The Consultative Committee for Space Data Systems

Draft Recommendation for Space Data System Standards

PROXIMITY-1 SPACE LINK PROTOCOL— DATA LINK LAYER

DRAFT RECOMMENDED STANDARD

CCSDS 211.0-P-5.1

PINK SHEETS

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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.

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 (reference [7]) Transfer Frame.

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.

Version-4 Transfer Frame: A Unified Space Data Link (USLP) 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;

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 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.

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.

PLTU: Proximity Link Transmission Unit, 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 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 rehail 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.

[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.

[7] *Unified Space Data Link Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.1-B-1. Washington, D.C.: CCSDS, October 2018.

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 either a Version-3 or Version-4 (see reference [7], annex E) Transfer Frame received from the ~~Frame~~Upper 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~~applies only to the specific functions of the Version-3 Frame Sublayer. Similarily, reference [7] applies to the Version-4 Frame. ~~On~~Generically, on the send side, the Frame Sublayer:

– creates either Version-3 or Version-4 (see reference [7], annex E) 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~~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 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~~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).

2.1.4.2 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.

3 PROTOCOL DATA UNITS

3.1 OVERVIEW~~—~~

3.1.1 INTRODUCTION

There are two Transfer Frame protocol data units supported by CCSDS over the Proximity-1 Coding and Synchronization Sublayer (reference [5]). They are:

a) the Version-3 Transfer Frame defined in 3.2; and

b) the Version-4 (USLP) Transfer Frame defined in reference [7].

3.1.2 CONTEXT OF THE VERSION-3 TRANSFER FRAME

~~Figure~~ 3-1 ~~is the Proximity-1 protocol data unit context diagram.~~
The Version-3 Transfer Frame (i.e., the Proximity-1 Transfer Frame) is the protocol data unit of the Proximity-1 Space Data Link Protocol. Figure 3-1 shows the Version-3 protocol data unit context diagram. (See reference [5] for the specification of the PLTU.)

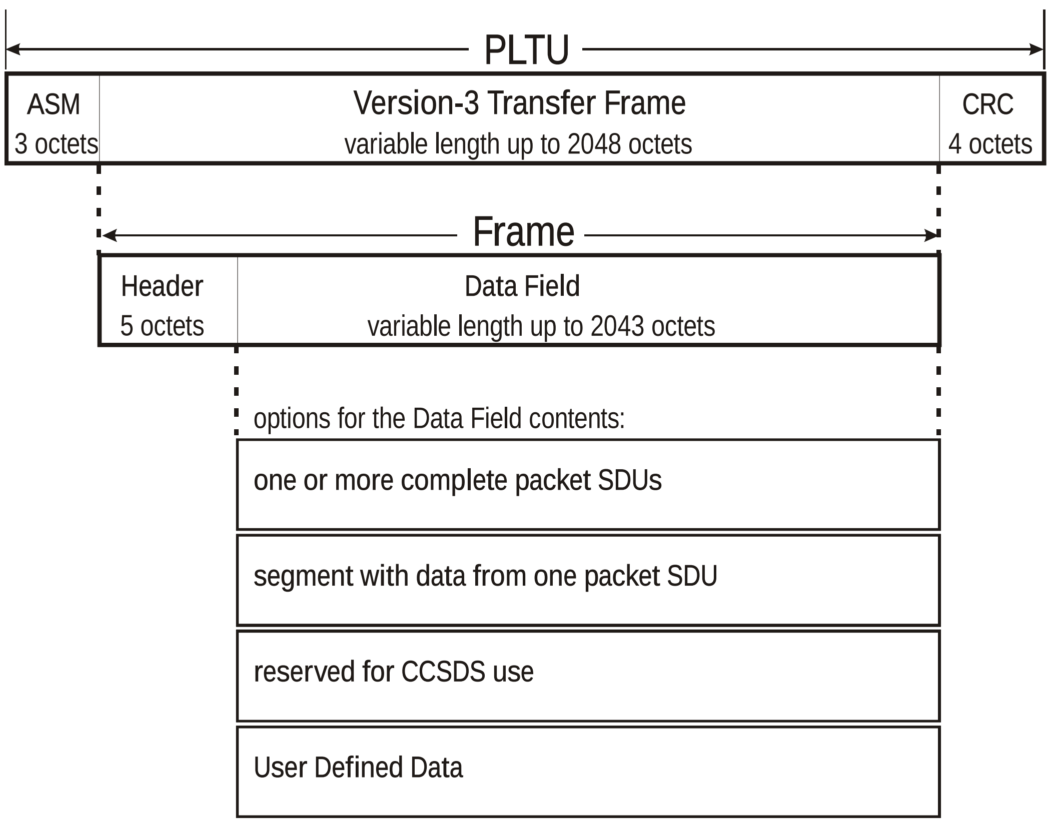


Figure 3-1: ~~Proximity-1~~Version-3 Protocol Data Unit Context Diagram

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

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~~Version-3 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.

3.2.2.9.3 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 (= *source)*	*true*	MIB parameter Remote_Spacecraft_ID	6.2.4.2; 6.7.2 d)
0 (= *source)*	*false*	No test is performed	6.2.4.2; 6.7.2 d)
1 (= *destination)*	*true* or *false*	MIB Parameter Local_Spacecraft_ID	6.7.2 c)

NOTE – Assignment procedures for SCIDs in ~~Proximity-1~~Version-3 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.

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).

3.2.2.11 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).

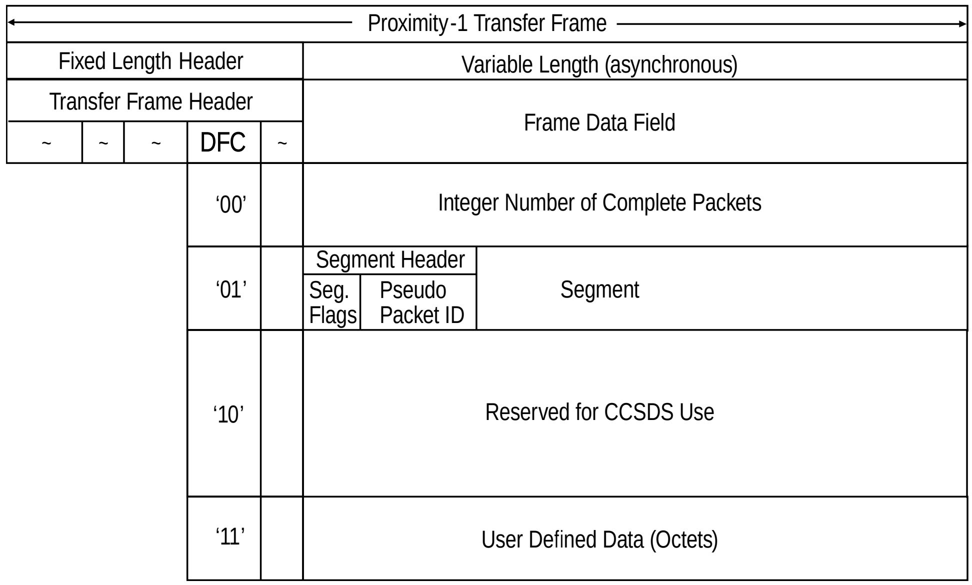


Figure 3-4: ~~Proximity-1~~Version-3 Transfer Frame Data Field Contents of a U-Frame

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,

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).

3.3 VERSION-4 TRANSFER FRAME

Alternatively, the Version-4 Transfer Frame defined in the *Unified Space Data Link Protocol* (reference [7]) may be used in lieu of the Version-3 frame as the Transfer Frame protocol data unit over the Proximity-1 Coding Sublayer. In this case, the functionality in the Proximity-1 Frame Sublayer is replaced by the USLP Space Data Link Protocol.

NOTE – Annex C of reference [7] describes the differences and similarities between the Version-3 and Version-4 Transfer Frame fields. Reference [5] describes use of the Version-4 Transfer Frame over the Proximity-1 Coding and Synchronization sublayer.

4 DATA LINK LAYER

4.1 FRAME SUBLAYER

4.1.1 OVERVIEW

The Frame Sublayer specified in this section applies only to Version-3 Transfer Frames. When Version-4 Transfer Frames are used in lieu of the Version-3 frame as the Transfer Frame protocol data unit over the Proximity-1 Coding Sublayer, the functionality in the Proximity-1 Frame Sublayer is replaced by the USLP Space Data Link Protocol.

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 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.

4.1.2.2 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 Data Services Sublayer;

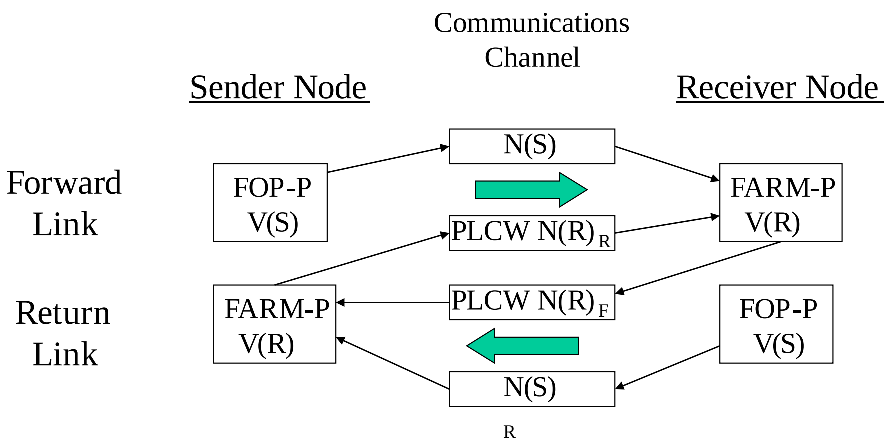
e) if the frame is a valid P-frame, route the contents of the frame (SPDUs) to the MAC Sublayer;

f) if the frame is a valid P-frame and contains a PLCW, route the PLCW to the Data Services Sublayer.

4.1.3 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 Physical Layer.



Notes:

1 The User data frames (U-frames) in the forward link contain the frame sequence number $N(S)_F$. The U-frames in the return link contain the frame sequence number $N(S)_R$.

2 The PLCW Supervisory protocol frames (P-frames) in the forward link are reporting return link progress and contain the frame sequence number $N(R)_R$. The P-frames in the return link are reporting forward link progress and contain the frame sequence number, $N(R)_F$.

Figure 4-1: COP-P Process

Both the Sender Node and the Receiver Node contain two types of procedures: the send side procedures, i.e., the FOP-P; and the receive side procedures, i.e., the FARM-P.

The FOP-P drives the Expedited and Sequence Controlled services. It is responsible for ordering and multiplexing the user-supplied data and maintaining synchronization with the FARM-P. It initiates a retransmission when required. If a valid PLCW is not received in a reasonable time period (defined by the MIB parameter, Synch_Timeout), the Sender Node's FOP-P notifies the local controller that it is not synchronized with the Receiver Node's FARM-P. If the MIB parameter Resync_Local equals *false*, it is the responsibility of the local controller to decide how synchronization will be re-established. Otherwise, the Sender Node's FOP-P forces a resynchronization by executing the SET V(R) activity.

The FARM-P is data-driven, i.e., it simply reacts to what it receives from the FOP-P and provides appropriate feedback via the PLCW. The FARM-P utilizes the services of the C&S Sublayer to verify that the frame was received error free. The FARM-P depends upon the Frame Sublayer to verify that the frame is a valid Version-3 Transfer Frame and that it should be accepted for processing by the Data Services Sublayer. When Version-4 Transfer Frames are used, the applicability of the FOP-P and FARM-P is specified in reference [7].

The FOP-P and FARM-P procedures control both Expedited and Sequence Controlled qualities of service.

4.3.4 DISCUSSION—INTERFACE TO HIGHER SUBLAYER

FOP-P provides frame level accounting, i.e., V(S) and VE(S) to the I/O Sublayer for every Sequence Controlled and Expedited frame it numbers.

4.4 INPUT/OUTPUT SUBLAYER

4.4.1 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 Physical Channel Identifier (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 MAP 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.

4.4.2 FUNCTIONS

4.4.2.1 Sending. 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) PDU type (user data or protocol directives),

   4) the frame data field construction rules to build a Version-3 Transfer Frame (see 3.2.2.5),

   5) Remote_Spacecraft_ID,

   6) PCID,

   7) Source-or-Destination Identifier;

b) using the value of the MIB parameters Maximum_Packet_Size and Maximum_Frame_Length (see annex C for Version-3 frames and section 5 of reference [7] for Version-4 frames), 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);

NOTE – 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.

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

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, and so on).

5.2 TIME TAG RECORDING

NOTE – The following method specifies the time tagging of ~~Proximiy-1~~ 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 ~~Proximiy-1~~Version-3 Transfer Frame or Version-4 Transfer Frame (reference [7]) of any type when available as required in reference [5].

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* and operating in the Data Services Sublayer.

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 to the responder to capture its time tag measurements.

6 DATA SERVICES OPERATIONS

6.1 OVERVIEW

Section 6 consists of a comprehensive set of state tables, state variable descriptions, and state diagrams for Proximity-1 data services operations. This section applies to either Version-3 or Version-4 Transfer Frames. Annex C of reference [7] describes the differences and similarities between the Version 3 and Version 4 Transfer Frame fields. Table 6-1 below provides a roadmap to help navigate through this section.

Table 6-1: Proximity-1 Data Services Operations Roadmap

Operations	Applicable Proximity-1 State Tables	Applicable State Transition Tables	Applicable State Transition Diagram
Full Duplex	Tables 6-2, 6-3	Session Establishment and Data Services: table 6-7 COMM_CHANGE: table 6-8 Session Termination: table 6-9	Full Duplex Operations: figure 6-1
Half Duplex	Tables 6-2, 6-4	Session Establishment and Data Services: table 6-10 COMM_CHANGE: table 6-11 Session Termination: table 6-12	Half Duplex Operations: figure 6-2
Simplex	Tables 6-2, 6-5	Simplex State Transition Table: table 6-13	Simplex Operations: figure 6-3

6.2 PROXIMITY-1 STATE TABLES

6.2.1 OVERVIEW

The operating states for the Proximity-1 protocol are shown in tables 6-2 through 6-5. These states are dependent 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 solely defined for asynchronous data links. (See 1.5.1.2 for these definitions.)

Table 6-2: States Independent of the DUPLEX Variable

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	Description
S1	Inactive	*off*	*off*	*inactive*	*off*	0	The only actions that are permitted in state S1 are those in response to local directives. In this state the Data Services operational variables and MIB parameter values can be modified and their status read via local directives from the local controller. When the protocol enters this state the variables identified in table 6-6 are initialized. The Local SET INITIALIZE MODE directive forces entry to this state.
S2	Waiting for Hail	*on*	*off*	*connecting-L*	*off*	0	In this state, receiving operations are enabled. FARM-P operations are enabled but only for processing received supervisory directives; i.e., Transfer Frame Version-3 header PDU TYPE ID or Version-4 header PROTOCOL CONTROL COMMAND FLAG = '1'. It should be noted that only receiving operations are enabled so that transmission is not permitted.
S80	Reconnect	*on*	*off*	*active*	off	0	In this state, the caller attempts to maintain the current Prox-1 session by reconnecting with the responder as follows: the caller's transmitter is turned off (for Drop_Carrier_Duration) to force the responder to drop carrier lock and transition into State S2: Waiting for Hail. The FARM-P and FOP-P variables of the caller and responder are not reset.

Table 6-3: States When DUPLEX = Full

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	Description
S31	Start Hail Action	*on*	*async*	*connecting-T*	*on*	1	In this state the Hail activity starts with the radiation of the carrier signal.
S32	Send Hail Acquisition	*on*	*async*	*connecting-T*	*on*	2	In this state the idle pattern is radiated to achieve symbol lock with the hailed remote unit.
S33	Send Hail Directives	*on*	*async*	*connecting-T*	*on*	3	In this state the HAIL directives: (if present) SET_PL EXTENSIONS, SET_TRANSMITTER_PARAMETERS (if present), SET PL EXTENSIONS, SET_RECEIVER_PARAMETERS) in that order are radiated in one ~~Proximity-1~~ Transfer Frame to initiate a session with the hailed remote unit, i.e., the responder.
S34	Send Hail Tail	*on*	*async*	*connecting-T*	*on*	4	In this state the idle pattern is radiated to allow the HAIL directives to be received and processed through the decoding chain of the responder.
S35	Wait for Hail Response	*on*	*async*	*connecting-T*	*off*	5	In this state the transmitter is turned off and the receiver awaits a response from the hailed remote unit.
S41	Radiate Carrier Only	*on*	*sync*	*active*	*on*	1	In this state the receiver is *on* and ready to process all received data while the transmission process is started with carrier radiation only.
S42	Radiate Acquisition Idle	*on*	*sync*	*active*	*on*	2	In this state the receiver is *on* and processing all received data while the transmission process is trying to achieve bit lock with a potential partnered transceiver, i.e., the caller transceiver.
S40	Data services	*on*	*sync*	*active*	*on*	0	In this state data transfer services controlled by the COP-P protocol are conducted with a partnered transceiver.

Table 6-4: States When DUPLEX = Half

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	Description
S11	Start Hail Action	*off*	*async*	*connecting-T*	*on*	1	In this state the Hail activity starts with the radiation of the carrier signal.
S12	Send Hail Acquisition	*off*	*async*	*connecting-T*	*on*	2	In this state the idle pattern is radiated to achieve symbol lock with the hailed remote unit.
S13	Send Hail Directives	*off*	*async*	*connecting-T*	*on*	3	In this state the HAIL directives: (if present) SET_PL EXTENSIONS (transmit), SET_TRANSMITTER_PARAMETERS (if present), SET PL EXTENSIONS (receive), SET_RECEIVER_PARAMETERS) in that order are radiated in one ~~Proximity-1~~ Transfer Frame to initiate a session with the hailed remote unit, i.e., the responder.
S14	Send Hail Tail	*off*	*async*	*connecting-T*	*on*	4	In this state the idle pattern is radiated to allow the HAIL directives to be received and processed through the decoding chain of the responder.
S36	Wait for Hail Response	*on*	*off*	*connecting-T*	*off*	5	In this state the transceiver awaits a response from the called remote unit.
S51	Radiate Carrier Only	*off*	*sync*	*active*	*on*	1	In this state the transmission process is started with carrier radiation only.
S52	Radiate Acquisition Idle	*off*	*sync*	*active*	*on*	2	In this state the transmission process is trying to achieve symbol lock with a potential partnered transceiver.
S50	Data Services (send)	*off*	*sync*	*active*	*on*	0	In this state the user data transmission process functions.
S54	Terminate Reply	*off*	*sync*	*active*	*on*	3	In this state the transmission process is sending the termination directive.

(6.2.3.6.2). No_Frames_Pending (6.3.2.3) occurs when none of the conditions for selecting an SPDU (including a PLCW) or U-frame is satisfied. Output FIFO = empty (6.3.2.2) is *true* when the last bit contained within the Output FIFO is extracted.

6.7 RECEIVING OPERATIONS

6.7.1 FRAME RECEPTION

6.7.1.1 Establishment of physical channel characteristics and inititalization of receiving procedures shall be accomplished via a SET MODE (*connecting-L*) or SET MODE (*connecting-T*) local directive (see 6.3.3.1.1 and 6.2.2.1).

6.7.1.2 The Frame Sublayer shall accept for validation frames delivered via the C&S Sublayer ChannelAccess.indication service primitive (see reference [5], annex B).

NOTES

1 When the Receive State is *on*, the received (optionally decoded) bitstream is processed by the C&S Sublayer to delimit the contained frames (this process requires frame synchronization and frame length determination using the frame header length field).

2 The delimited frame and the attached CRC-32 are processed by the C&S Sublayer to determine if the frame contains errors. Erred frames are rejected as invalid.

6.7.2 FRAME VALIDATION

Frame Validation Criteria shall be as follows:

a) ~~If the Frame Version Number does not equal binary '10', the frame is rejected as invalid.~~

a) The Transfer Frame header must not contain any values that are inconsistent with the implemented features for that spacecraft.

b) The value of the Frame Length must be consistent with the number of octets that are present.

c) If the Spacecraft ID field in the Transfer Frame header does not contain the value of the Local_Spacecraft_ID (MIB parameter) when the Source-or-Destination Identifier value equals '1', i.e., *destination*, the frame is rejected as invalid.

d) If the Spacecraft ID field in the Transfer Frame header does not contain the value equal to the RECEIVING_SCID_BUFFER for all frames received (i.e., Remote_Spacecraft_ID, MIB parameter) when the RECEIVING_SCID_BUFFER is non-zero and the Source-or-Destination Identifier value equals '0', i.e., *source*, and Test_Source is *true*, a session violation has occurred and the vehicle controller is

7 COMMUNICATION OPERATIONS PROCEDURE FOR PROXIMITY LINKS

7.1 OVERVIEW

An important overview of the COP-P protocol is provided in 4.3.3. This section applies to both Version-3 and Version-4 Transfer Frames.

The sending and receiving procedures for COP-P use single octet variables that are modulo-256 counters. When subtracting or comparing any two of these variables, special handling is required:

– Subtraction: The difference, A–B, is the number of times B needs to be incremented to reach A.

– Comparison: B < A is true if the difference, A–B, is between 1 and 127.

B > A is true if the difference, A–B, is between 128 and 255.

B = A is true if the difference, A–B, is 0.

7.2 SENDING PROCEDURES (FOP-P)

7.2.1 QUEUE

The FOP-P shall maintain a single output queue.

NOTES

1 The **Sent Frame queue** contains Sequence Controlled frames that have been sent but not yet acknowledged by the receiver. (This name is abbreviated to ‘Sent queue’ in the state table).

2 The local directive CLEAR QUEUE (*Queue Type*) allows for the clearing of frames within a specified queue.

7.2.2 FOP-P VARIABLES

FOP-P variables are:

a) VE(S): an 8-bit positive integer whose value shall represent the sequence number (modulo 256) of the next Expedited frame to be sent.

b) V(S): an 8-bit positive integer whose value shall represent the sequence number (modulo 256) of the next new Sequence Controlled frame to be sent.

7.3 RECEIVING PROCEDURES (FARM-P)

7.3.1 FARM-P STATE TABLE

Events	Event #/Name	Action
'Entered this state' at each session startup	**RE0** **Initialization**	R(S) = *false*; V(R) = 0; EXPEDITED_FRAME_COUNTER = 0; NEED_PLCW AND NEED_STATUS_REPORT = *true*;
Invalid frame arrives	**RE1** **Invalid Frame**	Discard the frame;
Valid 'SET V(R)' directive arrives	**RE2** **SET V(R)**	R(S) = *false*; Set V(R) to the SEQ_CTRL_FSN in the directive; NEED_PLCW = *true;*
Valid Expedited frame arrives	**RE3** **Valid Expedited Frame**	Accept/Pass the frame to I/O Sublayer; Increment EXPEDITED_FRAME_COUNTER;
Valid Sequence Controlled frame arrives, N(S)= V(R)	**RE4** **Sequence Frame 'in-sequence'**	Accept/Pass the frame to I/O Sublayer; R(S) = *false*; Increment V(R); NEED_PLCW = *true*;
Valid Sequence Controlled frame arrives, N(S)>V(R)	**RE5** **Sequence Frame 'gap detected'**	Discard the frame; R(S) = *true*; NEED_PLCW = *true*;
Valid Sequence Controlled frame arrives, N(S)<V(R)	**RE6** **Sequence Frame 'already received'**	Discard the frame;
Frame Sublayer requests content for PLCW	**RE7** **Report PLCW contents**	Report value of R(S), V(R), and EXPEDITED_FRAME_COUNTER;

7.3.2 INTERNAL FARM-P VARIABLES

The internal FARM-P variables shall be:

a) V(R): an 8-bit positive integer whose value represents the sequence number plus one (modulo 256) of the last Sequence Controlled frame acknowledged by the receiver;

b) R(S): a Boolean variable (i.e., its value is either *true* or *false*) that is copied to the PLCW, indicating whether or not Sequence Controlled frames need to be retransmitted;

c) N(S): an 8-bit positive integer whose value represents the sequence number (modulo 256) contained in the Transfer Frame header of the ~~Proximity-1~~Transfer Frame;

d) EXPEDITED_FRAME_COUNTER: a 3-bit positive integer whose value represents the number of Expedited frames received (modulo 8). This counter can be used by the receiver to keep track of the number of Expedited frames received over a communications session.

8 INPUT/OUTPUT SUBLAYER OPERATIONS

8.1 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 this functionality.

8.2 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.

ANNEX C

MANAGEMENT INFORMATION BASE PARAMETERS

(NORMATIVE)

This table lists each MIB parameter in the document along with how it is used and in what layer or sublayer it is used. Values for the Layer column are: P = Physical, C = C&S, F = Frame, M = MAC, D = Data Services, I = I/O, U = USLP. Parameter Definitions are provided where they are referenced in the specification.

Parameter	Use	Layer
Acquisition_Idle_Duration	Mandatory. Used in full-, half-duplex, and simplex session establishment and COMM_CHANGE. Session static. (See 6.2.4.4.)	P, M
Carrier_Loss_Timer_Duration	Mandatory. Used in full- and half-duplex operations. Session static. (See 6.2.4.6.)	D
Carrier_Only_Duration	Mandatory. Used in full-, half-duplex, and simplex session establishment and COMM_CHANGE. Session static. (See 6.2.4.3.)	P, M
Comm_Change_Lifetime	Mandatory. Used in the COMM_CHANGE persistent activity. Session static. (See 6.2.4.10.)	M
Comm_Change_Notification	Mandatory. Used in the COMM_CHANGE persistent activity. Session static. (See 6.2.4.9.)	M
Comm_Change_Response	Mandatory. Used in the COMM_CHANGE persistent activity. Session static. (See 6.2.4.8.)	M
Comm_Change_Waiting_Period	Mandatory. Used in the COMM_CHANGE persistent activity. Session static. (See 6.2.4.7.)	M
Hail_Lifetime	Mandatory. Used in the hailing persistent activity. Session static. (See 6.2.4.14.)	M
Hail_Notification	Mandatory. Used in the hailing persistent activity. Session static. (See 6.2.4.13.)	M

Parameter	Use	Layer
Hail_Response	Mandatory. Used in the hailing persistent activity. Session static. (See 6.2.4.12.)	M
Hail_Wait_Duration	Mandatory. Used in the hailing persistent activity. Session static. (See 6.2.4.11.)	M
Hailing_Channel	Mandatory. Channel assignment used in the hailing persistent activity during link establishment. Session static. (See 6.2.4.15.)	P,M
Hailing_Data_Rate	Mandatory. Data rate used in the hailing persistent activity during link establishment. Session static. (See 6.2.4.16.)	P,M
Interval_Clock	Mandatory. A frequency (e.g., 100 Hz) that is used for interval timing. Session static. (See 6.3.)	C
Local_PCID	Optional. Used to set the value of the local receiver's PCID.	M
Local_Spacecraft_ID	Mandatory. Used as a frame validation check when Source-or-Destination ID equals *source*. Session static. (See 3.2.2.9.3.)	M
Maximum_Failed_Token_Passes	Optional. Half-duplex. Defines the maximum number of times the transceiver is allowed to cycle through S50->S56->S58->S62->E50->S51->S52->S50 before E83 is triggered forcing the transceiver into S80 (reconnect).	D
Frame Version in use	3 (Proximity-1) or 4 (USLP)	F,U
Maximum_Frame_Length	Mandatory. Defines the maximum size ~~Proximity-1~~ Transfer Frame transferred between nodes. Link efficiency at various data rates may require varying frame lengths. Session dynamic. (See 3.2.3.1 and reference [7], subsection 5.2.) The maximum allowed value depends on the Frame Version in use.	F,U
Maximum_Packet_Size	Mandatory if packets are used. Maximum size of a packet in octets. Used in the segmentation process. Session static. (See 4.4.2.1.)	I

SNR	Signal to Noise Ratio
SPDU	Supervisory Protocol Data Unit
SS	Sub-State
TCP	Time Correlation Packet
TX	Transmit/Transmitter
UDD	User-Defined Data
U-frame	User Data Frame
UHF	Ultra High Frequency
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