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Space data and information transfer systems — Proximity-1 space link protocol — Data link layer

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The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2015

ISBN 978 0 580 87628 8

ICS 49.140

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 December 2015.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

Space data and information transfer systems — Proximity-1 space link protocol — Data link layer

*Systèmes de transfert des informations et données spatiales —
Protocole pour liaisons spatiales de proximité 1 — Couche de liaisons
de données*





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This third edition of ISO 22663:2015 cancels and replaces the second edition (ISO 22663:2007), which has been technically revised.

Recommendation for Space Data System Standards

PROXIMITY-1 SPACE LINK PROTOCOL— DATA LINK LAYER

RECOMMENDED STANDARD

CCSDS 211.0-B-5

BLUE BOOK

December 2013

AUTHORITY

Issue:	Recommended Standard, Issue 5
Date:	December 2013
Location:	Washington, DC, USA

This document has been approved for publication by the Management Council of the Consultative Committee for Space Data Systems (CCSDS) and represents the consensus technical agreement of the participating CCSDS Member Agencies. The procedure for review and authorization of CCSDS documents is detailed in *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-3), and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This document is published and maintained by:

CCSDS Secretariat
Space Communications and Navigation Office, 7L70
Space Operations Mission Directorate
NASA Headquarters
Washington, DC 20546-0001, USA

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- Swiss Space Office (SSO)/Switzerland.
- United States Geological Survey (USGS)/USA.

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 211.0-B-1	Proximity-1 Space Link Protocol	October 2002	Original issue, superseded
CCSDS 211.0-B-2	Proximity-1 Space Link Protocol— Data Link Layer	April 2003	Superseded
CCSDS 211.0-B-3	Proximity-1 Space Link Protocol— Data Link Layer	May 2004	Superseded
CCSDS 211.0-B-4	Proximity-1 Space Link Protocol— Data Link Layer, Recommended Standard, Issue 4	July 2006	Superseded
CCSDS 211.0-B-5	Proximity-1 Space Link Protocol— Data Link Layer, Recommended Standard, Issue 5	December 2013	Current issue: This update includes several improvements and clarifications— accomplishing better alignment and consistency with the other Proximity-1 Blue Books—and the addition of an option for Low- Density Parity-Check (LDPC) codes.

NOTE – Changes from the previous issue are too numerous to permit markup.

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommended Standard is to specify the Data Link Layer used with the Proximity-1 Data Link Coding and Synchronization Sublayer (reference [5]) and Physical Layer (reference [6]). Proximity space links are defined to be short-range, bi-directional, fixed or mobile radio links, generally used to communicate among probes, landers, rovers, orbiting constellations, and orbiting relays. These links are characterized by short time delays, moderate (not weak) signals, and short, independent sessions.

1.2 SCOPE

This Recommended Standard defines the Data Link Layer (Framing, Medium Access Control, Data Services, and Input/Output [I/O] Sublayers). The specifications for the protocol data units, framing, media access control, expedited and sequenced-controlled data transfer, timing service, I/O control, and the procedures for establishing and terminating a session between a caller and responder are defined in this document. The Coding and Synchronization Sublayer is defined in the separate CCSDS Recommended Standard entitled, *Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer* (reference [5]). The Physical Layer is defined in the separate CCSDS Recommended Standard entitled, *Proximity-1 Space Link Protocol—Physical Layer* (reference [6]).

This Recommended Standard does not specify a) individual implementations or products, b) implementation of service interfaces within real systems, c) the methods or technologies required to perform the procedures, or d) the management activities required to configure and control the protocol.

1.3 APPLICABILITY

This Recommended Standard applies to the creation of Agency standards and to future data communications over space links between CCSDS Agencies in cross-support situations. It applies also to internal Agency links where no cross support is required. It includes specification of the services and protocols for inter-Agency cross support. It is neither a specification of, nor a design for, systems that may be implemented for existing or future missions.

The Recommended Standard specified in this document is to be invoked through the normal standards programs of each CCSDS Agency and is applicable to those missions for which cross support based on capabilities described in this Recommended Standard is anticipated. Where mandatory capabilities are clearly indicated in sections of this Recommended Standard, they must be implemented when this document is used as a basis for cross support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross-support agreements between the Agencies involved.

1.4 RATIONALE

The CCSDS believes it is important to document the rationale underlying the recommendations chosen, so that future evaluations of proposed changes or improvements will not lose sight of previous decisions. Concepts and rationale behind the decisions that formed the basis for Proximity-1 are documented in the CCSDS Proximity-1 Space Link Green Book (reference [H9]).

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 DEFINITIONS

1.5.1.1 Terms from the Open Systems Interconnection (OSI) Basic Reference Model

This Recommended Standard makes use of a number of terms defined in reference [1]. In this Recommended Standard those terms are used in a generic sense, i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are as follows:

- a) connection;
- b) Data Link Layer;
- c) entity;
- d) Physical Layer;
- e) protocol control information;
- f) protocol data unit;
- g) real system;
- h) segmenting;
- i) service;
- j) service data unit.

1.5.1.2 Terms Defined in This Recommended Standard

For the purposes of this Recommended Standard, the following definitions also apply. Many other terms that pertain to specific items are defined in the appropriate sections.

asynchronous data link: A data link consisting of a sequence of variable-length Proximity Link Transmission Units (PLTUs), which are not necessarily concatenated.

caller and responder: Initiator and receiver, respectively, in a Proximity space link session.
A **caller transceiver** is the initiator of the link establishment process and manager of

negotiation (if required) of the session. A **responder transceiver** typically receives link establishment parameters from the caller. The caller initiates communication between itself and a responder on a prearranged communications channel with predefined controlling parameters. As necessary, the caller and responder may negotiate the controlling parameters for the session (at some level between fully controlled and completely adaptive).

COP-P: Communication Operations Procedure for Proximity links (COP-P). The COP-P includes both the FARM-P and FOP-P of the caller and responder unit.

enterprise: A project or undertaking, especially one of some scope, complexity, and risk.

FARM-P: Frame Acceptance and Reporting Mechanism for Proximity links, for Sequence Controlled service carried out within the receiver in the Proximity-1 link.

FOP-P: Frame Operation Procedure for Proximity links, for ordering the output frames for Sequence Controlled service carried out in the transmitter in the Proximity-1 link.

forward link: That portion of a Proximity space link in which the caller transmits and the responder receives (typically a command link).

hailing: The persistent activity used to establish a Proximity link by a caller to a responder in either full or half duplex. It does not apply to simplex operations.

hailing channel: The forward and return frequency pairs that a caller and responder use to establish physical link communications.

mission phase: A mission period during which specified communications characteristics are fixed. The transition between two consecutive mission phases may cause an interruption of the communications services.

PCID: Physical Channel ID, carried in transfer frames and in PLCWs. The PCID is intended primarily for a receiving system having two concurrently operating transceiver units (primary and backup, for example), where the PCID can be used to select which receiver processes the received frame. It may identify either of two redundant receivers at the receiving end.

P-frame: A Version-3 Transfer Frame that contains only self-identified and self-delimited supervisory protocol data units (compare U-frame).

physical channel: The Radio Frequency (RF) channel upon which the stream of symbols is transferred over a space link in a single direction.

PLCW: Proximity Link Control Word, the protocol data unit for reporting Sequence Controlled service status via the return link from the responder back to the caller.

CCSDS RECOMMENDED STANDARD FOR PROXIMITY-1 SPACE DATA LINK PROTOCOL

PLTU: Proximity Link Transmission Unit, the data unit composed of the Attached Synchronization Marker (ASM), the Version-3 Transfer Frame, and the attached Cyclic Redundancy Check (CRC)-32.

Port ID: Identifier of the logical or physical port that is the destination for a user's service data unit.

protocol object: Directives, PLCWs, or status reports contained within an SPDU.

Proximity link: A full-duplex, half-duplex, or simplex link for the transfer of data between Proximity-1 nodes in a session.

pseudo packet ID: The temporary packet ID assigned by the protocol to a user's packet within the segmentation process.

reconnect: Process in which the caller attempts to reestablish the responder (because of lack of communication progress) during the data services phase within the ongoing session. Upon entering this state, the FARM-P and FOP-P variables of the caller and responder are not reset (in particular their frame sequence counters).

resynchronization (COP-P): Process in which a sequence count anomaly is detected by the caller and the caller forces the responder to readjust its Sequence Controlled frame numbers via the SET V(R) activity.

return link: That portion of a Proximity space link in which the responder transmits and the caller receives (typically a telemetry link).

Routing ID: Unique identifier of a user's packet through the segmentation and reassembly process. It is an internal identifier used by the I/O Sublayer and it consists of a PCID, Port ID, and pseudo packet ID.

Sent queue (Sent Frame queue): Temporarily stored Sequence Controlled frames that have been sent but not yet acknowledged by the receiver.

session: A dialog between two or more communicating Proximity link transceivers. A session consists of three distinct operational phases: session establishment, data services (which may include resynchronization and/or reconnect subphases), and session termination. Session termination may be coordinated (through the exchange of no-more-data-to-send directives), or if communication is lost (inability to resynchronize or reconnect), the transceivers should eventually independently conclude the dialog is over.

space link: A communications link between transmitting and receiving entities, at least one of which is in space.

SPDU: Supervisory Protocol Data Unit, used by the local transceiver either to control or to report status to the remote partnered transceiver. Consists of one or more directives, reports, or PLCWs.

synchronous channel: A data channel where the symbol data are continuously modulated onto the channel at a fixed data rate. When no PLTU is available for transmission, Idle data is transmitted to maintain the continuous symbol stream.

U-frame: A Version-3 Transfer Frame that contains user data information (compare P-frame).

vehicle controller: The entity (e.g., spacecraft control computer) which receives the notifications defined in annex D and potentially acts upon them.

Version-3 Transfer Frame: A Proximity-1 transfer frame.

1.5.2 NOMENCLATURE

1.5.2.1 NORMATIVE TEXT

The following conventions apply for the normative specifications in this Recommended Standard:

- a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;
- b) the word ‘should’ implies an optional, but desirable, specification;
- c) the word ‘may’ implies an optional specification;
- d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

NOTE – These conventions do not imply constraints on diction in text that is clearly informative in nature.

1.5.2.2 INFORMATIVE TEXT

In the normative sections of this document, informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

- Overview;
- Background;
- Rationale;
- Discussion.

1.5.3 CONVENTIONS

In this document, the following convention is used to identify each bit in an N -bit field. The first bit in the field to be transmitted (i.e., the most left-justified when drawing a figure) is defined to be ‘Bit 0’, the following bit is defined to be ‘Bit 1’, and so on up to ‘Bit $N-1$ ’. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) is the first transmitted bit of the field, i.e., ‘Bit 0’, as shown in figure 1-1.

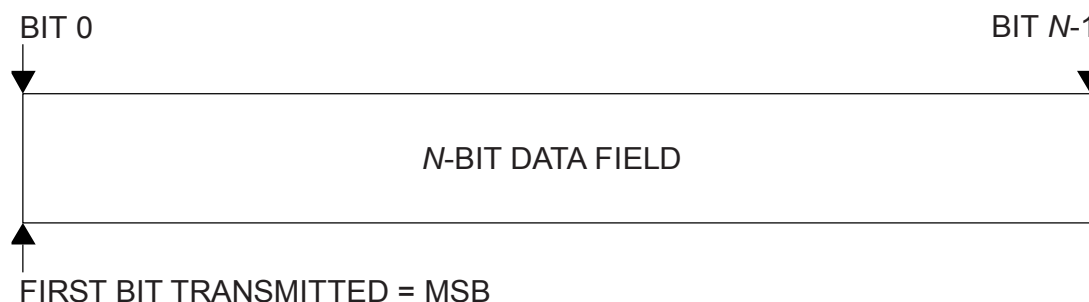


Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into 8-bit ‘words’ that conform to the above convention. Throughout this Recommended Standard, such an 8-bit word is called an ‘octet’.

The numbering for octets within a data structure begins with zero. Octet zero is the first octet to be transmitted.

By CCSDS convention, all ‘spare’ bits are permanently set to value ‘zero’.

Throughout this Recommended Standard, directive, parameter, variable, and signal names are presented with all upper-case characters; data-field and Management Information Base (MIB)-parameter names are presented with initial capitalization; values and state names are presented with predominantly lower-case characters, and are italicized.

In Proximity-1, data rate (R_d), coded symbol rate (R_{cs}), and channel symbol rate (R_{chs}) are used to denote respectively:

- the data rate of the bitstream composed by PLTUs and Idle data measured at the encoder input;
- the coded symbol rate measured at the interface between the Coding and Synchronization Sublayer and the Physical Layer; and
- the rate measured at the output of the transmitter.

The terms are used as shown in figure 1-2.

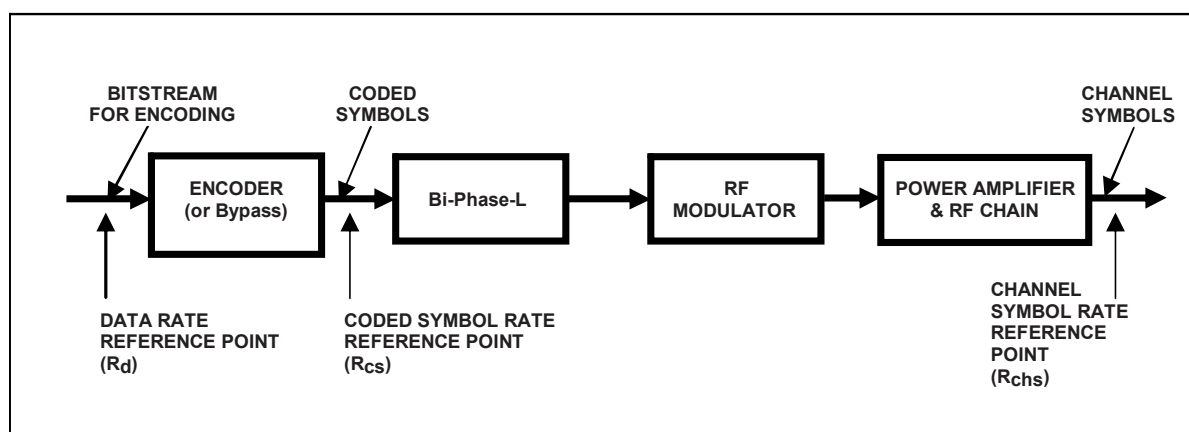


Figure 1-2: Proximity-1 Rate Terminology

1.6 REFERENCES

The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All publications are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS publications.

- [1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. International Standard, ISO/IEC 7498-1:1994. 2nd ed. Geneva: ISO, 1994.
- [2] *TM Synchronization and Channel Coding*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.0-B-2. Washington, D.C.: CCSDS, August 2011.
- [3] *CCSDS Global Spacecraft Identification Field Code Assignment Control Procedures*. Issue 6. Recommendation for Space Data System Standards (Blue Book), CCSDS 320.0-B-6. Washington, D.C.: CCSDS, October 2013.
- [4] *Time Code Formats*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 301.0-B-4. Washington, D.C.: CCSDS, November 2010.
- [5] *Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.2-B-2. Washington, D.C.: CCSDS, December 2013.
- [6] *Proximity-1 Space Link Protocol—Physical Layer*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.1-B-4. Washington, D.C.: CCSDS, December 2013.

2 OVERVIEW

2.1 CONCEPT OF PROXIMITY-1

Proximity-1 is a bi-directional Space Link Layer protocol for use by space missions. It has been designed to meet the requirements of space missions for efficient transfer of data over various types and characteristics of Proximity space links.

2.1.1 LAYERED MODEL

The Proximity-1 model consists of a Physical Layer (reference [6]) and a Data Link Layer.

Proximity-1 activities are divided between a send side and a receive side. The send side is concerned with the transmitted physical channel, and also with the acquisition of the received physical channel in order to establish a Proximity-1 link. The receive side is concerned with the reception of data on the received physical channel: the input bitstream and the protocol data units it contains.

On the send side, the Data Link Layer is responsible for providing data to be transmitted by the Physical Layer. The operation of the transmitter is state-driven.

On the receive side, the Data Link Layer accepts the serial data output from the receiver and processes the protocol data units received. It accepts directives both from the local vehicle controller and across the Proximity link to control its operations. Once the receiver is turned on, its operation is modeless. It accepts and processes all valid local and remote directives and delivers received service data units to the users.

The interactions of the Proximity-1 layers and associated data and control flows are shown in figure 2-1.

2.1.2 PHYSICAL LAYER

On the send side, the Physical Layer:

- accepts control variables from the Data Link Layer for control of the transceiver;
- accepts a PLTU from the Coding and Synchronization Sublayer for modulation onto the radiated carrier;
- performs the required (as specified by the control variables) channel coding.

On the receive side, the Physical Layer:

- provides status signals (CARRIER_ACQUIRED and SYMBOL_INLOCK_STATUS) to the Data Link Layer;
- outputs the serial coded symbol stream from the receiver's Physical Layer to the Coding and Synchronization Sublayer.

CCSDS RECOMMENDED STANDARD FOR PROXIMITY-1 SPACE DATA LINK PROTOCOL

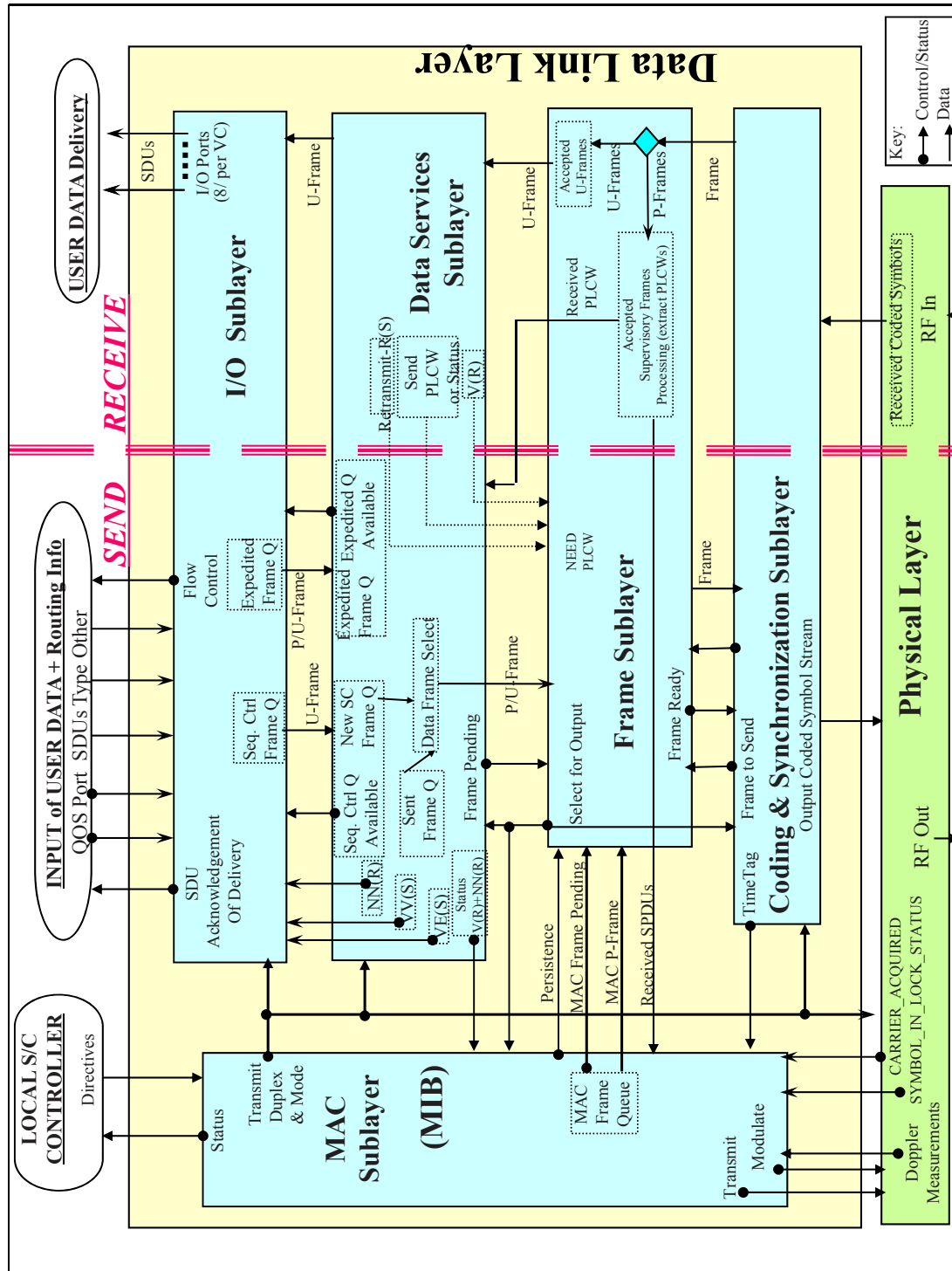


Figure 2-1: Proximity-1 Layered Protocol Model

2.1.3 DATA LINK LAYER

2.1.3.1 Sublayers in the Data Link Layer

There are five component sublayers within the Data Link Layer:

- Coding and Synchronization (C&S) Sublayer;
- Frame Sublayer;
- Medium Access Control (MAC) Sublayer;
- Data Services Sublayer;
- I/O Sublayer.

2.1.3.2 Coding and Synchronization Sublayer

The C&S Sublayer is specified separately in reference [5]. On the send side, the actions of the C&S Sublayer include:

- construction of PLTUs, where each PLTU contains a Version-3 Transfer Frame received from the Frame Sublayer;
- provision of the coded symbol stream (including PLTU and Idle data) to the Physical Layer for inclusion of Idle data, adding channel coding and modulation onto the radiated carrier.

On the receive side, the C&S Sublayer actions include:

- delimiting each PLTU contained in the data output from the receiver in the Physical Layer;
- validation of the PLTUs, including channel decoding;
- for each valid PLTU, delivering the delimited transfer frame to the Frame Sublayer.

On both the send and receive sides, the C&S Sublayer provides time-tagged data on request to support the Proximity-1 timing services.

2.1.3.3 Frame Sublayer

Subsection 4.1 specifies the functions of the Frame Sublayer. On the send side, the Frame Sublayer:

- creates Version-3 Transfer Frames, carrying user data or protocol data (directives and reports) in the frame data field;
- completes the fields in the frame header of a transfer frame;

- determines the order of frame transmission;
- delivers frames to the C&S Sublayer.

On the receive side, the Frame Sublayer:

- receives frames from the C&S Sublayer;
- completes the frame validation by checking fields in the header of a transfer frame;
- delivers a valid frame to the Data Services Sublayer or to the MAC Sublayer.

2.1.3.4 Medium Access Control Sublayer

Subsection 4.2 specifies the functions of the MAC Sublayer. The MAC Sublayer:

- controls the establishment, maintenance, and termination of communications sessions for point-to-point communications between Proximity entities;
- accepts Proximity-1 directives both from the local vehicle controller and across the Proximity link to control its operations;
- controls the modification of characteristics, such as data rate changes;
- controls the operational state of the Data Link and Physical Layers, using state control variables (MODE, TRANSMIT, DUPLEX);
- stores and distributes the MIB parameters.

2.1.3.5 Data Services Sublayer

Subsection 4.3 specifies the functions of the Data Services Sublayer. The Data Services Sublayer includes the COP-P. COP-P provides two qualities of service (Sequence Controlled and Expedited) that determine how reliably data from the sending user are delivered to the receiving user (see 2.2.3).

Section 7 specifies COP-P. On the send side, COP-P defines the FOP-P. On the receive side, COP-P defines the FARM-P.

2.1.3.6 Input/Output Sublayer

Subsection 4.4 specifies the functions of the I/O Sublayer. The I/O Sublayer provides the user interface between the Proximity-1 protocol and the onboard data systems and applications that use the protocol. On the send side, it accepts user data consisting of Service Data Units (SDUs) and associated routing information. On the receive side it delivers SDUs to the users via frame designated Port IDs.

2.1.4 PROTOCOL-UNIQUE FEATURES

2.1.4.1 General

The Proximity-1 protocol controls and manages data interchange across the communications link. This Data Link Layer protocol provides the capability to send user data, control reports, and control directives between the transceiver units. The directives are used for selection of communications frequencies, data rates, modulation, coding, and link directionality (full duplex, half duplex, and simplex). The Data Link Layer provides for the transfer of both packets and user-defined data units. All of these units can be transferred using either an Expedited or a Sequence Controlled (reliable) service supportive of applications involving remote space vehicles.

State tables and diagrams describe the actions the protocol takes when responding to events during full-duplex, half-duplex, and simplex operations. (See section 6, Data Services Operations, and section 7, Communication Operations Procedure for Proximity Links.)

The terms ‘transfer frame’ and ‘frame’ in this document refer to the Version-3 Transfer Frame, specified in section 3. Each transfer frame contains a header, which provides information for handling and processing the frame, including its Transfer Frame Data field. This data field contains either SDUs or Supervisory Protocol Data Units (SPDUs).

2.1.4.2 Service Data Units

SDUs carry user data from applications in the sending node to applications in the receiving node. A frame with SDU data in its data field is called a user frame (U-frame). The data field of a U-frame can contain an integer number of unsegmented packets, a single packet segment, or a collection of user-provided octets.

2.1.4.3 Supervisory Protocol Data Units

SPDUs carry Proximity-1 protocol directives and reports. A frame with SPDUs in its data field is called a protocol frame (P-frame).

Protocol directives are used for configuring and controlling the protocol processor at the receiving node; for the establishment, maintenance, and termination of a communications session; and for the transfer of time-correlation and synchronization data. Protocol reports are used for reporting the configuration and status of the transmitting node.

2.1.5 PROXIMITY LINK TRANSMISSION UNIT

The PLTU is the data structure used by the C&S Sublayer. It is flexibly sized to fit its data content, i.e., a variable-length frame containing variable-length packets. The relationship of the frame to the PLTU is shown in figure 3-1.

The PLTU is intended for use on links characterized by short time delays, moderate (not weak) signals, and short, independent sessions. These link characteristics determine the type of Attached Synchronization Marker (ASM) (24-bit), with its associated bit error tolerance for synchronization. A PLTU includes a 32-bit Cyclic Redundancy Check (CRC) for detection of transmission errors. The specification of the PLTU is in reference [5].

Symbol synchronization is maintained in the data channel by the insertion of an idle sequence between PLTUs, and these variable-length PLTUs are only inserted into the data link when a physical connection has been achieved.

2.1.6 ADDRESSING

A triad of addressing capabilities is incorporated for specific functionality within the link. The Spacecraft Identifier (SCID) identifies the source or destination of transfer frames transported in the link connection based upon the Source-or-Destination Identifier. The Physical Channel Identifier (PCID) may identify either of two redundant receivers at the receiving end, capable of supporting both the Sequence Controlled and Expedited services. The Port ID provides the means to route user data internally (at the transceiver's output interface) to specific logical ports, such as applications or transport processes, or to physical ports, such as onboard buses or physical connections (including hardware command decoders).

2.1.7 PROTOCOL DESCRIPTION

The Proximity-1 protocol is described in terms of:

- a) the services provided to the users (transfer of SDUs);
- b) the Protocol Data Units (PDUs);
- c) the protocol directives and reports (SPDUs described in 3.2.4);
- d) the procedures performed by the protocol as described in the state tables.

This protocol specification also defines the requirements for the underlying services provided by the lower layers.

2.2 OVERVIEW OF SERVICES

2.2.1 COMMON FEATURES OF SERVICES

Proximity-1 provides users with data transfer services known as Space Data Link Proximity-1 services. When a user, such as the spacecraft vehicle controller, supplies an SDU for transfer, the user also specifies:

- the PCID;

- the service quality (Sequence Controlled service or Expedited service);
- the Port ID of the destination port.

2.2.2 SERVICE TYPES

2.2.2.1 General

The Proximity-1 protocol provides data transfer services and timing services. There are two data transfer services: the first accepts and delivers packets, while the second accepts and delivers user-defined data. The timing service provides time tagging upon ingress/egress of selected PLTUs and the transfer of time from sender to receiver. (See 5.1 for details on the Proximity-1 timing service.)

2.2.2.2 CCSDS Packet Delivery Service

The packet delivery service provides for the transfer of packets across the Proximity space link. The packets have a Packet Version Number (PVN) authorized by CCSDS (see reference [H8]). These include CCSDS Space Packets and Encapsulation Packets.

If a packet is greater than the maximum frame data field size it is segmented before being inserted into multiple transfer frames: the packet is reassembled for delivery to the receiving user. When packets are smaller than the maximum frame data field size allowed in the link, then one or more packets can be placed in a single frame.

In this service the delivery process makes use of the Port ID to identify the specific physical or logical port through which the packet is to be routed.

2.2.2.3 User Defined Data Delivery Service

The user-defined data delivery service provides for the transfer of a single user's collection of octets across the Proximity space link. The SDU is an octet-aligned data unit, the format of which is unknown to the service. The service does not use any information from the contents of the SDU.

The SDU is placed in one or more frames as required based upon the size of the SDU. If the SDU is transferred in multiple frames, the service delivers the octets from each frame when the frame is received. Unlike the packet delivery service, the user-defined data delivery service does not reassemble the SDU.

In this service the delivery process makes use of the Port ID to identify the specific physical or logical port through which the octets are to be routed.

2.2.2.4 Timing Services

The Proximity-1 protocol specifies two timing services for both time tagging transfer frames in support of time correlation as well as transferring time to a remote asset. (See section 5.)

2.2.3 SERVICE QUALITIES

2.2.3.1 General

The Proximity-1 data services protocol provides two qualities of service (Sequence Controlled and Expedited) that determine how reliably SDUs supplied by the sending user are delivered to the receiving user. The controlling procedure is called COP-P and consists of a FOP-P, used on the sending side of the service, and a FARM-P, used on the receiving side of the service.

Each data transfer with one of the data transfer services has a service quality associated with it. Packetized data units that are larger than the maximum frame size in asynchronous frames can be transferred only by using the segmentation process, utilizing either the Sequence Controlled service or the Expedited service.

2.2.3.2 Sequence Controlled Service

The Sequence Controlled service ensures that data are reliably transferred across the space link and delivered in order, without gaps, errors, or duplications within a single communication session without COP-P resynchronization during the session (see 4.3.2). This service is based on a 'go-back-n' type of Automatic Repeat Queuing (ARQ) procedure that utilizes sequence-control mechanisms of both sending and receiving ends and a standard report (PLCW) returned from the receiving end to the sending end.

SDUs supplied by a sending user for transfer with the Sequence Controlled quality of service are inserted into transfer frames as required and transmitted on a physical channel in the order in which they are presented. SDUs are passed to the receiving user via the identified port. The retransmission mechanism ensures with a high probability of success that:

- a) no SDU is lost;
- b) no SDU is duplicated;
- c) no SDU is delivered out of sequence.

2.2.3.3 Expedited Service

The Expedited service is nominally used with upper-layer protocols that provide their own retransmission features, or in exceptional operational circumstances such as during spacecraft recovery operations.

Expedited SDUs supplied by the sending user are transmitted without ARQ. At the sending end, Expedited SDUs are transmitted on specified physical channels independently of the Sequence Controlled SDUs waiting to be transmitted on the same physical channel. At the receiving end, the SDUs are passed to the receiving user via the identified port. It should be noted that Expedited SDUs may be sent once or multiple times, but they are not sent again as a result of a request for retransmission. If such a request occurs it is performed outside the purview of the protocol.

There is no guarantee that all Expedited SDUs will be delivered to the receiving user. If the packet delivery service is used to transfer packets using segmentation in the Expedited service, then the service delivers only complete packets to the user.

NOTE – In Expedited service the capability is provided to deliver portions of user-defined data units that are greater than the maximum frame size allowed for the link.

3 PROTOCOL DATA UNITS

3.1 OVERVIEW—CONTEXT OF THE VERSION-3 TRANSFER FRAME

Figure 3-1 is the Proximity-1 protocol data unit context diagram.

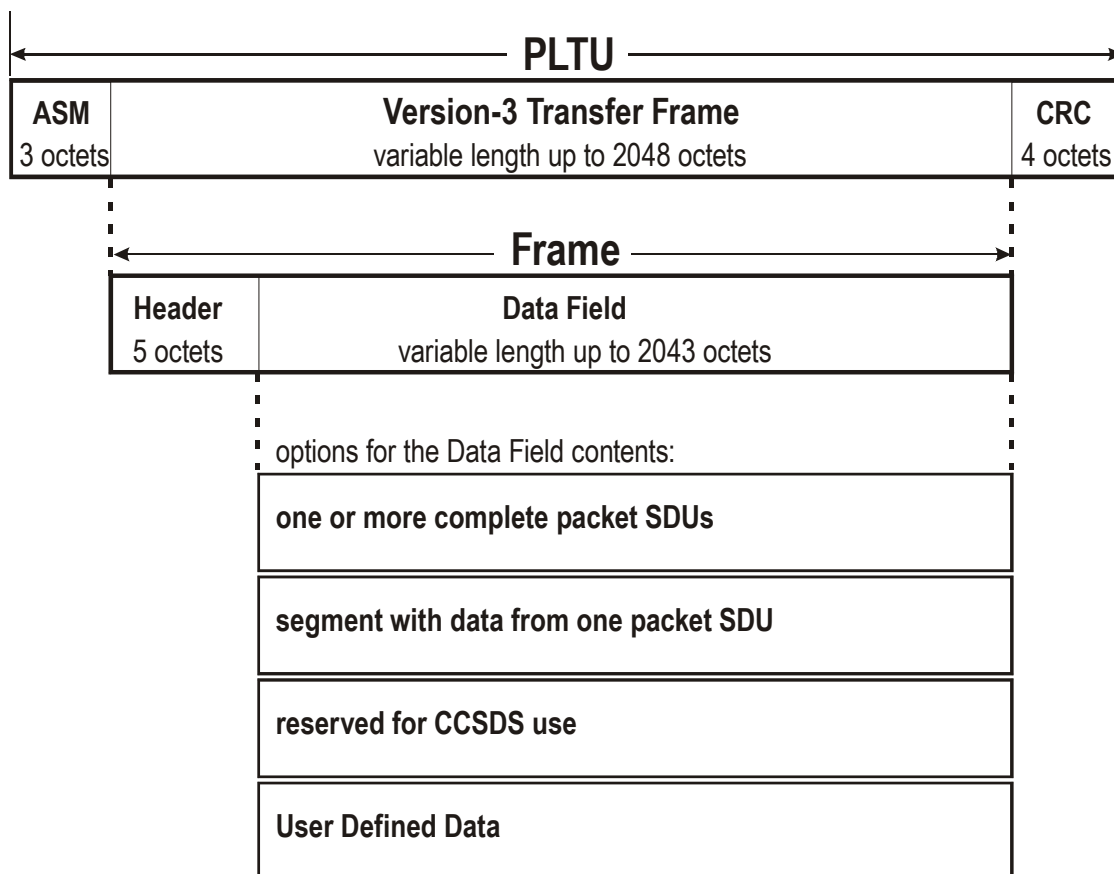


Figure 3-1: Proximity-1 Protocol Data Unit Context Diagram

Annex J contains more a detailed decomposition of the Proximity-1 data formats.

3.2 VERSION-3 TRANSFER FRAME

3.2.1 VERSION-3 TRANSFER FRAME STRUCTURE

A Version-3 Transfer Frame shall encompass the following fields, positioned contiguously, in the following sequence:

- Transfer Frame Header (5 octets, mandatory);
- Transfer Frame Data field (up to 2043 octets).

NOTES

- 1 The Version-3 Transfer Frame is the PDU transmitted from the send side of the Frame Sublayer at one end of a link to the receive side of the Frame Sublayer at the other end of the link.
- 2 The maximum transfer frame length allowed by a particular spacecraft or ground implementation on a particular physical channel may be less than the maximum specified here.
- 3 The composition of the Version-3 Transfer Frame is shown in figure 3-2.

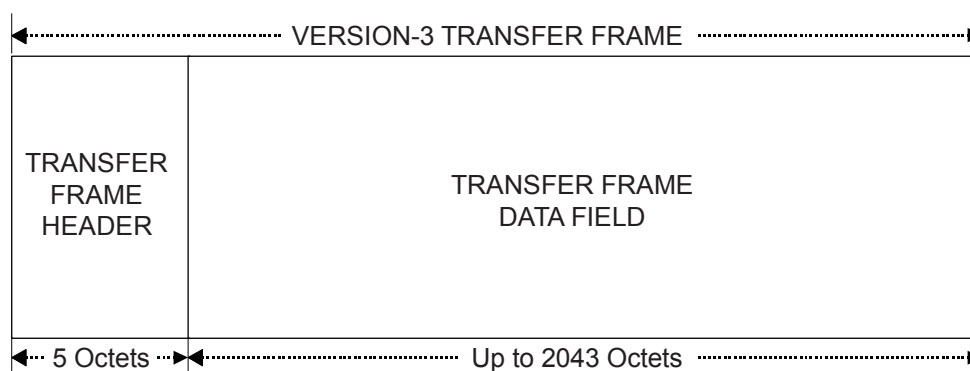


Figure 3-2: Version-3 Transfer Frame

3.2.2 TRANSFER FRAME HEADER

3.2.2.1 Summary of Header Fields

The Transfer Frame Header is mandatory and shall consist of ten mandatory fields, positioned contiguously, in the following sequence:

- a) Transfer Frame Version Number (2 bits);
- b) Quality of Service (QoS) Indicator (1 bit);
- c) PDU Type ID (1 bit);
- d) Data Field Construction Identifier (DFC ID) (2 bits);
- e) Spacecraft Identifier (SCID) (see reference [3]) (10 bits);
- f) Physical Channel Identifier (PCID) (1 bit);
- g) Port ID (3 bits);
- h) Source-or-Destination Identifier (1 bit);
- i) Frame Length (11 bits);

j) Frame Sequence Number (interpretation is QoS dependent) (8 bits).

NOTE – The format of the Transfer Frame Header is shown in figure 3-3.

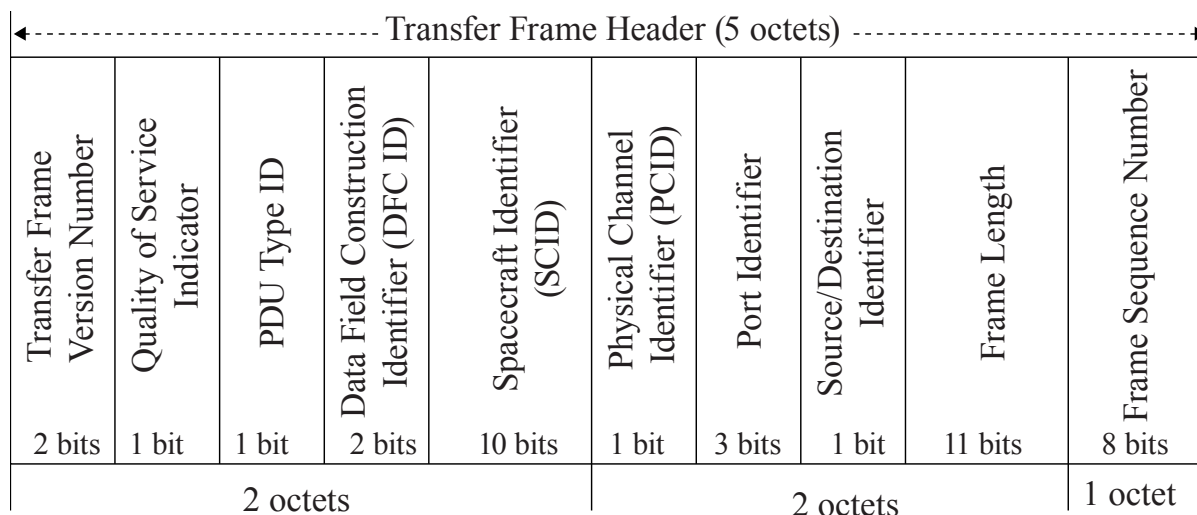


Figure 3-3: Transfer Frame Header

3.2.2.2 Transfer Frame Version Number

3.2.2.2.1 Bits 0–1 of the Transfer Frame Header shall contain the Transfer Frame Version Number.

3.2.2.2.2 The Transfer Frame Version Number field shall contain the binary value ‘10’.

NOTE – This Recommended Standard defines the Version-3 Transfer Frame. For other transfer frames defined by CCSDS for use with other protocols (see references [H6] and [H7]).

3.2.2.3 Quality of Service Indicator

3.2.2.3.1 Bit 2 of the Transfer Frame Header shall contain the QoS Indicator.

3.2.2.3.2 The QoS Indicator shall indicate the transfer service:

- The QoS Indicator is set to ‘0’ for a frame on the Sequence Controlled service.
- The QoS Indicator is set to ‘1’ for a frame on the Expedited service.

NOTE – At the receiving end, the COP-P procedures check the frame sequence number of frames on the Sequence Controlled service. Frames on the Expedited service bypass the sequence number check.

3.2.2.4 PDU Type ID

3.2.2.4.1 Bit 3 of the Transfer Frame Header shall contain the PDU Type ID.

3.2.2.4.2 The PDU Type ID shall specify whether the Transfer Frame Data field is conveying protocol supervisory data or user data information.

- a) The PDU Type ID is set to '0' when the Transfer Frame Data field contains user data.
- b) The PDU Type ID is set to '1' when the Transfer Frame Data field contains SPDUs.

NOTES

- 1 When the PDU Type ID is '0', the Data Field Construction ID indicates the arrangement of user data in the Transfer Frame Data field.
- 2 The SPDUs are specified in 3.2.4.
- 3 A frame with PDU Type ID '0' is called a U-frame, and a frame with PDU Type ID '1' is called a P-frame.

3.2.2.5 Data Field Construction ID

3.2.2.5.1 Bits 4–5 of the Transfer Frame Header shall contain the DFC ID.

3.2.2.5.2 In a P-frame, the DFC ID is not used and shall be set to the binary value '00'.

3.2.2.5.3 In a U-Frame, the DFC ID shall indicate the contents of the Transfer Frame Data field as defined in table 3-1.

Table 3-1: U-Frame Data Field Construction Rules

DFC ID	Frame Data Field Content	Subsection
'00'	Packets (integer number of unsegmented packets)	3.2.3.2
'01'	Segment Data (a complete or segmented packet)	3.2.3.3
'10'	Reserved for future CCSDS definition	3.2.3.4
'11'	User Defined Data	3.2.3.5

3.2.2.6 Spacecraft Identifier

3.2.2.6.1 Bits 6–15 of the Transfer Frame Header shall contain the SCID.

3.2.2.6.2 The 10-bit SCID shall provide the identification of the spacecraft that is either the source or the destination of the data contained in the transfer frame.

NOTES

- 1 The Source-or-Destination Identifier specified in 3.2.2.9 indicates whether the SCID identifies the source or destination spacecraft.
- 2 The procedures for the assignment of SCID values for use in Proximity-1 transfer frames are specified in reference [3].

3.2.2.7 Physical Channel Identifier

3.2.2.7.1 Bit 16 of the Transfer Frame Header shall contain the PCID.

NOTES

- 1 The PCID is intended primarily for a receiving system having two concurrently operating transceiver units (primary and backup, for example), where the PCID can be used to select which receiver processes the received frame.
- 2 An implementation could treat the PCID as a ‘don’t care’ value and receive both PCID 0 and PCID 1, using the same set of MIB parameters and all state machines, including COP-P, for frames with either value.
- 3 For simplification of operations, if the receiving spacecraft has only one transponder powered at a time, the PCID should not be used for selection of the transponder.

3.2.2.7.2 If an implementation distinguishes between the two PCID values, each PCID physical channel shall have a completely separate set of MIB parameters and all state machines, including COP-P.

3.2.2.8 Port Identifier

3.2.2.8.1 Bits 17–19 of the Transfer Frame Header shall contain the Port ID.

3.2.2.8.2 In a P-frame, the Port ID is not used and shall be set to the value ‘0’.

3.2.2.8.3 In a U-frame, the Port ID shall identify the output port to which the I/O Sublayer delivers the SDUs contained in the frame.

NOTES

- 1 The Port ID can be used to address different physical or logical connection ports to which user data are routed. For example, a Port ID could designate a physical data port, such as a port to a spacecraft bus, or it could designate a process within the connected command and data handling system.
- 2 There are eight ports, with Port ID values 0 through 7. CCSDS reserved Port ID values are specified in reference [H8].
- 3 The ports are independent of the physical channel assignment. Therefore, all SDUs that are addressed to the same Port ID are delivered to the same port, even if they are transferred with different PCIDs.

3.2.2.9 Source-or-Destination Identifier

3.2.2.9.1 Bit 20 of the Transfer Frame Header shall contain the Source-or-Destination Identifier.

3.2.2.9.2 The sending node shall set the Source-or-Destination Identifier to indicate the contents of the SCID field as shown in table 3-2.

Table 3-2: Setting the SCID Field and Source-or-Destination Identifier When the Frame Is Created

Source-or-Destination Identifier Value	SCID Field Contents	Transmitted SCID
0 (= <i>source</i>)	SCID of spacecraft that is sending the frame over this link	MIB parameter Local Spacecraft ID
1 (= <i>destination</i>)	SCID of spacecraft that is intended to receive the frame over this link	MIB parameter Remote Spacecraft ID

3.2.2.9.3 The behavior of a receiving node with respect to the SCID field and Source-or-Destination Identifier shall be as shown in table 3-3.

Table 3-3: SCID Field and Source-or-Destination Identifier When the Frame Is Received

Source-or-Destination Identifier Value	Test_Source Value	SCID Used to Validate	Subsection(s) That Specify Behavior
0 (= <i>source</i>)	<i>true</i>	MIB parameter Remote Spacecraft ID	6.2.4.2; 6.7.2 c)
0 (= <i>source</i>)	<i>false</i>	No test is performed	6.2.4.2; 6.7.2 c)
1 (= <i>destination</i>)	<i>true</i> or <i>false</i>	MIB Parameter Local Spacecraft ID	6.7.2 b)

NOTE – Assignment procedures for SCIDs in Proximity-1 transfer frames are controlled by reference [3].

3.2.2.10 Frame Length

3.2.2.10.1 Bits 21–31 of the Transfer Frame Header shall contain the Frame Length.

3.2.2.10.2 This 11-bit field shall contain a length count C , which equals one fewer than the total number of octets in the transfer frame.

- The count shall be measured from the first octet of the Transfer Frame Header to the last octet of the Transfer Frame Data field.
- The length count C is expressed as: $C = (\text{total number of octets in the transfer frame}) - 1$.

NOTE – The size of the Frame Length field limits the maximum length of a transfer frame to 2048 octets ($C = 2047$). The minimum length is 5 octets ($C = 4$).

3.2.2.11 Frame Sequence Number (Sequence Controlled or Expedited)

3.2.2.11.1 Bits 32–39 of the Transfer Frame Header shall contain the Frame Sequence Number (FSN).

3.2.2.11.2 The FSN shall increment monotonically and independently for the set of frames assigned to a PCID that are associated with the Sequence Controlled service (QoS Indicator set to '0'). In this case, the FSN is called the Sequence_Controlled_FSN (SEQ_CTRL_FSN).

3.2.2.11.3 The FSN shall increment monotonically for the set of frames assigned to a PCID that are associated with the Expedited service (QoS Indicator set to '1'). In this case, the FSN is called the Expedited_FSN (EXP_FSN).

NOTES

- 1 The FSN (controlled within the Data Services Sublayer) for each service is initialized to '0' by the SET INITIALIZE MODE directive (see 6.3.3.1.1.2).
- 2 The SEQ_CTRL_FSN enables the Sequence Controlled process to number sequentially and then check the sequence of incoming Sequence Controlled transfer frames.
- 3 The EXP_FSN is not used in the frame validation process but is required for correlations associated with timing services.
- 4 The FSN is PCID-dependent for both the Sequence Controlled and Expedited services.

3.2.3 TRANSFER FRAME DATA FIELD

3.2.3.1 General

The Transfer Frame Data field shall:

- a) follow, without gap, the Transfer Frame Header;
- b) be of variable length;
- c) contain from zero octets up to the lesser of
 - 1) 2043 octets (maximum frame length of 2048 less 5 octets for the frame header),
or
 - 2) the MIB parameter Maximum_Frame_Length less 5 octets;
- d) contain either an integer number of octets of data corresponding to one or more SDUs (U-frame), or an integer number of octets of protocol information (P-frame).

NOTE – In a U-frame, the Transfer Frame Data field contains SDU data and other data fields based upon the DFC ID. (See figure 3-4.)

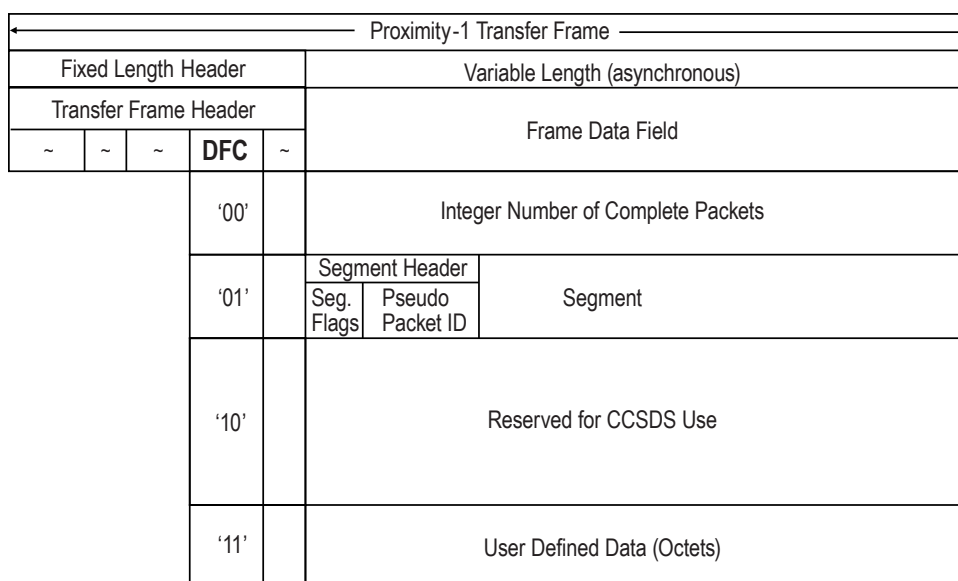


Figure 3-4: Proximity-1 Transfer Frame Data Field Contents of a U-Frame

3.2.3.2 Packets in a U-frame

3.2.3.2.1 When the DFC ID field of a U-frame contains the binary value '00', the Frame Data field shall consist of an integer number of packets each designated to the same Port ID and PCID (see figure 3-4).

3.2.3.2.2 The first bit of the Frame Data field shall be the first bit of a packet header.

3.2.3.3 Segment Data Units in a U-frame

3.2.3.3.1 When the DFC ID field of a U-frame contains the binary value '01', the Frame Data field shall contain a segment data unit consisting of an 8-bit segment header followed by a segment of a packet (see figure 3-4).

3.2.3.3.2 The contents of the segment header and segment data field shall be as follows:

- a) bits 0 and 1 of the segment header compose the sequence flags, which identify the position of the segment relative to the packet of which the segment is a part as specified in table 3-4;
- b) the remaining 6 bits of the segment header compose an identifier field, the pseudo packet identifier, which is adaptively used to associate all the segments of a packet data unit;
- c) segments are placed into the data link in the following order:
 - 1) segments of the same packet shall be sent in frames of the same PCID and Port ID,

- 2) segments from another packet may be interspersed but only in frames containing a different PCID or Port ID.

Table 3-4: Segment Header Sequence Flags

Sequence Flags	Interpretation
‘01’	first segment
‘00’	continuing segment
‘10’	last segment
‘11’	no segmentation (i.e., contains the entire packet)

3.2.3.3.3 Prior to delivery to the user, the Data Link Layer shall re-assemble all the segments using the same Routing ID, i.e., using the same PCID, Port ID, and pseudo packet ID, into a packet.

NOTE – Subsection 1.5.1.2 should be consulted for the definitions of Routing ID and pseudo packet ID.

3.2.3.3.4 Only complete packets shall be delivered to the user.

3.2.3.3.5 The accumulated packet shall be discarded and this event shall be logged into the session accountability report whenever any of the following errors occur:

- a) the packet length field does not agree with the number of bytes received and aggregated from the segments;
- b) the first segment received for a Routing ID is not the start segment of the data unit;
- c) the last segment for a Routing ID is not received before the starting segment of a new packet is received.

3.2.3.4 CCSDS Reserved Value (U-frame)

In a U-frame, the binary value ‘10’ for the DFC ID field is reserved by CCSDS and shall not be used.

3.2.3.5 User-Defined Data in a U-frame

When the DFC ID field of a U-frame contains the binary value ‘11’, the Frame Data field shall consist of user-defined data (see figure 3-4).

NOTE – The user can choose to transmit only Transfer Frame Headers with the Frame Data field consisting of zero octets.

3.2.3.6 Transfer Frame Data Field Contents in a P-frame

In a P-frame, the Transfer Frame Data field shall consist of Supervisory PDUs (SPDUs).

NOTE – SPDUs are specified in 3.2.4.

3.2.4 SUPERVISORY PDU

3.2.4.1 Overview

The protocol data units discussed below are used by the local transceiver either for local control within the transceiver, or for reporting status to and controlling the remote transceiver.

SPDUs are of either fixed or variable length based upon the value of the SPDU format ID. Currently there is only one fixed-length SPDU defined, i.e., PLCW. Variable-length SPDUs provide the capability for concatenating and multiplexing protocol objects, i.e., directives and status reports. Each SPDU Type is further described in tables 3-5 and 3-6.

SPDUs can be transmitted using only the Expedited QoS (QoS = '1').

SPDUs are all self-identifying and self-delimiting. Only variable-length SPDUs further decompose into specific types of supervisory directives or reports. (See annex B for the detailed specification of variable-length SPDUs.)

3.2.4.2 General

3.2.4.2.1 Fixed-length SPDUs shall consist of the following fields positioned contiguously in the following sequence:

- a) SPDU Header (2 bits) consisting of:
 - 1) SPDU Format ID (1 bit),
 - 2) SPDU Type Identifier (1 bit);
- b) SPDU Data field (14 bits) consisting of either the data field of a fixed-length PLCW or the data field of a CCSDS-reserved SPDU.

3.2.4.2.2 Variable-length SPDUs shall consist of the following fields positioned contiguously in the following sequence:

- a) SPDU Header (1 octet) consisting of:
 - 1) SPDU Format ID (1 bit),
 - 2) SPDU Type Identifier (3 bits),

- 3) Data Field Length (4 bits) (this represents the actual number of octets in the data field of the SPDU);

NOTE – Data Field Length is not a ‘length minus one’ field.

- b) Supervisory Data field (variable length, i.e., 0 to 15 octets) consisting of one or more supervisory directives or status reports of the same SPDU type.

3.2.4.3 Fixed-Length SPDU

3.2.4.3.1 General

A ‘1’ in the SPDU Format ID field shall identify a 16-bit fixed-length SPDU. This format provides for only two fixed SPDUs (see table 3-5), which shall be differentiated by the SPDU Type Identifier field:

- a) a ‘0’ in the SPDU Type Identifier field identifies the SPDU as a PLCW;
b) a ‘1’ in the SPDU Type Identifier field is reserved for future CCSDS specification.

Table 3-5: Fixed-Length Supervisory Protocol Data Unit

Fixed-Length SPDU (16 bits)	SPDU Header (2 bits)		SPDU Data (14 bits)
	SPDU Format ID (Bit 0)	SPDU Type Identifier (Bit 1)	(Contains 1 protocol object, i.e., directive or report or PLCW) (Bits 2 through 15)
Type F1	‘1’	‘0’	Fixed Length PLCW (see 3.2.4.3.2)
Type F2	‘1’	‘1’	Reserved for CCSDS Use

3.2.4.3.2 Type F1 SPDU: Proximity Link Control Word

3.2.4.3.2.1 General

3.2.4.3.2.1.1 The PLCW shall consist of seven fields positioned contiguously in the following sequence (described from least significant bit, Bit 15, to most significant bit, Bit 0—see figure 3-5):

- a) Report Value (8 bits);
b) Expedited Frame Counter (3 bits);

- c) Reserved Spare (1 bit);
- d) PCID (1 bit);
- e) Retransmit Flag (1 bit);
- f) SPDU Type Identifier (1 bit);
- g) SPDU Format ID (1 bit).

3.2.4.3.2.1.2 The PLCW shall be transmitted using the Expedited QoS (see 3.2.2.3).

NOTE – The structural components of the PLCW are shown in figure 3-5. (See F4.3 for NASA Mars Surveyor Project 2001 Odyssey PLCW definition.)

Bit 0		Bit 15				
SPDU Header		SPDU Data Field				
SPDU Format ID	SPDU Type Identifier	Retransmit Flag	PCID	Reserved Spare	Expedited Frame Counter	Report Value (FSN) 8 bits
1 bit	1 bit	1 bit	1 bit	1 bit	3 bits	

Figure 3-5: Proximity Link Control Word Fields

3.2.4.3.2.2 Report Value

3.2.4.3.2.2.1 Bits 8–15 of the PLCW shall contain the Report Value.

3.2.4.3.2.2.2 The Report Value field shall contain the value of V(R) (see 7.3.2).

3.2.4.3.2.2.3 Separate Report Values shall be reported for each physical channel independent of the I/O port.

3.2.4.3.2.3 Expedited Frame Counter

3.2.4.3.2.3.1 Bits 5–7 of the PLCW shall contain the EXPEDITED_FRAME_COUNTER.

3.2.4.3.2.3.2 The EXPEDITED_FRAME_COUNTER shall provide a modulo-8 counter indicating that Expedited frames have been received.

3.2.4.3.2.4 Reserved Spare

3.2.4.3.2.4.1 Bit 4 of the PLCW shall contain a Reserved Spare bit.

3.2.4.3.2.4.2 The Reserved Spare bit field shall be set to '0'.

3.2.4.3.2.5 Physical Channel Identification

3.2.4.3.2.5.1 Bit 3 of the PLCW shall contain the PCID field.

3.2.4.3.2.5.2 The 1-bit PCID field shall contain the PCID of the physical channel with which this report is associated. (See 6.2.3.10, 'RECEIVING_PCID_BUFFER'.)

NOTE – Each PCID in use has its own PLCW reporting activated.

3.2.4.3.2.6 PLCW Retransmit Flag

3.2.4.3.2.6.1 Bit 2 of the PLCW shall contain the PLCW Retransmit Flag.

3.2.4.3.2.6.2 A setting of '0' in the PLCW Retransmit Flag shall indicate that there are no outstanding frame rejections in the sequence received so far, and thus retransmissions are not required.

3.2.4.3.2.6.3 A setting of '1' in the PLCW Retransmit Flag shall indicate that a received frame left a frame sequence number gap and that a retransmission of the expected frame is required.

3.2.4.4 Variable-Length SPDU

3.2.4.4.1 General

A '0' in the SPDU Format ID field shall identify a variable-length SPDU data field, which may contain from 0 to 15 octets of supervisory data.

NOTE – This form of SPDU uses bits 1 through 3 of the SPDU header to identify one of eight possible SPDU types, summarized in table 3-6. Currently three of these eight types are defined in the following two subsections. The remainder are reserved for future CCSDS specification.

Table 3-6: Variable-Length Supervisory Protocol Data Unit

Variable-Length SPDU	SPDU Header (1 octet, fixed)			SPDU Data Field (0-15 octets)
	Format ID (Bit 0)	SPDU Type Identifier (Bits 1,2,3)	Length of SPDU Data Field (Bits 4,5,6,7)	(Contains 1 or more protocol objects, i.e., directives, reports)
Type 1	‘0’	‘000’	Length in Octets	Directives/Reports (see note)
Type 2	‘0’	‘001’	"	TIME DISTRIBUTION PDU
Type 3	‘0’	‘010’	"	Status Reports
Type 4	‘0’	‘011’	"	Reserved for CCSDS Use
Type 5	‘0’	‘100’	"	Reserved for CCSDS Use
Type 6	‘0’	‘101’	"	Reserved for CCSDS Use
Type 7	‘0’	‘110’	"	Reserved for CCSDS Use
Type 8	‘0’	‘111’	"	Reserved for CCSDS Use
NOTE – Directives and Reports can be multiplexed within the SPDU Data Field.				

3.2.4.4.2 Type 1 SPDU: Directives/Reports

An SPDU Type Identifier equal to ‘000’ shall identify a Type 1 SPDU with a data field containing from zero to seven 16-bit concatenated and multiplexed protocol objects, i.e., directives or reports.

NOTE – Variable-length SPDU Types are shown in table 3-6. Formats of variable-length SPDU data fields are defined in annex B.

3.2.4.4.3 Type 2 SPDU: TIME DISTRIBUTION PDU

3.2.4.4.3.1 An SPDU Type Identifier equal to ‘001’ shall identify a Type 2 SPDU with a data field containing from 1 to 15 octets of TIME DISTRIBUTION supervisory data.

3.2.4.4.3.2 Octet 0 of the data field shall contain the TIME DISTRIBUTION directive type, followed by the actual time field value (1 to 14 octets).

NOTE – Variable-length SPDU Types are shown in table 3-6. Formats of variable-length SPDU data fields are defined in annex B.

3.2.4.4.4 Type 3 SPDU: Status Reports

An SPDU Type Identifier equal to '010' shall identify a Type 3 SPDU with a data field containing from 0 to 15 octets of Status Report information.

NOTES

- 1 The format of these reports is enterprise specific and is left up to the implementation.
- 2 Provision is made in the protocol to identify when a status report is required (NEED_STATUS_REPORT) and when a status report is requested (see Type 1 SPDU Report Request, B1.6).

4 DATA LINK LAYER

4.1 FRAME SUBLAYER

4.1.1 FRAME SUBLAYER FUNCTIONS

4.1.1.1 At the sending end, the Frame Sublayer shall perform the following functions:

- a) accept frames supplied by the Data Services and MAC Sublayers and modify field values as necessary;
- b) formulate PLCWs and status reports as needed and incorporate them into a P-frame;
- c) determine the order of frame transmission;
- d) transfer the frames to the C&S Sublayer.

4.1.1.2 At the receiving end, the Frame Sublayer shall perform the following functions:

- a) receive a frame from the C&S Sublayer;
- b) validate that the received frame is a Version-3 Transfer Frame;
- c) validate that the frame should be accepted by the local transceiver based on the Spacecraft ID field and the Source-or-Destination ID of the transfer frame;
- d) if the frame is a valid U-frame, route it to the Data Services Sublayer;
- e) if the frame is a valid P-frame, route the contents of the frame (SPDUs) to the MAC Sublayer;
- f) if the frame is a valid P-frame and contains a PLCW, route the PLCW to the Data Services Sublayer.

4.1.2 FRAME SELECTION FOR OUTPUT PROCESSING AT THE SENDING END

4.1.2.1 Overview

The Frame Sublayer provides the control for formulating the frame headers and the SPDU data for transmission. The frame is delivered to the C&S Sublayer to be assembled into a PLTU prior to delivery to the Physical Layer.

4.1.2.2 Frame Multiplexing Process Control

4.1.2.2.1 Frames shall be generated and sent when the TRANSMIT parameter (6.2.2.3) is set to *on*. When the PLTU contents are ready for transmission and while TRANSMIT is *on*, the data shall be transferred to the C&S Sublayer for processing.

4.1.2.2.2 When either `NEED_PLCW` or `NEED_STATUS_REPORT` (6.2.3.6) is set to *true*, the required status and/or PLCW data shall be generated and inserted into a P-frame for delivery.

4.1.2.3 Frame Selection

Each time a frame is to be dispatched to the C&S Sublayer, its selection from a series of sources shall be based on the following priority scheme:

- a) first priority is given to a frame from the MAC queue in the MAC Sublayer;
- b) second priority is given to a PLCW or status report, if `U-frame_last_sent` is *true*;
- c) third priority is given to an Expedited frame from the Expedited Frame queue in the I/O Sublayer;
- d) fourth priority is given to a Sequence Controlled frame, first from the Sent queue if required, and then from the Sequence Controlled Frame queue in the I/O Sublayer;
- e) fifth priority is given to a PLCW or status report, if `U-frame_last_sent` is *false*.

NOTES

- 1 `U-frame_last_sent` is set to *true* on session initialization.
- 2 `U-frame_last_sent` is set to *false* whenever a PLCW or Status_report is sent.
- 3 `U-frame_last_sent` is set to *true* for all other frames sent.
- 4 When `PERSISTENCE` is *true*, only supervisory protocol frames from the MAC queue are sent. (See 4.2.2.5.1.)

4.2 MEDIUM ACCESS CONTROL SUBLAYER

4.2.1 OVERVIEW

The MAC Sublayer is responsible for the establishment and termination of each communications session. It is also responsible for any operational changes in the Physical Layer configuration made during the data services phase.

Some of the operations performed by the MAC Sublayer require a ‘handshaking’ process between the sending transceiver and the responding transceiver. This handshake is often based upon interpretation of values of the Physical Layer control signals, i.e., `CARRIER_ACQUIRED` and `SYMBOL_INLOCK_STATUS`. Because of the potential for loss of an inter-transceiver control message because of corruption across the space link, MAC control activities require a ‘persistence’ process to ensure that the expected results of an activity are verified before any other activity is started. This process is generically defined as a persistent activity.