The Consultative Committee for Space Data Systems

Draft Recommendation for
Space Data System Standards

PROXIMITY-1 SPACE LINK PROTOCOL—DATA LINK LAYER

PROPOSED DRAFT RECOMMENDED STANDARD

CCSDS 211.0-P-6.2

PROPOSED PINK BOOK
April 2026

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The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of its members. The Committee meets periodically to address data systems problems that are common to all participants, and to formulate sound technical solutions to these problems. Inasmuch as participation in the CCSDS is completely voluntary, the results of Committee actions are termed **Recommended Standards** and are not considered binding on any Agency.

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FOREWORD

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in the *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-4). Current versions of CCSDS documents are maintained at the CCSDS Web site:

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PREFACE

This document is a draft CCSDS Recommended Standard. Its 'Pink Book' status indicates that the CCSDS believes the document to be technically mature and has released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process.

Implementers are cautioned **not** to fabricate any final equipment in accordance with this document's technical content.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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CCSDS 211.0-B-1	Proximity-1 Space Link Protocol	October 2002	Original issue, superseded
CCSDS 211.0-B-2	Proximity-1 Space Link Protocol—Data Link Layer	April 2003	Superseded
CCSDS 211.0-B-3	Proximity-1 Space Link Protocol—Data Link Layer	May 2004	Superseded
CCSDS 211.0-B-4	Proximity-1 Space Link Protocol—Data Link Layer, Recommended Standard, Issue 4	July 2006	Superseded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	Superseded
CCSDS 211.0-B-6	Proximity-1 Space Link Protocol—Data Link Layer, Recommended Standard, Issue 6	July 2020	Superseded
CCSDS 211.0-P-6.2	Proximity-1 Space Link Protocol—Data Link Layer, Draft Recommended Standard, Issue 6.2	April 2026	Removed data service sublayer and COP-P, removed Annex C (Mars Odyssey), D (MRO). Transferred P1 state tables, diagrams, and SPDU formats.

NOTE – Changes bars reflect additions and modifications, but deletions from the previous issue are not marked.

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommended Standard is to specify the Data Link Layer (DLL) used with the Proximity-1 Data Link Coding and Synchronization (C&S) sublayer (reference [6]) and Physical Layer (PL) (reference [7]). 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 DLL (Framing, Medium Access Control [MAC], and Input/Output [I/O] sublayers). The specifications for the protocol data units, framing, media access control, timing service, and I/O control are defined in this document. The C&S sublayer is defined in the separate CCSDS Recommended Standard entitled *Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer* (reference [6]). The PL is defined in the separate CCSDS Recommended Standard entitled *Proximity-1 Space Link Protocol—Physical Layer* (reference [7]).

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 for which 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, their implementation 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 [C9]).

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 DEFINITIONS

1.5.1.1 Terms from the Open Systems Interconnection Basic Reference Model

This Recommended Standard makes use of a number of terms defined in the Open Systems Interconnection (OSI) Basic Reference Model (reference [1]). In this Recommended Standard, those terms are used in a generic sense, that is, 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) DLL;

c) entity;

d) PL;

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).

Communication Operations Procedure-Proximity, COP-P: Procedure to enable the delivery of service data units to the receiving end of the layer above, correct and without omission or duplication, and in the same sequential order in which they were received from the layer above at the sending end. The COP-P includes both the Frame Acceptance and Reporting Mechanism-Proximity (FARM-P) and Frame Operation Procedure-Proximity **(**FOP-P) of the caller and responder unit.

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

Frame Acceptance and Reporting Mechanism-Proximity, FARM-P: Procedure for returning reports on the status of Transfer Frame acceptance for the Sequence Controlled service carried out within the receiver in the Proximity-1 link.

Frame Operation Procedure-Proximity, FOP-P: Procedure 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.

Physical Channel ID, PCID: Identifier carried in Transfer Frames and in Proximity Link Control Words (PLCWs). The PCID is intended primarily for a receiving system having two concurrently operating transceiver units (primary and backup, for example), in which 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 or Version-4 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.

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

Proximity Link Transmission Unit, PLTU: The data unit composed of the Attached Synchronization Marker (ASM), the Version-3 or Version-4 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 a Supervisory Protocol Data Unit (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 rehail the responder (because of lack of communication progress) during the data exchange 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.

Supervisory Protocol Data Unit, SPDU: Protocol Data Unit (PDU) 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.

Transfer Frame: The Protocol Data Unit of the Proximity-1 Space Data Link Protocol. In this document it can be either a Version-3 or a Version-4 Transfer Frame.

U-frame: A Version-3 or a Version-4 Transfer Frame that contains user data information (compare P-frame).

vehicle controller: The entity (e.g., spacecraft control computer) that receives the notifications (defined in reference [5], annex G) and potentially acts upon them.

Version-3 Transfer Frame: A Proximity-1 Transfer Frame (see 3.3 of this document).

Version-4 Transfer Frame: A Unified Space Data Link Protocol (USLP) Transfer Frame (see annex C of reference [8] and section 3.3 of this document).

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, that is, 'Bit 0', as shown in figure 1-1.

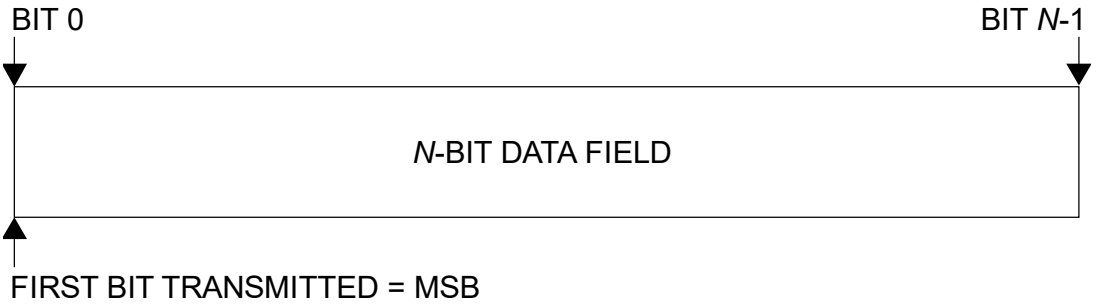

Figure 1-1: Bit Numbering Convention

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 C&S sublayer and the PL; and

– the rate measured at the output of the transmitter.

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

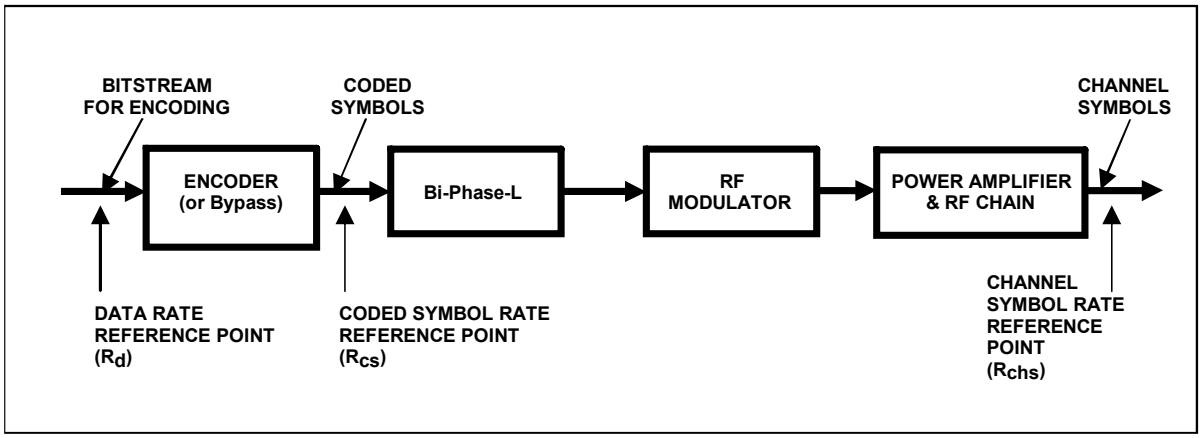

Figure 1-2: Proximity-1 Rate Terminology

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*. 2nd ed. ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[2] *TM Synchronization and Channel Coding*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.0-B-5. Washington, D.C.: CCSDS, September 2023.

[3] *CCSDS Spacecraft Identification Field Code Assignment Control Procedures*. Issue 7. Recommendation for Space Data System Practices (Magenta Book), CCSDS 320.0-M-7. Washington, D.C.: CCSDS, November 2017.

[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] *Space Communications Session Control*. Issue 1. Proposed Draft Recommendation for Space Data System Standards (Red Book), CCSDS 235.1-R-1. Washington, D.C.: CCSDS, forthcoming.

[6] *Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.2-B-4. Washington, D.C.: CCSDS, forthcoming.

[7] *Proximity-1 Space Link Protocol—Physical Layer*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.1-B-5. Washington, D.C.: CCSDS, forthcoming.

[8] *Unified Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.1-B-3. Washington, D.C.: CCSDS, June 2024.

2 OVERVIEW

2.1 CONCEPT OF PROXIMITY-1

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

2.2 LAYERED MODEL

The Proximity-1 model consists of a PL (reference [7]) and a DLL.

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 DLL is responsible for providing data to be transmitted by the PL. The operation of the transmitter is state-driven.

On the receive side, the DLL 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 (sub)layers with associated data flows are shown in figure 2-1.

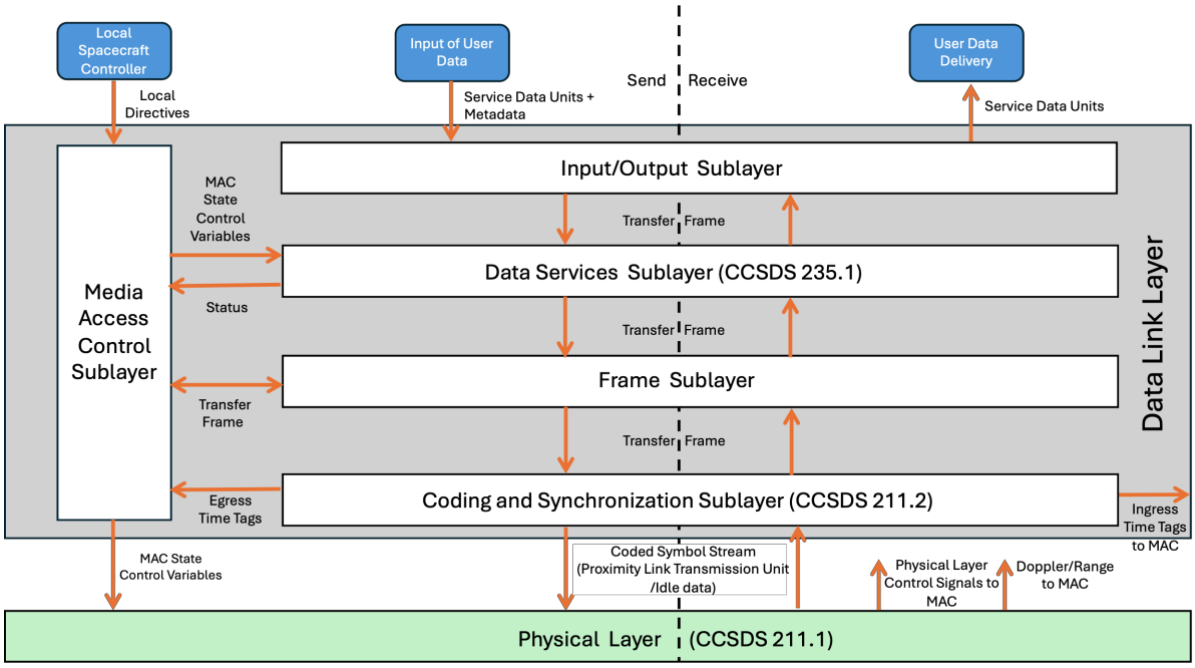

Figure 2-1: Overview of Proximity-1 (Sub)layers

2.2.1 PHYSICAL LAYER

On the send side, the PL accepts:

– control variables from the MAC sublayer of the DLL for the transceiver control;

– coded symbol stream (consisting of PLTU/Idle data) from the C&S sublayer for modulation onto the radiated carrier.

On the receive side, the PL:

– provides status signals (CARRIER_ACQUIRED and SYMBOL_INLOCK_STATUS) to the MAC sublayer of the DLL;

– outputs the serial coded symbol stream from the receiver's PL to the C&S sublayer.

2.2.2 DATA LINK LAYER

2.2.2.1 Sublayers in the Data Link Layer

There are five component sublayers within the DLL:

– C&S sublayer (reference [6]);

– Frame sublayer;

– MAC sublayer;

– Data Services (DS) sublayer (reference [5]);

– I/O sublayer.

2.2.2.2 Coding and Synchronization Sublayer

The C&S sublayer is specified separately in reference [6]. On the **send** side, the actions of the C&S sublayer include:

– construction of PLTUs, where each PLTU contains either a Version-3 or Version-4 Transfer Frame received from the Upper sublayer (i.e., either the Proximity-1 'Frame sublayer' or USLP Data Protocol sublayer; see 3.3);

– production of the bitstream for encoding (including PLTUs and Idle Data);

– channel coding (four channel codes for use on Proximity-1 links: an optional convolutional code and three optional low density parity check [LDPC] codes); and

– provision of the coded symbol stream (including encoded PLTU and Idle data) at a constant rate (R_{cs}) to the PL for modulation onto the radiated carrier.

On the **receive** side, the C&S sublayer actions include:

– reception of the coded symbols stream from the receiver in the PL at a constant rate (R_{cs});

– channel decoding;

– delimiting each PLTU contained in the data output from the receiver in the PL including validation;

– for each valid PLTU, delivering the delimited Transfer Frame to the Proximity-1 Frame sublayer or USLP Data Protocol sublayer.

On both sides, the C&S sublayer supports Proximity-1 timing services defined in section 5 by capturing the values of the clock, frame sequence number, Quality Of Service (QOS) Indicator, and direction (ingress or egress) associated with each Transfer Frame over the commanded interval.

2.2.2.3 Frame Sublayer

Subsection 4.1 applies only to the specific functions of the Version-3 Frame sublayer. Similarly, reference [8] applies to the Version-4 Frame. Generically, on the send side, the Frame sublayer:

– creates transfer frames: either Version-3 or Version-4, carrying user 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.

Generically, 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 DS sublayer (reference [5]) or to the MAC sublayer.

2.2.2.4 Medium Access Control Sublayer

Subsection 4.2 specifies the functions of the MAC sublayer, which:

- accepts Proximity-1 directives both from the local vehicle controller and across the Proximity link to control its operations;
- controls the modification of data link/physical layer characteristics, such as data/symbol rate changes;
- controls the operational state of the DLLs and PLs, using state control variables (MODE, TRANSMIT, DUPLEX);
- stores and distributes the MIB parameters.

2.2.2.5 Data Services Sublayer

The DS sublayer functionality is defined in the Space Communications Session Control blue book, reference [5]. In summary:

DS Operations control the order of user data transfer (including user-supplied directives) that are to be transmitted within the session. It provides the following two qualities of service:

- Expedited service ensures transmission of Expedited frame data in the order received without errors.
- Sequence Controlled service guarantees that data within a communication session are delivered in order without errors, gaps, or duplications.

The guarantee of reliable data delivery by the Sequence Controlled service is constrained to a single communication session without COP-P resynchronization. Sessions with COP-P resynchronization may result in duplicate or lost data because of factors outside the scope of the protocol.

The mechanisms provided will not eliminate duplicate data associated with the transition between the end of one session and the beginning of the next. Elimination of this problem is left to the controlling data system.

DS Operations are implemented through session states that depend on four state-controlling variables: MODE, DUPLEX, TRANSMIT (T), and SUB-STATE (SS). The Receive and Send State Descriptions consist of the values *off*, *on*, *synchronous* (channel), and *asynchronous* (channel). Currently, Proximity-1 is defined solely for asynchronous data links (definitions in 1.5.1.2).

DS Operations control the establishment, data exchange/potential reconnection, and termination of communications sessions for point-to-point communications between Proximity entities. These operations are detailed in section 5 of reference [5] with a comprehensive set of session state tables, variables, and diagrams. The state tables and corresponding diagrams describe the state transitions, events that trigger them, and resulting actions for both the caller and responding nodes undergoing link establishment, data exchange, and link termination.

2.2.2.6 Input/Output Sublayer

Subsection 4.3 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 meta data. On the receive side it delivers SDUs to the users via frame-designated Port IDs for Version-3 frames and Virtual Channels for Versions-4 frames.

2.2.3 PROTOCOL-UNIQUE FEATURES

2.2.3.1 General

The Proximity-1 protocol controls and manages data interchange across the communications link. This DLL 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 DLL 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 reference [5], sections 5 and 6, DS Operations and Communication Operations Procedure for Proximity Links, respectively.)

If not specifically identified as a Version-4 Transfer Frame, 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).

2.2.3.2 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.

2.2.4 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, that is, 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 ASM (24-bit), with its associated bit error tolerance for synchronization. A PLTU includes a CRC-32 for detection of transmission errors. The specification of the PLTU is in reference [6].

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.

2.2.5 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).

2.2.6 PROTOCOL DESCRIPTION

The Proximity-1 protocol is described in terms of PDUs and services provided to the users (transfer of SDUs). This protocol specification also defines the requirements for the underlying services provided by the lower layers.

2.3 OVERVIEW OF SERVICES

2.3.1 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.

2.3.2 SERVICE TYPES

2.3.2.1 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.)

2.3.2.2 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 [C8]). 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.

2.3.2.3 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.

2.3.2.4 Timing Services

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

3 PROTOCOL DATA UNITS

3.1 OVERVIEW

There are two Transfer Frame protocol data units supported by CCSDS over the Proximity-1 C&S sublayer (reference [6]). They are:

a) the Version-3 Transfer Frame defined in 3.3;

b) the Version-4 (USLP) Transfer Frame defined in reference [8].

The Version-4 Transfer Frame may be used in lieu of the Version-3 frame as the Transfer Frame PDU over the Proximity-1 C&S sublayer. In this case, the functions provided by the Proximity-1 Frame sublayer (see 2.2.2.3) are replaced by the USLP Space Data Link Protocol reference [8].

NOTE – Annex C of reference [8] describes the differences and similarities between the Version-3 and Version-4 Transfer Frame fields. Reference [6] describes use of the Version-4 Transfer Frame over the Proximity-1 C&S sublayer.

3.1.1 CONSTRAINT ON THE USE OF THE TRANSFER FRAME OVER THE PROXIMITY-1 DATA LINK

3.1.1.1 Only transfer frames of the same version number shall be contained in the same PLTU stream once the link has been established, to avoid mixing fixed and variable length frames in the same symbol stream.

3.2 VERSION-3 TRANSFER FRAME

3.2.1 CONTEXT OF THE VERSION-3 TRANSFER FRAME

The Version-3 Transfer Frame (i.e., the Proximity-1 Transfer Frame) is the PDU of the Proximity-1 Space Data Link Protocol. Figure 3-1 shows the Version-3 protocol data unit context diagram. (See reference [6] for the specification of the PLTU.)

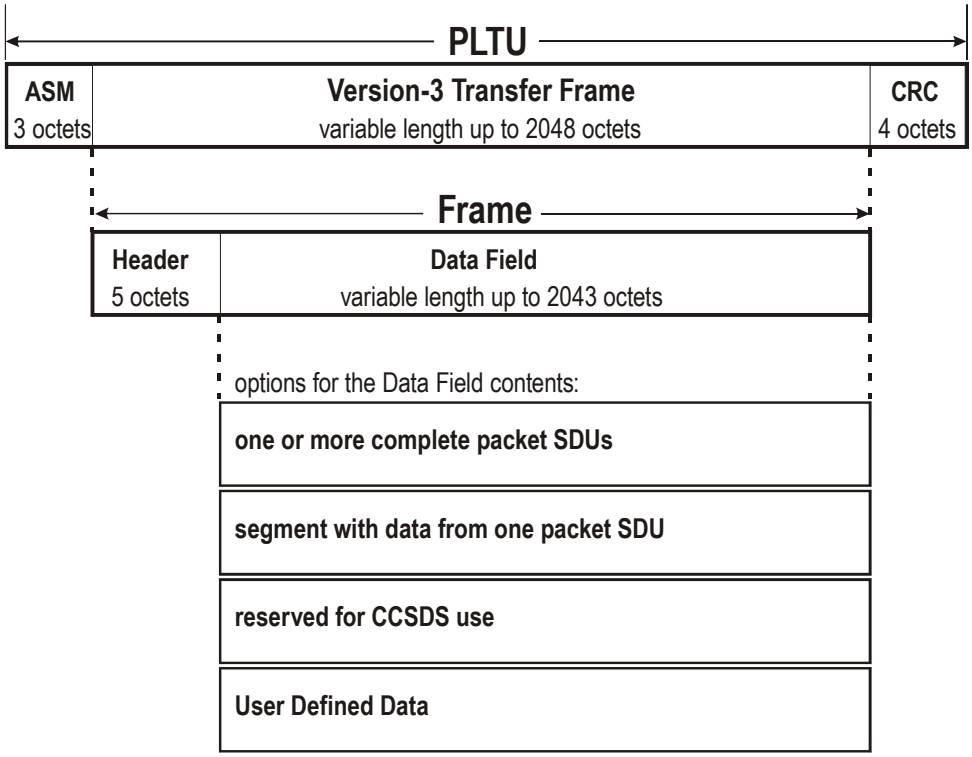

Figure 3-1: Version-3 Protocol Data Unit Context Diagram

NOTE – Annex E contains a more detailed decomposition of the Proximity-1 (Version-3) data formats.

3.3 VERSION-3 TRANSFER FRAME

3.3.1 VERSION-3 TRANSFER FRAME STRUCTURE

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

a) Transfer Frame Header (5 octets, mandatory);

b) 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.

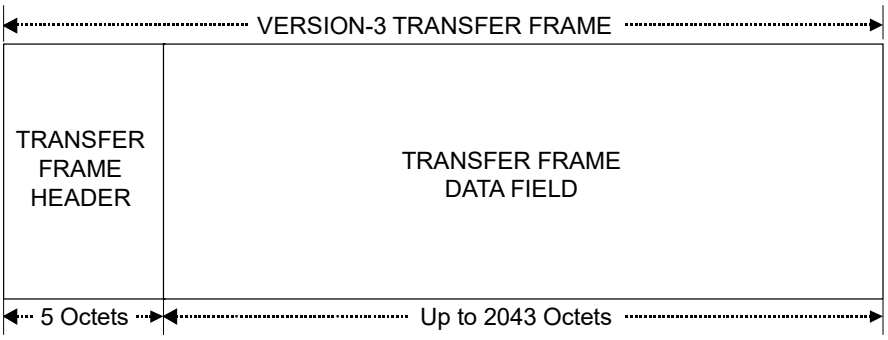

Figure 3-2: Version-3 Transfer Frame

3.3.2 TRANSFER FRAME HEADER

3.3.2.1 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) SCID (see reference [3]) (10 bits);

f) 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.

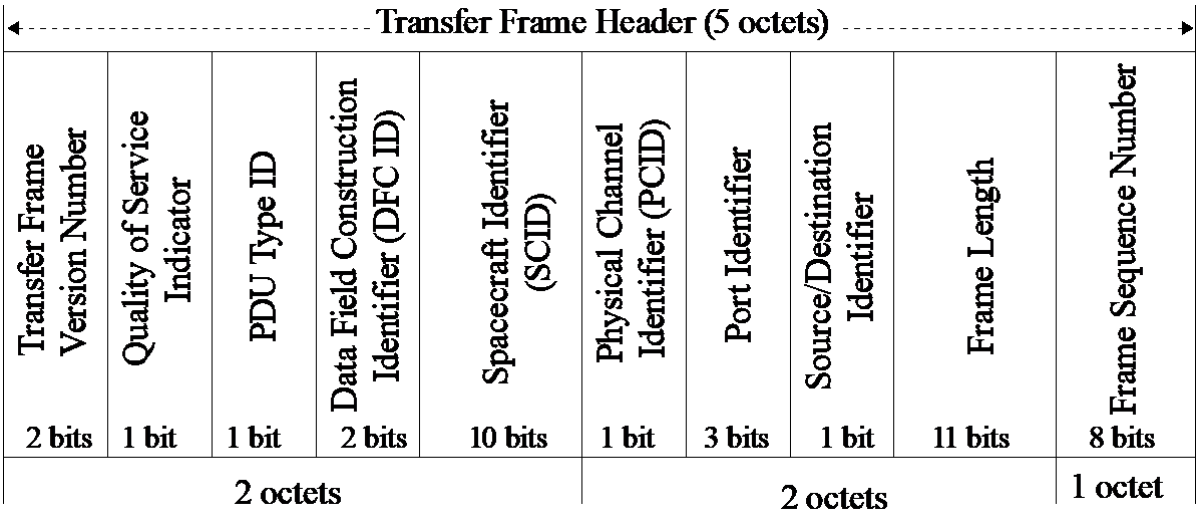

Figure 3-3: Transfer Frame Header

3.3.2.2 Transfer Frame Version Number

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

3.3.2.2.2 The Transfer Frame Version Number field shall contain the binary value '10'.

NOTE – This Recommended Standard defines the Version-3 Transfer Frame. References [C6] and [C7] specify other Transfer Frames defined by CCSDS.

3.3.2.3 Quality of Service Indicator

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

3.3.2.3.2 The QoS Indicator shall indicate the transfer service:

a) The QoS Indicator is set to '0' for a frame on the Sequence Controlled service.

b) 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.

3.3.2.4 PDU Type ID

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

3.3.2.4.2 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 reference [5].

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.

3.3.2.5 Data Field Construction ID

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

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

3.3.2.5.3 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)	3.3.3.2
'01'	Segment Data (a complete or segmented packet)	3.3.3.3
'10'	Reserved for future CCSDS definition	3.3.3.4
'11'	User Defined Data	3.3.3.5

3.3.2.6 Spacecraft Identifier

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

3.3.2.6.2 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 3.3.2.9 indicates whether the SCID identifies the source or destination spacecraft.

2 The procedures for the assignment of SCID values for use in Version-3 Transfer Frames are specified in reference [3].

3.3.2.7 Physical Channel Identifier

3.3.2.7.1 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 PCID 0 or PCID 1 for frames with either value, using the same set of MIB parameters and all state machines, including COP-P.

3 For operational simplicity, if the receiving spacecraft has only one transponder powered at a time, the PCID should not be used for transponder selection.

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

3.3.2.8 Port Identifier

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

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

3.3.2.8.3 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 [C8].

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.

3.3.2.9 Source-or-Destination Identifier

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

3.3.2.9.2 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: SCID Field and Source-or-Destination Identifier When the Frame Is Created

Source-or-Destination Identifier Value	SCID Field Contents	Transmitted SCID
0 (= *source)*	SCID of spacecraft that is sending the frame over this link	MIB parameter Local_Spacecraft_ID
1 (= *destination)*	SCID of spacecraft that is intended to receive the frame over this link	MIB parameter Remote_Spacecraft_ID

3.3.2.9.3 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	Where Behavior Is Specified
0 (= *source)*	*true*	MIB parameter Remote_Spacecraft_ID	Reference [5], subsections 5.1.3.2 and 5.6.2 c)
0 (= *source)*	*false*	No test is performed	Reference [5], subsections 5.1.3.2 and 5.6.2 c)
1 (= *destination)*	*true* or *false*	MIB Parameter Local_Spacecraft_ID	Reference [5], subsection 5.6.2 b)

NOTE – Assignment procedures for SCIDs in Version-3 Transfer Frames are controlled by reference [3].

3.3.2.10 Frame Length

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

3.3.2.10.2 This 11-bit field shall contain a length count *C*, which equals one fewer than the total number of octets in the Transfer Frame.

a) The count shall be measured from the first octet of the Transfer Frame Header to the last octet of the Transfer Frame Data field.

b) The length count *C* is expressed as: *C* = (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).

3.3.2.11 Frame Sequence Number (Sequence Controlled or Expedited)

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

3.3.2.11.2 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).

3.3.2.11.3 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 DS sublayer) for each service is initialized to '0' by the SET INITIALIZE MODE directive (see subsection 5.2.3.1.1.2 in reference [5]).

2 The SEQ_CTRL_FSN is used by 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.

3.3.3 TRANSFER FRAME DATA FIELD

3.3.3.1 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).

NOTES

1 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).

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

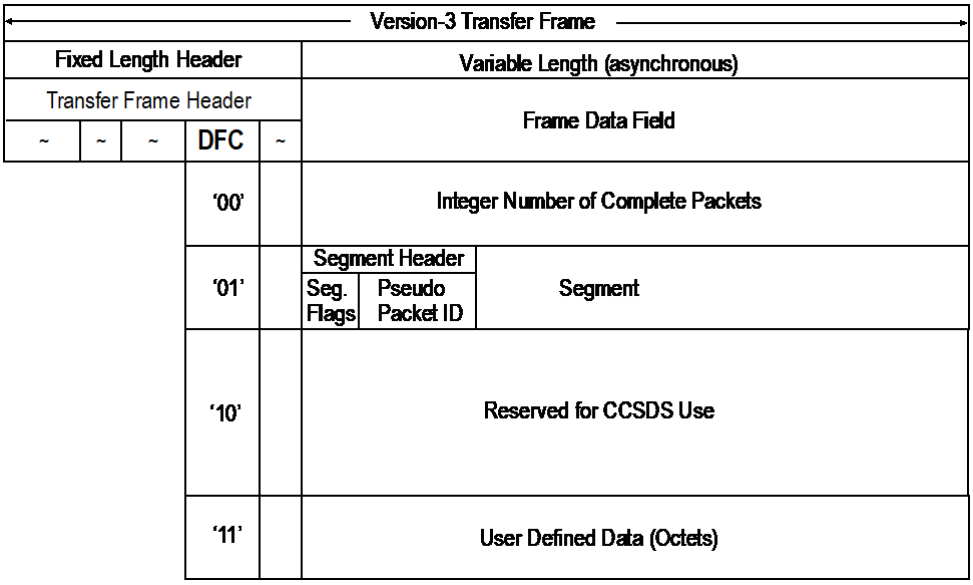

Figure 3-4: Version-3 Transfer Frame Data Field Contents of a U-Frame

3.3.3.2 Packets in a U-frame

3.3.3.2.1 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).

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

3.3.3.3 Segment Data Units in a U-frame

3.3.3.3.1 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).

3.3.3.3.2 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)

3.3.3.3.3 Prior to delivery to the user, the DLL shall re-assemble all the segments using the same Routing ID, that is, 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.

3.3.3.3.4 Only complete packets shall be delivered to the user.

3.3.3.3.5 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.

3.3.3.4 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.

3.3.3.5 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.)

3.3.3.6 Transfer Frame Data Field Contents in a P-frame

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

NOTE – SPDUs are specified in reference [5].

4 DATA LINK LAYER

4.1 FRAME SUBLAYER

4.1.1 OVERVIEW

The frame sublayer creates transfer frames based on the managed parameter Frame Version In Use. It enforces frame prioritization, validates frames, and delivers them to the MAC and DS sublayers. The functionality of the frame sublayer is specified below.

4.1.2 FRAME SUBLAYER FUNCTIONS

4.1.2.1 At the sending end, the Frame sublayer shall perform the following functions:

a) accept frames supplied by the DS Operations (reference [5]) and the MAC sublayer and modify field values as necessary;

b) formulate PLCWs and status reports and incorporate them into a P-frame;

c) determine the order of frame transmission;

d) transfer the frames to the C&S sublayer.

4.1.2.2 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 either a Version-3 or Version-4 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 DS 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 DS sublayer.

4.1.3 FRAME SELECTION FOR OUTPUT PROCESSING AT THE SENDING END

4.1.3.1 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 PL.

4.1.3.2 Frame Multiplexing Process Control

4.1.3.2.1 Frames shall be generated and sent when the TRANSMIT parameter (reference [5], subsection 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.

4.1.3.2.2 When either NEED_PLCW or NEED_STATUS_REPORT (reference [5], subsection 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.

4.1.3.3 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* (see reference [5]).

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 reference [5], subsection 4.3).

4.2 MEDIUM ACCESS CONTROL SUBLAYER

4.2.1 OVERVIEW

The MAC sublayer is responsible for any operational changes in the PL configuration made during the data services phase.

4.2.2 MAC CONTROL MECHANISMS

4.2.2.1 Overview

The following mechanisms are used to coordinate and control operations between the MAC and other sublayers.

4.2.2.2 MAC_FRAME_PENDING

4.2.2.2.1 The MAC_FRAME_PENDING parameter shall be provided from the MAC sublayer to the Frame sublayer.

4.2.2.2.2 The MAC_FRAME_PENDING shall be set to *true* when a complete frame is loaded into the MAC queue.

4.2.2.2.3 MAC_FRAME_PENDING shall be set to *false* when the last bit of the frame is extracted from the MAC queue.

4.2.3 MAC BUFFERS

4.2.3.1 SENT_TIME_BUFFER

The SENT_TIME_BUFFER shall store all of the egress clock times, associated frame sequence numbers, and QoS Indicator when time tag data is collected.

4.2.3.2 RECEIVE_TIME_BUFFER

The RECEIVE_TIME_BUFFER shall store all of the ingress clock times, associated frame sequence numbers, and QoS Indicator when time tag data is collected.

NOTE – Management of the MAC buffers is an implementation detail.

4.2.4 DISCUSSION—INTERFACE TO HIGHER SUBLAYER

FOP-P provides frame level accounting, that is, V(S) and VE(S) to the I/O sublayer for every Sequence Controlled and Expedited frame it numbers (see reference [5]).

4.3 INPUT/OUTPUT SUBLAYER

4.3.1 OVERVIEW

The Logical Input/Output Port identifiers (I/O Port IDs) within a physical entity (Spacecraft ID) are the data acceptance and distribution points for handling the data within the frame. For a Version-3 frame, the I/O Port ID is the concatenation of the PCID value and I/O Port ID

value. For a Version-4 frame, the I/O Port ID is the concatenation of the Virtual Channel Identifier (VCID) value and the Multiplexer Access Point Identifier (MAP ID) value. Each I/O Port ID within the remote entity (SCID) is loaded with the necessary processing rules for handling the received frame data.

4.3.2 FUNCTIONS

4.3.2.1 At the sending end, the I/O sublayer shall:

a) accept for transfer the data for which the user specifies:

   1) the required QoS;

   2) the output Port ID;

   3) Protocol Data Unit (PDU) type (user data or protocol directives);

   4) the frame data field construction rules to build a Version-3 Transfer Frame (see 3.3.2.5);

   5) Remote_Spacecraft_ID;

   6) PCID;

   7) Source-or-Destination Identifier;

b) organize the received data (including metadata) to form the Frame Data Unit and the Transfer Frame Header (frame sequence number shall be set to null) using the value of the following MIB parameters:

   1) Maximum_Packet_Size; and

   2) Transfer_Frame_Length (for fixed-length frames); or

   3) Maximum_Frame_Length (for variable-length frames).

   NOTES

   1. This process determines how to integrate the received packets into the frames. It includes segmenting packets (asynchronous data links) when their size is too large to fit within the maximum allowed frame size.

   2. The MIB parameters listed in paragraph b) are found in reference [5] annex F for Version-3 frames (Prox-1), and reference [8] for Version-4 (USLP) frames.

c) notify the user when an Expedited SDU is radiated;

d) notify the user when a Sequence Controlled SDU has been successfully transferred across the communications channel.

4.3.2.2 At the receiving end, the I/O sublayer shall:

a) receive U-frames accepted via the lower sublayers;

b) assemble received segments into packets and verify that each packet is complete;

c) deliver only complete packets to the user (length of the rebuilt packet must match packet length field), and discard incomplete packets;

d) deliver the packets/user-defined data via the specified output Port ID in the U-frame header.

4.3.3 INTERFACE TO THE LOWER SUBLAYERS

4.3.3.1 For received U-frames, the I/O sublayer shall provide two queues, Expedited queue and Sequence Controlled queue, capable of supporting the maximum data rate expected using the communications channel with that transceiver.

4.3.3.2 The I/O sublayer shall:

a) pass SDUs that require the Sequence Controlled service via the Sequence Controlled queue;

b) pass SDUs that require the Expedited service via the Expedited queue.

4.3.3.3 For Sequence Controlled service, the I/O sublayer shall:

a) maintain an association between each SDU provided to the DS sublayer and the frame sequence number of the frame that contains the last octet of that SDU;

b) evaluate NN(R) (see reference [5], subsection 6.2.2) to validate that a complete SDU was received from the DS sublayer;

c) notify the user when acknowledged transfer of the SDU has been accomplished.

4.3.4 I/O SUBLAYER QUEUES AND ASSOCIATED CONTROL SIGNALS

4.3.4.1 While any data units are stored within the Sequence Controlled Frame queue, SEQUENCE_CONTROLLED_FRAME_AVAILABLE shall be *true*; otherwise, it shall be *false*.

NOTE – The Sequence Controlled Frame queue contains Sequence Controlled frames that are ready for transmission but have not yet been sent. This name is abbreviated to ‘SEQ queue’ in FOP-P State Table Events (see reference [5], subsection 6.2.3).

4.3.4.2 While any data units are stored within the Expedited Frame queue, EXPEDITED_FRAME_AVAILABLE shall be *true*; otherwise, it shall be *false*.

NOTE – The Expedited Frame queue contains Expedited frames that are ready for transmission but have not yet been sent. This name is abbreviated to ‘EXP queue’ in FOP-P State Table Events (see reference [5], subsection 6.2.3).

4.3.4.3 When the DS sublayer extracts a frame from either queue, that frame is permanently removed from the queue, and the appropriate frame available parameter is re-evaluated.

NOTE – The local directive, CLEAR QUEUE (*Queue Type*) allows for the clearing of frames based upon the queue type specified in the directive.

5 PROXIMITY-1 TIMING SERVICES

5.1 OVERVIEW

The Proximity-1 protocol specifies two timing services for both time tagging Transfer Frames (either Version-3 or Version-4) as well as transferring time to a remote asset. These two timing services can support a time correlation function that is outside the scope of this specification. They are specified here solely in an abstract sense and specify the information made available to the user in order to execute this functionality. The way in which a specific implementation makes this information available is not constrained by this specification. In addition to the parameters specified below, an implementation can provide other parameters to the service user (e.g., parameters for controlling the service, monitoring performance, facilitating diagnosis).

5.2 TIME TAG RECORDING

NOTE – The following method specifies the time tagging of Transfer Frames (either Version-3 or Version-4) exchanged between two Proximity-1 transceivers (initiator/responder) upon ingress to and egress from a Proximity transceiver (two-way) depicted in figure 5-1, Proximity Time Tag Recording.

5.2.1 When time tagging is active, a Proximity-1 transceiver shall record the time of the trailing edge of the last bit of the ASM of every incoming and every outgoing Version-3 Transfer Frame or Version-4 Transfer Frame of any type when available as required in reference [6].

5.2.2 The egress/ingress captured time tags shall correspond to when the trailing edge of the last bit of the ASM of the outgoing/received PLTU crosses the clock capture point (defined by the implementation) within the transceiver.

5.2.3 All recorded time tags shall be correlatable to when the trailing edge of the last bit of the ASM of the outgoing/received PLTU crossed the time reference point.

5.2.4 The reference point for all timing calculations shall be defined by the enterprise.

5.2.5 Timing services require the transceiver's MODE to be *active* (see reference [5], subsection 5.1.1).

NOTE – Timing services can occur in full, half-duplex, or simplex operations. Timing services can occur concurrently with other data transfer activities.

5.2.6 To perform time tag capture, the vehicle controller shall instruct the initiating transceiver (initiator) to build and send a SET CONTROL PARAMETERS directive (see reference [5], subsection 5.2.3.2.7) to the responder to capture its time tag measurements.

5.2.7 After processing this instruction/directive, the MAC sublayer of both transceivers shall capture the local time reference and associated frame sequence numbers over the commanded

interval (i.e., for the number of frames defined within the Time Sample Field of the directive) as depicted in figure 5-1 and package the collection of time tags and metadata (time + sequence number + direction + QoS Indicator) for transfer to the time correlation process.

NOTES

1 MAC buffer requirements for ingress and egress clock times are specified in 4.2.3.

2 The way in which these two data sets are built and possibly transferred and correlated is outside the scope of this specification (though some comments on time correlation follow below).

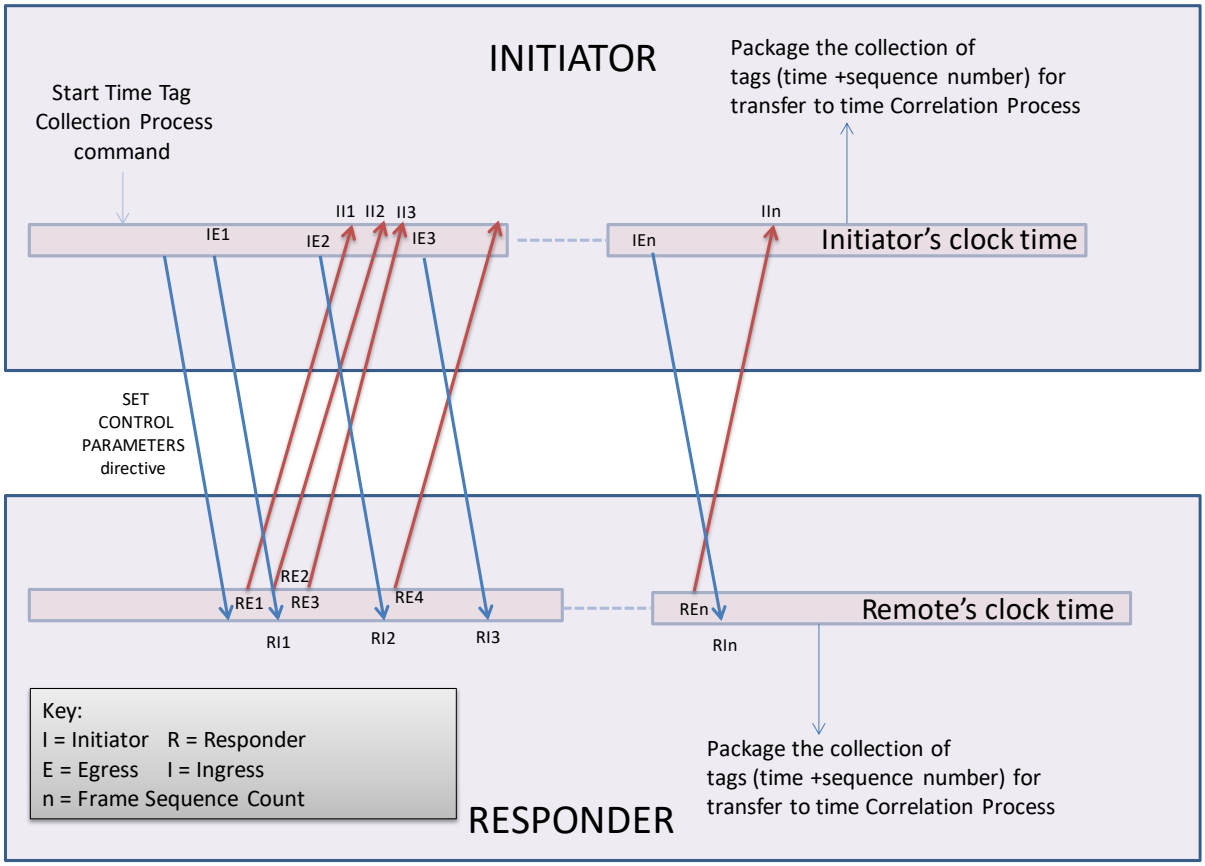

Figure 5-1: Proximity Time Tag Recording

5.3 TIME CORRELATION PROCESS

When time correlation data sets can be transferred, the time correlation process can be performed. The actual implementation details of this process are outside the scope of this specification. The time correlation process shall have access to the following information:

a) both initiator's and responder's data sets (time tags, sequence counts, direction, QoS Indicator);

b) the relationship of one of the transceiver's clocks to UTC;

c) all applicable path losses and delays associated with the end-to-end time tagging process;

d) time code formats per transceiver (reference [4]).

NOTES

1 It is up to the spacecraft implementer to measure and evaluate impact of all path losses and delays between the antenna and the radio antenna port.

2 It is up to the radio implementer to measure and evaluate impact of all path losses and delays internal to the radio.

3 The internal radio path delays are a function of the applied encoding option, symbol rate, modulation/demodulation mode, etc., and possibly implementation dependent elements (e.g., hardware type and configuration).

4 Time tag direction is labeled as either egress or ingress.

5 Simultaneous collection of time tag data in both directions provides accuracy.

5.4 TRANSFERRING TIME TO A REMOTE ASSET

5.4.1 A Proximity-1 transceiver shall provide the capability of distributing time to a remote asset.

NOTES

1 Independently from the capabilities of implementing the time correlation process, Proximity-1 systems have the possibility of coordinating their time reference.

2 In order to transfer accurate time to a remote asset (i.e., the responder), the initiator needs to maintain a correlation to the master clock for the enterprise and its local Proximity clock.

5.4.2 The method for transferring time to a remote asset shall consist of the following steps (see figure 5-2):

5.4.2.1 Optionally,

a) prior to the desired transfer of enterprise time to a remote node, the initiator's vehicle controller, based upon the mission's accuracy requirements, shall acquire/determine the one-way light time between itself and the remote node for the instant that the transfer is initiated;

b) the vehicle controller shall add that amount of time to the enterprise time for when the transfer is initiated;

c) this computed time shall be formatted as a CCSDS Unsegmented Time Code (reference [4]).

5.4.2.2 At the desired time, the vehicle controller shall command its transceiver to formulate a TIME DISTRIBUTION directive including the predetermined enterprise time, the internal sender path delay, and (if used) One Way Light Time (OWLT) propagation delay that is to be transmitted over the Proximity link.

5.4.2.3 The initiator shall then transmit the TIME DISTRIBUTION directive (see reference [5], subsection 3.3.3).

5.4.2.4 Upon receipt of the TIME DISTRIBUTION directive, the responder shall set its clock to the transmitted enterprise time and optionally determine, based upon the mission's accuracy requirements, whether it needs to add the sender path delay, OWLT, and its own path delay to the transmitted enterprise time before applying it.

NOTE – To distribute time more accurately to a remote asset, the above-mentioned method requires that the following information be known:

a) the initiator's time accuracy error;

b) the maximum delay from the time of the vehicle controller's request until the TIME DISTRIBUTION directive is transmitted;

c) the accuracy of the OWLT computation;

d) the delay from the time of receipt of the TIME DISTRIBUTION directive until it is loaded into the remote system master clock.

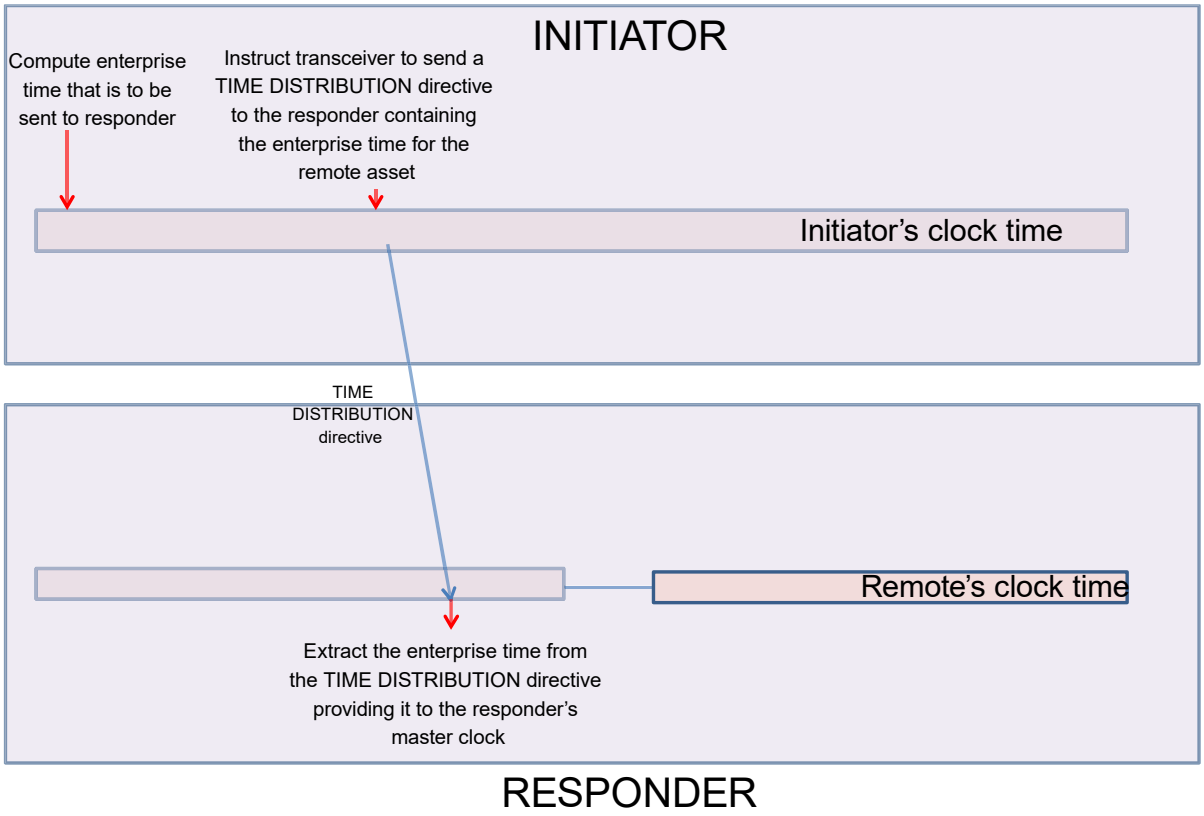

Figure 5-2: Transferring Time to a Remote Asset

6 INPUT/OUTPUT SUBLAYER OPERATIONS

6.1 OVERVIEW

The I/O sublayer provides the interface with the spacecraft data provider and data recipient. This section describes operations with a single user data source and single physical channel. It should be noted that implementations are not limited to a single data source. The fundamental role of the I/O sublayer is to form the frame data units for transfer across the link, and to pass received data units out to the physical and logical destinations identified in the received frame.

The I/O sublayer applies only to Version-3 frames. If Version-4 frames are used, USLP service users provide the functions of the I/O sublayer (see 2.2.2.5).

6.2 SENDING OPERATIONS

NOTE – The sending side of the I/O sublayer interfaces with the data supplier.

At the sending side, the I/O sublayer:

a) shall provide the procedures that accept the user service data units and prepare them for transfer across the communications channel;

b) may be required to parse large input packets into segments compatible with the maximum frame data size allowed in the asynchronous link;

c) shall assemble the data units for inclusion into frames in accordance with the restrictions imposed by various MIB parameters;

d) shall receive the user service data unit along with its routing and control instructions;

NOTE – These instructions are required for the formulation of the frame header and to determine whether data units can be combined into the same frame or not. The frame construction rules in section 3 imply that all data units within the same frame must be addressed to the same spacecraft destination, contain the same PDU type ID, the same physical channel ID, the same output Port ID, have the same QoS and must be of the same service data unit type (DFC ID).

e) shall have the responsibility to inform the data supplier which service data units were transmitted and, in the case of Sequence Controlled service, which data units were acknowledged as received by the communications partner.

NOTE – This notification is essential to enable reliable data service operations across multiple sessions, if desired. Sending operations also includes Simplex-Transmit.

6.3 RECEIVING OPERATIONS

NOTE – The receiving side of the I/O sublayer interfaces has a multitude of possible interfaces with the spacecraft. One of eight possible output ports can be identified in the frame using the Port ID field.

6.3.1 At the receiver side, the role of the I/O sublayer shall be to route a received 'complete' data unit to the identified port.

6.3.2 When segmentation is used, the I/O sublayer shall accept received segments and try to re-assemble the user's data unit.

6.3.3 The I/O sublayer shall deliver only completely reassembled data units; that is, partial data units are not delivered to the end user.

NOTE – Receiving operations also includes Simplex-Receive.

ANNEX A

PROTOCOL IMPLEMENTATION CONFORMANCE STATEMENT PROFORMA

(NORMATIVE)

A1 INTRODUCTION

A1.1 OVERVIEW

This annex provides the Protocol Implementation Conformance Statement (PICS) Requirements List (RL) for an implementation of *Proximity-1 Space Link Protocol—Data Link Layer* (CCSDS 211.0-P-6.0). The PICS for an implementation is generated by completing the RL in accordance with the instructions below. An implementation claiming conformance must satisfy the mandatory requirements referenced in the RL.

The RL support column in this annex is blank. An implementation's completed RL is called the PICS. The PICS states which capabilities and options have been implemented. The following can use the PICS:

– the implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;

– a supplier or potential acquirer of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;

– a user or potential user of the implementation, as a basis for initially checking the possibility of interworking with another implementation (it should be noted that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICSes);

– a tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A1.2 ABBREVIATIONS AND CONVENTIONS

The RL consists of information in tabular form. The status of features is indicated using the abbreviations and conventions described below.

Item Column

The item column contains sequential numbers for items in the table.

NOTE – The item-number prefix 'DLL' = 'Data Link Layer'.

Feature Column

The feature column contains a brief descriptive name for a feature. It implicitly means 'Is this feature supported by the implementation?'

Status Column

The status column uses the following notations:

M	mandatory.
O	optional.
O.<n>	optional, but support of at least one of the group of options labeled by the same numeral <n> is required.

Support Column Symbols

The support column is to be used by the implementer to state whether a feature is supported by entering Y, N, or N/A, indicating:

Y	Yes, supported by the implementation.
N	No, not supported by the implementation.
N/A	Not applicable.

The support column should also be used, when appropriate, to enter values supported for a given capability.

A1.3 INSTRUCTIONS FOR COMPLETING THE RL

An implementer shows the extent of compliance to the Recommended Standard by completing the RL; that is, the state of compliance with all mandatory requirements and the options supported are shown. The resulting completed RL is called a PICS. The implementer shall complete the RL by entering appropriate responses in the support or values supported column, using the notation described in A1.2. If a conditional requirement is inapplicable, N/A should be used. If a mandatory requirement is not satisfied, exception information must be supplied by entering a reference X*i*, where *i* is a unique identifier, to an accompanying rationale for the noncompliance.

A2 PICS PROFORMA FOR PROXIMITY-1 SPACE LINK PROTOCOL—DATA LINK LAYER (CCSDS 211.0-P-6.0)

A2.1 GENERAL INFORMATION

A2.1.1 Identification of PICS

Date of statement (DD/MM/YYYY)	
PICS serial number	
System conformance statement cross-reference	

A2.1.2 Identification of Implementation Under Test (IUT)

Implementation name	
Implementation version	
Special configuration	
Other information	

A2.1.3 Identification of Supplier

Supplier	
Contact point for queries	
Implementation name(s) and version(s)	
Other information necessary for full identification, for example, name(s) and version(s) for machines and/or operating systems; System name(s)	

A2.1.4 Identification of Specification

CCSDS 211.0-P-6.0	
Have any exceptions been required? NOTE – A YES answer means that the implementation does not conform to the Recommended Standard. Non-supported mandatory capabilities are to be identified in the PICS, with an explanation of why the implementation is non-conforming.	Yes [ ] No [ ]

A2.2 REQUIREMENTS LIST

Version-3 Transfer Frame					
Item	**Description**	**Reference**	**Status**	**Values Allowed**	**Support**
DLL-#	Transfer Frame Version Number	3.1.1.1	M	10 or 1100 (not both)	
DLL-1	Version-3 Transfer Frame	3.3.1	M		
DLL-2	Transfer Frame Header	3.3.2	M		
DLL-3	Transfer Frame Version Number	3.3.2.2	M	2	
DLL-4	Quality of Service Indicator	3.3.2.3	M	0, 1	
DLL-5	PDU Type ID	3.3.2.4	M	0, 1	
DLL-6	Data Field Construction ID	3.3.2.5	M	0–3	
DLL-7	SCID	3.3.2.6	M	0–1023	
DLL-8	PCID	3.3.2.7	M	0, 1	
DLL-9	Port Identifier	3.3.2.8	M	0–7	
DLL-10	Source-or-Destination Identifier	3.3.2.9	M	0, 1	
DLL-11	Frame Length	3.3.2.10	M	4–2047	
DLL-12	Frame Sequence Number (Sequence Controlled or Expedited)	3.3.2.11	M	0–255	
DLL-13	Transfer Frame Data Field	3.3.3	M	0–2043 octets	
DLL-14	PACKETS in a U-Frame (DFC ID = 0)	3.3.3.2	O.1		
DLL-15	SEGMENT DATA UNITS in a U-Frame (DFC ID = 1)	3.3.3.3	O.1		
DLL-16	CCSDS RESERVED FIELD (U-Frame) (DFC ID = 2)	3.3.3.4	O.1		
DLL-17	USER-DEFINED DATA in a U-Frame (DFC ID = 3)	3.3.3.5	O.1		
DLL-18	Transfer Frame Data Field Contents in a P-frame	3.3.3.6	M		

O.1 For the Transfer Frame Data Field at least one must be chosen.

Medium Access Control Sublayer					
Item	**Description**	**Reference**	**Status**	**Values Allowed**	**Support**
DLL-19	MAC Control Mechanisms	4.2.2	M		
DLL-20	MAC buffers	4.2.3	M		
DLL-21	SENT_TIME_BUFFER	4.2.3.1	M		
DLL-22	RECEIVE_TIME_BUFFER	4.2.3.2	M		

I/O Interface Sublayer					
Item	**Description**	**Reference**	**Status**	**Values Allowed**	**Support**
Send Side					
DLL-23	Accept user data for transfer	4.3.2.1 a)	M		
DLL-24	Form the Frame Data Unit and the Transfer Frame Header	4.3.2.1 b)	M		
DLL-25	Expedited SDU is radiated	4.3.2.1 c)	M		
DLL-26	Transfer of a Sequence Controlled SDU	4.3.2.1 d)	M		
Receive Side					
DLL-27	Output SDUs	4.3.2.2 a)	M		
DLL-28	Assemble segments/verify packets	4.3.2.2 b)	M		
DLL-29	Deliver only complete packets	4.3.2.2 c)	M		
DLL-30	Deliver the packets/user-defined data	4.3.2.2 d)	M		
Interface to the Lower Sublayers					
DLL-31	SDUs to appropriate Queues (Sequence or Expedited)	4.3.3.1	M		
DLL-32	Existence of Expedited queue and Sequence Controlled queue	4.3.3.1	M		
DLL-33	Association between SDU and frame sequence number	4.3.3.3	M		
DLL-34	Evaluation of NNR for complete SDU transfer	b)	M		
I/O Sublayer Queues and Control Signals					
DLL-35	Data units stored within the Sequence Controlled Frame queue	4.3.4.1	M		
DLL-36	Data units stored within the Expedited Frame queue	4.3.4.2	M		
DLL-37	Frame extraction from either queue	4.3.4.3	M		

Proximity-1 Timing Services					
Item	**Description**	**Reference**	**Status**	**Values Allowed**	**Support**
Time Tag Recording					
DLL-38	Time Tagged Bit	5.2.1	M		
DLL-39	Time Tag Event	5.2.2	M		
DLL-40	Time Tags relationship to time reference point	5.2.3	M		
DLL-41	Enterprise defined time reference point	5.2.4	M		
DLL-42	Operational Mode	5.2.5	M		
DLL-43	Initiate Time Tag Collection	5.2.6	M		
DLL-44	Capture and Package Time Tags + Meta Data	5.2.7	M		
DLL-45	Time Correlation Process	5.3	O		
Transferring Time to a Remote Asset					
DLL-46	Time Distribution	5.4.1	M		
DLL-47	Compute Enterprise Time	5.4.2.1	O		
DLL-48	Send Side: Formulate Time Distribution Directive	5.4.2.2	M		
DLL-49	Send Side: Transmit Time Distribution Directive	5.4.2.3	M		
DLL-50	Receive Side: Time Distribution Directive	5.4.2.4	M		

Input/Output Sublayer Operations					
Item	**Description**	**Reference**	**Status**	**Values Allowed**	**Support**
DLL-51	Sending Operations	6.2	M		
DLL-52	Receiving Operations	6.3	M		

Management Information Base Parameters (alphabetical)					
Item	**Description**	**Reference**	**Status**	**Values Allowed**	**Support**
DLL-53	Local_PCID	3.3.2.7	M		
DLL-54	Local_Spacecraft_ID	3.3.2.9.3	M		
DLL-55	Maximum_Frame_Length	3.3.3.1	M		
DLL-56	Maximum_Packet_Size	4.3.2.1	M		
DLL-57	Remote_PCID	3.3.2.7	M		
DLL-58	Remote_Spacecraft_ID	3.3.2.9.3	M		
DLL-59	Source_Destination_ID	3.3.2.9	M		

ANNEX B

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

B1 SECURITY CONSIDERATIONS

B1.1 SECURITY BACKGROUND

Security services may be required for IP datagram payloads over CCSDS space links based on threat assessment, mission security policies, and mission specifications. While security service specification is outside the scope of this document, a brief overview of the three available services is provided below:

- **Confidentiality**: Protects payload data from unauthorized access.
- **Integrity**: Protects payload data from undetected modification during transit.
- **Authentication**: Verifies the source of payload data (e.g., for command data).

B1.2 A SINGLE DATAGRAM MAY REQUIRE ALL THREE SECURITY SERVICES TO ENSURE THAT THE PAYLOAD IS CONFIDENTIAL, UNALTERED, AND AUTHENTIC.SECURITY CONCERNS

As stated in the previous subsection, various security services might need to be applied to the IP datagram depending on the threat, mission security policies, and mission planner specifications. This document assumes that either upper or lower layers of the OSI model will provide the security services depending on required granularity:

- Fine-grained user **authentication**: Application Layer;
- General **authentication**: Network or DLLs;
- Data **integrity** protection: Any layer (Application, Network, or Data Link);
- Data **confidentiality**: Any layer (Application, Network, or Data Link).

Reference [C4] provides more information regarding the choice of service and where it can be implemented.

B1.3 POTENTIAL THREATS AND ATTACK SCENARIOS

When authentication, integrity, and confidentiality protections are not implemented, spacecraft systems face the following threats:

- Without **authentication** unauthorized commands or software could be uploaded to spacecraft from unverified origins or data may be retrieved from unverified sources masquerading as legitimate users.
- Without **integrity** corrupted commands or software might reach the spacecraft, while corrupted telemetry from the spacecraft could lead to incorrect operational decisions.
- Without **confidentiality** sensitive or private information may be exposed to eavesdroppers during transmission.

B1.4 CONSEQUENCES OF NOT APPLYING SECURITY

The security services are out of scope of this document and should be applied at layers above or below those specified in this document. However, when required security controls are not properly implemented, the following vulnerabilities arise:

- If **authentication** is not implemented, unauthorized commands or software may be loaded onto the spacecraft.
- If **integrity** is not implemented, erroneous commands or software could be uploaded, potentially resulting in mission loss.
- If **confidentiality** is not implemented, data transmitted to or from the spacecraft becomes visible to unauthorized entities, leading to disclosure of sensitive information.

B2 SANA CONSIDERATION

The current issue of this Recommended Standard does not require any action from SANA. Existing SANA registries created in support of previous issues of this Recommended Standard should continue to be maintained.

B3 PATENT CONSIDERATIONS

No patents are known to apply to this Recommended Standard. Information concerning patent rights and licensing for LDPC coding is contained in annex B of reference [2]

ANNEX C

INFORMATIVE REFERENCES

(INFORMATIVE)

NOTE – References [C1]-[C3] define PL techniques that are not part of the Proximity-1 PL specification. They are included here so that transceivers with an extended PL can interoperate.

[C1] *Digital Video Broadcasting (DVB); Framing Structure, Channel Coding and Modulation for 11/12 GHz Satellite Services*. ETSI EN 300 421 V1.6.1 (2008-09). Sophia-Antipolis: ETSI, 2008.

[C2] *A 48/56/64 kbit/s Data Circuit-Terminating Equipment Standardized for Use on Digital Point-to-Point Leased Circuits*. ITU-T Recommendation V.38. Geneva: ITU, 1996.

[C3] *Performance Characteristics for Intermediate Data Rate Digital Carriers Using Convolutional Encoding/Viterbi Encoding*. Rev. 11. IESS 308. Washington, DC: INTELSAT, 2005.

[C4] *The Application of Security to CCSDS Protocols*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 350.0-G-3. Washington, D.C.: CCSDS, March 2019.

[C5] *Communications Operation Procedure-1*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 232.1-B-2. Washington, D.C.: CCSDS, September 2010.

[C6] *TC Space Data Link Protocol*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 232.0-B-4 Washington, D.C.: CCSDS, October 2021.

[C7] *TM Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 132.0-B-3 Washington, D.C.: CCSDS, October 2021.

[C8] "Registries." Space Assigned Numbers Authority. https://sanaregistry.org/r.

[C9] *Proximity-1 Space Link Protocol—Rationale, Architecture, and Scenarios*. Issue 2. Report Concerning Space Data System Standards (Green Book), CCSDS 210.0-G-2. Washington, D.C.: CCSDS, December 2013.

ANNEX D

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

ASM	attached synchronization marker
BER	bit error rate
BPSK	binary phase shift keying
C&S	coding and synchronization
CCSDS	Consultative Committee for Space Data Systems
COP-P	communication operations procedure-Proximity
CRC	cyclic redundancy check
CW	continuous wave
DFC ID	data field construction identifier
DLL	data link layer
EDL	entry, descent, and landing
ETSI	European Telecommunications Standards Institute
FARM-P	frame acceptance and reporting mechanism-Proximity
FOP-P	frame operations procedure-Proximity
FSK	frequency shift keying
FSN	frame sequence number
I/O	input/output
IP	Internet Protocol
ITU	International Telecommunications Union
LCCD	local COMM_CHANGE directive
LDPC	low density parity check
LNMD	LOCAL_NO_MORE_DATA
MAC	medium access control
MAP	multiplexer access point
MIB	management information base

MRO	Mars Reconnaissance Orbiter
MSB	most significant bit
NC	non-coherent
N(R)	last acknowledged frame sequence number +1
N(S)	frame sequence number within the Proximity-1 frame header
NN(R)	previous acknowledged frame sequence number +1
NRZ-L	non-return to zero-level
OSI	Open Systems Interconnection
OWLT	one way light time
PCID	physical channel ID
PDU	protocol data unit
P-frame	supervisory/protocol frame
PLCW	Proximity link control word
PLTU	Proximity link transmission unit
PSK	phase shift keyed
PVN	packet version number
QoS	quality of service
QPSK	quadrature phase shift keying
RF	radio frequency
RL	requirements list
RSL	received signal level
RX	receive/receiver
SANA	Space Assigned Numbers Authority
SCID	spacecraft identifier
SDU	service data unit
SNR	signal to noise ratio
SPDU	supervisory protocol data unit
TEMIC	Telefunken Electronic Microelectronics
TX	transmit/transmitter

U-frame	user data frame
USLP	Unified Space Data Link Protocol
V(S)	value of the next sequence controlled frame sequence number to be sent
VCID	virtual channel identification
VE(S)	value of the next expedited frame sequence number to be sent

ANNEX E

PROXIMITY-1 DATA FORMAT HIERARCHY

(INFORMATIVE)