSI-3 functionality

5.6.1 FC-FS frame header

The format of the standard FC-FS header as used by the Fibre Channel protocol is defined in table 9.

Table 9 - FCP frame header

Bits	31– 24	23–16	15–08	07–00
Word				
0	R_CTL	D_ID		
1	CS_CTL	S_ID		
2	TYPE	F_CTL		
3	SEQ_ID	DF_CTL	SEQ_CNT	
4	OX_ID		RX_ID	
5	PARAMETER			

All fields use the standard FC-FS definitions. The following explanations of some of the fields provide information about the use of those fields to implement FCP functionality.

5.6.2 Frame header fields

5.6.2.1 R_CTL

The values in the R_CTL field identify the frame as part of an FCP I/O Operation and identify the information category. All Sequences containing FCP command, data, response, and data descriptor information shall be composed of Device_Data frames.

The information category associated with each IU is defined in table 7 and table 8.

5.6.2.2 D_ID

The value in the D_ID field is the D_ID of the frame. For FCP FC-4 Device_Data frames, the D_ID transmitted by the Exchange Originator is the address identifier of the target. The D_ID transmitted by the Exchange Responder is the address identifier of the initiator.

5.6.2.3 CS_CTL

The values in the CS_CTL field are defined by FC-FS for class specific control information and do not interact with the Fibre Channel protocol.

5.6.2.4 S_ID

The value in the S_ID field is the S_ID of the frame. For FCP FC-4 Device_Data frames, the S_ID transmitted by the Exchange Originator is the address identifier of the initiator. The S_ID transmitted by the Exchange Responder is the address identifier of the target.

5.6.2.5 TYPE

The value in the TYPE field shall be 08h for all frames of SCSI FCP Sequences.

5.6.2.6 F_CTL

The bits in the F_CTL field manage the beginning and normal or abnormal termination of Sequences and Exchanges. The bits and definitions shall be as defined by FC-FS.

5.6.2.7 SEQ_ID

The value in the SEQ_ID field identifies each Sequence between a particular Exchange Originator and Exchange Responder with a unique value as defined by FC-FS.

5.6.2.8 DF_CTL

The bits in the DF_CTL field indicate any optional headers that may be present. The Fibre Channel protocol does not use any optional headers.

5.6.2.9 SEQ_CNT

The value in the SEQ_CNT field indicates the frame order within the Sequence as defined by FC-FS.

5.6.2.10 OX_ID

The value in the OX_ID field is the Originator Exchange Identifier and is one of the identifiers contained in the FQXID. The OX_ID shall be assigned and shall have a value other than FFFFh.

5.6.2.11 RX_ID

The value in the RX_ID field is the Responder Exchange Identifier and is one of the identifiers contained in the FQXID. The RX_ID shall have the unassigned value of FFFFh until the Exchange Responder assigns a different value in its response to the Exchange Originator. The Exchange Originator shall use the value assigned by the Exchange Responder for subsequent frames.

5.6.2.12 PARAMETER

The PARAMETER field has two definitions for Device_Data frames with the FCP type.

For frames of the solicited data category (FCP_DATA IUs), the PARAMETER field shall contain a relative offset. The RELATIVE OFFSET PRESENT bit of the F_CTL field shall be set to one, indicating that the PARAMETER field value is a relative offset. For the solicited data category (FCP_DATA IUs), the relative offset is the application client buffer offset as described by SAM-2. For solicited data category frames, the relative offset shall have a value that is 0 modulo 4 (i.e., each frame of each FCP_DATA IU shall begin on a word boundary).

For frames of the unsolicited control category (FCP_CMND IUs), the PARAMETER field value depends on whether task retry identification is active. If the target and initiator have agreed upon performing task retry identification, the PARAMETER field shall contain the task retry identifier. If the target and initiator have not agreed upon performing task retry identification, the PARAMETER field shall contain a value of zero. In both cases, the RELATIVE OFFSET PRESENT bit of the F_CTL field shall be set to zero.

For all other Device_Data frames with the FCP type, the RELATIVE OFFSET PRESENT bit of the F_CTL field shall be set to zero and the PARAMETER field shall contain a value of zero.

For FCP FC-4 Link Service frames, the PARAMETER field is specified in the description of the individual link services.

6 FCP basic and extended link service definitions

6.1 Overview of link service requirements

The FCP link-level protocol includes the basic link services and extended link services defined by FC-FS. The protocol also includes the Process Login and Process Logout extended link services defined by FC-FS, the Process Login FCP Service Parameter pages defined in this standard, and the Read Exchange Concise extended link service with usage as defined in this standard.

Link-level protocols are used to configure the FC environment, including the establishment of configuration information and address information. FCP devices introduced into a configuration or modifications in the addressing or routing of the configuration may require the login and discovery procedures to be executed again.

6.2 Overview of Process Login/Logout

The extended link service command of Process Login (PRLI) is defined in FC-FS. The PRLI allows for a process at one FCP_Port to be related to a corresponding process at another FCP_Port as an image pair. In addition, the PRLI allows one or more FC-4 capabilities to be reported by the initiating FCP_Port to the recipient FCP_Port. The recipient FCP_Port indicates its acceptance or rejection of the capabilities in its response to the PRLI request. The PRLI is optional, since implicit login may be established by configuration conventions outside the scope of this standard.

PRLI requests shall only be initiated by devices having the initiator capability. Devices having only target capability shall not perform a PRLI request. An initiator shall have successfully completed a PRLI with a target that establishes an image pair before any FCP IUs are exchanged. An image pair may also be established by an implicit PRLI established by methods outside the scope of this standard. An image pair is removed by a PRLO (see 6.4). If an image pair is not established by an initiator to a target, the initiator and target shall not exchange any FCP IUs. Any FCP IUs received by a target from an N_Port or NL_Port that has not established an image pair with that target shall be discarded. In addition, a target that receives an FCP_CMND IU from an N_Port or NL_Port that has not established an image pair with that target shall discard the FCP_CMND IU and respond with an explicit PRLO.

Process_Associators shall not be used in initiators and targets. If multiple images are required in an initiator, they shall be provided by transparent aliasing of the N_Port Identifier of the initiator. If multiple images are required in a target, they shall be provided by SCSI logical units.

The creation of image pairs behind an FCP_Port has no effect on the Fibre Channel protocol.

The FC-4 Service Parameter pages for the Fibre Channel protocol are defined in the following subclauses.

Execution of a PRLI or PRLO extended link service command performs the clearing actions defined in 4.9.

Process Login has two actions that can be performed, selected by the ESTABLISH IMAGE PAIR bit. (See 6.3.4.)

- a) Informative action
Service parameter information is exchanged during the Process Login enabling subsequent negotiation for image pair establishment.
- b) Binding action
Service parameter information is exchanged that establishes an image pair relationship between processes in the communicating N_Port or NL_Ports. The relationship does not allow any communication types or paths other than those established by the PRLI.

6.3 Process Login (PRLI)

6.3.1 Use of Process Login by the Fibre Channel protocol

The PRLI request is transmitted from an Originator FCP_Port to a Responder FCP_Port to identify to the destination the capabilities that the Originator FCP_Port expects to use with the Responder FCP_Port and to determine the capabilities of the Responder. (See FC-FS.)

If the PRLI is requesting an informative action by setting the ESTABLISH IMAGE PAIR bit to zero, the PRLI accept reports the capabilities of the Responder to the Originator.

If the PRLI is requesting a binding action by setting the ESTABLISH IMAGE PAIR bit to one, the PRLI accept reports the capabilities of the responder to the Originator and establishes an image pair. An image pair shall be established only if the FCP devices have complementary initiator and target capabilities. If both FCP devices have both initiator and target capabilities, a single image pair allows both initiators to access the complementary target capabilities of the other device in the pair. Some capabilities require support by both the Originator and Responder before they can be used (see 6.3.4). The IMAGE PAIR ESTABLISHED bit in the PRLI accept indicates that an image pair was successfully established.

A reason code shall be provided if the PRLI request is incorrect or if a requested image pair cannot be established.

A link service reject (LS_RJT) indicates that the PRLI request is not supported or is incorrectly formatted.

The PRLI common service parameters and accept response codes are defined in FC-FS. FC-4 service parameters for mappings other than the Fibre Channel protocol are defined in other FC-4 standards.

6.3.2 Process_Associator requirements

Operation of the PRLI depends on the Originator's and Responder's requirements for Process_Associators as specified in FC-FS. Process_Associators are not used in the Fibre Channel protocol and shall not be used by FCP devices.

The Fibre Channel protocol assumes that the Originator has knowledge of the capabilities of the Responder. That information may be obtained by performing a PRLI requesting an informative action or by other mechanisms outside the scope of this standard.

6.3.3 New or repeated PRLI

After the completion of any new or repeated binding PRLI, all clearing actions specified in 4.9 shall be performed.

After the completion of any new or repeated informative PRLI, the state of the Originator and Responder remains unchanged.

If the change in parameters affects any outstanding FCP Exchanges, those Exchanges shall be terminated by the initiator using a recovery abort operation. A recovery qualifier may be established after the recovery abort, temporarily restricting the choice of OX_ID values by the initiator and RX_ID values by the target. Only actions for image pairs that are being referenced by the PRLI are affected.

FCP devices may have default PRLI information provided in a manner outside the scope of this standard. Such devices do not require the execution of a PRLI to perform normal FCP I/O operations. If default PRLI information is complete enough so that login (PLOGI) is sufficient to perform an implicit PRLI, then PLOGI shall perform the same clearing actions and establish the same Unit Attention condition that would normally be performed and established by PRLI.

6.3.4 Process Login request FCP Service Parameter page format

The FCP Service Parameter page for the Process Login request is shown in table 10.

Table 10 - FCP Service Parameter page, PRLI request

FCP service parameter	Word	Bit
SCSI FCP (08h)	0	31–24
reserved for TYPE code extension	0	23–16
ORIGINATOR PROCESS_ASSOCIATOR VALID	0	15
RESPONDER PROCESS_ASSOCIATOR VALID	0	14
ESTABLISH IMAGE PAIR	0	13
RESERVED	0	12–0
ORIGINATOR PROCESS_ASSOCIATOR	1	31–0
RESPONDER PROCESS_ASSOCIATOR	2	31–0
RESERVED	3	31–10
TASK RETRY IDENTIFICATION REQUESTED	3	9
RETRY	3	8
CONFIRMED COMPLETION ALLOWED	3	7
DATA OVERLAY ALLOWED	3	6
INITIATOR FUNCTION	3	5
TARGET FUNCTION	3	4
OBSOLETE	3	3
OBSOLETE	3	2
READ FCP_XFER_RDY DISABLED (shall be one)	3	1
WRITE FCP_XFER_RDY DISABLED	3	0

Word 0, Bits 31–24: FCP specific code: The value of 08h in this byte indicates that this Service Parameter page is defined for the Fibre Channel protocol. (See FC-FS.)

Word 0, Bit 15: ORIGINATOR PROCESS_ASSOCIATOR VALID: The ORIGINATOR PROCESS_ASSOCIATOR VALID bit is defined in FC-FS. For the Fibre Channel protocol, the ORIGINATOR PROCESS_ASSOCIATOR VALID bit shall be zero, indicating that the ORIGINATOR PROCESS_ASSOCIATOR is not valid.

Word 0, Bit 14: RESPONDER PROCESS_ASSOCIATOR VALID: The RESPONDER PROCESS_ASSOCIATOR VALID bit is defined in FC-FS. For the Fibre Channel protocol, the RESPONDER PROCESS_ASSOCIATOR VALID bit shall be zero, indicating that the RESPONDER PROCESS_ASSOCIATOR is not valid.

Word 0, Bit 13: ESTABLISH IMAGE PAIR: If the ESTABLISH IMAGE PAIR bit is set to zero, the PRLI only exchanges service parameters as defined in FC-FS.

If the ESTABLISH IMAGE PAIR bit is set to one, the PRLI exchanges service parameters and attempts to establish an image pair as defined in FC-FS.

Word 1: ORIGINATOR PROCESS_ASSOCIATOR: The ORIGINATOR PROCESS_ASSOCIATOR field is the Originator Process_Associator as defined by FC-FS.

Word 2: RESPONDER PROCESS_ASSOCIATOR: The RESPONDER PROCESS_ASSOCIATOR field is the Responder Process_Associator as defined by FC-FS.

Word 3, Bit 9: TASK RETRY IDENTIFICATION REQUESTED: When the TASK RETRY IDENTIFICATION REQUESTED bit is set to one, the Originator of the PRLI requests that the task retry identification function be used. If both the Originator of the PRLI and the Responder to the PRLI request that the task retry identification function be used, then it shall be used between the initiator and all logical units for that port. The PARAMETER field for each FCP_CMND IU shall be set to a unique non-zero value. The PARAMETER field for any REC Extended Link Service request or SRR FCP FC-4 Link Service request for that command shall be set to the same value.

When the TASK RETRY IDENTIFICATION REQUESTED bit is set to zero by either the Originator of or the Responder to the PRLI, the task retry identification function shall not be used. The PARAMETER fields for FCP_CMND IUs, for REC Extended Link Service requests, and for SRR FCP FC-4 Link Service requests shall be zero.

Word 3, Bit 8: RETRY: When the RETRY bit is set to one, the Originator or Responder is indicating that it supports as an initiator the capability of requesting a retransmission of unsuccessfully transmitted data or as a target the capability of performing a requested retransmission. When the RETRY bit is set to zero, the Originator or Responder is indicating that it does not support the capability of requesting or performing retransmissions of unsuccessfully transmitted data.

If the process has both initiator and target capabilities, the RETRY bit shall apply to both. SRR may be both transmitted by and accepted by the process.

An initiator and target shall use the retransmission capability only if the RETRY bit is set in both the request payload and in the accept payload. If the RETRY bit is set to zero in either the request payload or the accept payload, the SRR shall not be performed by the initiator. If an SRR FCP FC-4 Link Service is received by a target that has set the RETRY bit to zero, the SRR shall be rejected with FCP_RJT.

If the image pair is allowed to use the retransmission capability, overlay of data as defined for SRR shall be allowed regardless of the state of the DATA OVERLAY ALLOWED bit.

Word 3, Bit 7: CONFIRMED COMPLETION ALLOWED: When the CONFIRMED COMPLETION ALLOWED bit is set to one, the Originator's or Responder's initiator function has the capability of supporting confirmed completion. When the CONFIRMED COMPLETION ALLOWED bit is set to zero, the initiator function does not have the capability of supporting confirmed completion. The CONFIRMED COMPLETION ALLOWED bit shall be zero for FCP devices having only target function. If the initiator function supports confirmed completion, then a target may optionally request an FCP_CONF IU by setting the FCP_CONF_REQ bit to one as specified by 4.4. If the initiator function does not have the capability of supporting confirmed completion, the target shall not set the FCP_CONF_REQ bit to one.

Word 3, Bit 6: DATA OVERLAY ALLOWED: When the DATA OVERLAY ALLOWED bit is set to one, the Originator or Responder is indicating that its initiator function has the capability of supporting data overlay. When the data overlay allowed bit is set to zero, the initiator function does not have the capability of performing data overlay. The data overlay allowed bit shall be zero for FCP devices having only target function. If the initiator function supports data overlay, then a target may optionally perform random buffer access that performs a transfer to or from the same offset in the application client buffer more than once during execution of a command.