The Consultative Committee for Space Data Systems

Draft Recommendation for
Space Data System Standards

SPACE COMMUNICATIONS SESSION CONTROL

DRAFT RECOMMENDED STANDARD

CCSDS 235.1-R-1

RED BOOK
April 2026

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This **Recommended Standard** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommendation** is entirely voluntary. Endorsement, however, indicates the following understandings:

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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 'Red 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

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1 INTRODUCTION

1.1 PURPOSE

The Recommended Standard specifies the data services operations for Space Communications Session Control (hereafter 'Session Control') used with CCSDS Space Communications Protocols.

1.2 SCOPE

This Recommended Standard defines data services operations, expedited and sequenced-controlled data transfer, and the procedures for establishing and terminating a session between a caller and responder.

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 is anticipated based on capabilities described in this Recommended Standard. Where mandatory capabilities are clearly indicated in sections of this Recommended Standard, they must be implemented when this document is used as a basis for cross-support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross-support agreements between the Agencies involved.

1.4 RATIONALE

The CCSDS believes it is important to document the rationale underlying the recommendations chosen so that future evaluations of proposed changes or improvements will not lose sight of previous decisions. Concepts and rationale behind the decisions that formed the basis of Session Control are documented in the Space Communications Session Control Green Book (planned).

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) Data Link Layer (DLL);

b) entity;

c) Physical Layer (PL);

d) Session Layer;

e) protocol data unit;

f) real system;

g) service;

h) 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 data units that are not necessarily concatenated.

caller and responder: Initiator and receiver, respectively, in a 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-P, 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-P (FARM-P) and Frame Operation Procedure-P (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-P, 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 space link.

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

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

hailing: The persistent activity used to establish a 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.

hail frame: The single transfer frame that contains all the necessary directives required to establish the link and move onto the working channel.

Protocol 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.

P-frame: Protocol (transfer) 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.

reconnect: Process in which the caller attempts to re-hail 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. This activity is optional.

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

session: A dialog between two or more communicating 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 Proximity Link Transmission Unit (PLTU) is available for transmission, Idle data is transmitted to maintain the continuous symbol stream.

Sync-Marked Transfer Frame, SMTF: The data unit that consists of the ASM and the Transfer Frame

Transfer Frame: The protocol data unit of a Space Data Link Protocol. In this document it can be either a Version-3 or a Version-4 Transfer Frame.

U-frame: User (transfer) frame. Any CCSDS version 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 Annex G and potentially acts upon them.

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.

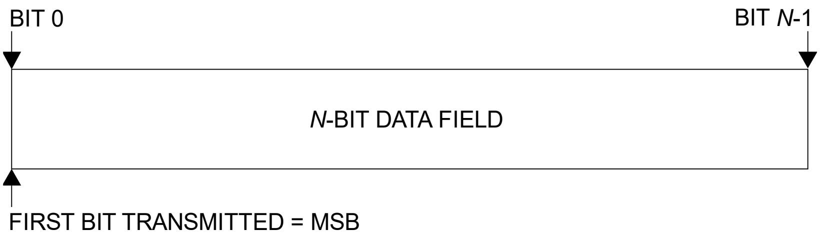

Figure 1-1: Bit Numbering Convention

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’.

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] *Time Code Formats*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 301.0-B-4. Washington, D.C.: CCSDS, November 2010.

[4] *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.

[5] *Proximity-1 Space Link Protocol—Physical Layer*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.1-B-5. Washington, D.C.: CCSDS, forthcoming.

[6] *Proximity-1 Space Link Protocol—Data Link Layer*. Issue 6. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.0-P-6.0. Washington, D.C.: CCSDS, forthcoming.

[7] *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.

[8] *AOS Space Data Link Protocol*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.0-B-5. Washington, D.C.: CCSDS, October 2025.

[9] *Pseudo-Noise (PN) Ranging Systems*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 414.1-B-3. Washington, D.C.: CCSDS, January 2022.

2 OVERVIEW

2.1 CONCEPT OF SPACE COMMUNICATIONS SESSION CONTROL

Session Control is a generic function that operates within the Data Services Sublayer (DSS) of the DLL and provides the following sub-functions:

a) Link Management, which controls:

   – session establishment, i.e., hailing (section 5);

   – data and/or ranging exchange;

   – session maintenance, e.g., optional reconnection;

   – configuration changes in physical/coding parameters via persistence activities (section 4);

   – link termination using directives (Annexes B-E) and MIB parameters (ANNEX F).

b) Quality of Service (QoS), which ensures reliable delivery via the Go-Back-*N* sequence-controlled Automatic Repeat Queuing (ARQ) procedure and expedited delivery for priority communication in COP-P (section 6).

c) Supervisor Protocol Data Unit (SPDU) exchange, which manages SPDUs (section 3) for directives, transceiver status, time, ranging, and COP-P/Space Data Link Security reporting.

A summary of each sub-function is provided below.

2.1.1 LINK MANAGEMENT OVERVIEW

This document controls the establishment, data exchange, potential reconnection, and termination of sessions for point-to-point communications between Proximity entities. These data services operations are detailed in section 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.

Table 2-1: Data Services Operations Roadmap

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

Data services 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). Hailing is required to establish a link for both full and half-duplex operations. Hailing is not used to establish a simplex transmit or receive session.

2.1.2 COP-P CONSTRAINTS

Data services operations control the order of user data transfer, including user-supplied directives to transmit within the session. It provides the following two qualities of service:

– Expedited: ensures transmission of Expedited frame data in the order received without errors.

– Sequence-Controlled: 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 (see 2.3 for a summary of the COP-P functionality). 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.

2.1.3 SUPERVISORY PROTOCOL DATA UNITS

SPDUs are used by the local transceiver for local control or for controlling and reporting status to the remote transceiver. SPDUs carry protocol directives and reports as defined in section 3.

Protocol reports are used for reporting the configuration and status of the transmitting node. Protocol directives are used for:

- configuring and controlling the protocol processor at the receiving node;
- establishing, enabling local changes, and terminating a communications session;
- transferring time-correlation data and distributing time;
- configuring the ranging channel and taking range measurements.

SPDUs are self-identifying and self-delimiting. They come in fixed or variable length based on the value of the SPDU format ID. Currently, there are only two fixed-length SPDUs defined: for a 16- and 32-bit PLCW. Variable-length SPDUs provide the capability for concatenating and multiplexing protocol objects such as directives and status reports. Only variable-length SPDUs further decompose into specific types of supervisory directives or reports (see Annexes B–E for detailed specification of variable-length SPDUs).

SPDUs are transmitted between transceivers in the data fields of Version-3 (Proximity-1) or Version-4 (USLP) transfer frames, which are called Protocol frames (P-frames). They are transmitted by setting:

- for Version-3:
  - PDU Type ID to ‘P-Frame’;
  - QoS Indicator Flag to ‘Expedited’;
- for Version-4:
  - Protocol Control Command Flag to ‘P-Frame’;
  - Bypass/Sequence Control Flag to ‘Expedited QoS’.

2.2 LAYERED MODEL

DSS is independent of any specific Space Data Link (SDL) layer protocol, C&S Sublayer, or PL. Instead, it provides a generic interface to both CCSDS frame and MAC sublayers.

Activities are divided between send and receive sides:

- The **send** side manages the transmitted physical channel and the acquisition of the received physical channel to establish a Proximity-1 link. DLL provides data for PL transmission. Transmitter operation is state-driven.
- The **receive** side processes incoming data from the physical channel. The receiver takes in the coded symbol stream and outputs serial data to the DLL, which then processes the PDUs. Once activated, receiver operation is modeless. It accepts and processes valid local and remote directives and delivers received service data units to the users.

The simplified data and control flows of the DSS with the other DLL sublayers are shown in Figure **2-1**.

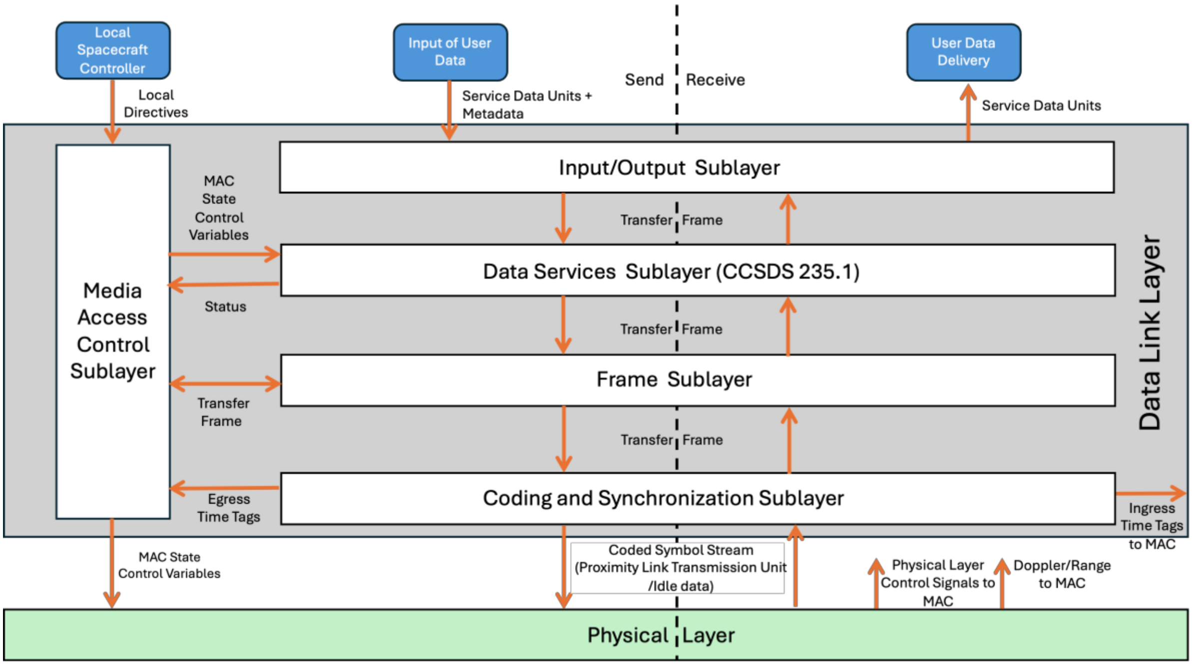

Figure 2-1: Generic Physical and Data Link Sublayers

2.2.1 DATA SERVICES SUBLAYER

The DSS contains both the COP-P and the comprehensive set of session state tables, variables, and diagrams (Table 2-1, section 6). The functionality of the COP-P is explained below. COP-P defines:

– Forward Operations Procedure (FOP-P) on the send side;

– Frame Acceptance and Reporting Mechanism (FARM-P) on the receive side.

The additional functionality of this sublayer is specified in the various state/operational control variables, timers, queues, buffers, and counters described throughout section 5.

2.2.1.1 COP-P Send Side Functionality

The send side:

a) runs the FOP-P process;

b) processes received PLCWs;

c) acknowledges delivery of complete service data units (SDUs) to the input/output (I/O) Sublayer;

d) provides frame accountability to the I/O Sublayer;

e) accepts an Expedited or Sequence Controlled frame from the I/O Sublayer.

2.2.1.2 COP-P Receive Side Functionality

The receive side runs the FARM-P process and accepts U-frames from the Frame Sublayer.

2.3 COP-P FOR PROXIMITY LINKS

2.3.1 GENERAL

The COP-P protocol is a direct link between one sender node and one receiver node. The sender delivers frames to the receiver. COP-P provides two qualities of service (Sequence Controlled and Expedited) that determine how reliably data are delivered from the sending to the receiving nodes.

The receiver accepts all valid Expedited frames and valid Sequence Controlled frames that arrive in sequence. The receiver provides feedback to the sender in the form of a PLCW. The sender uses this feedback to retransmit Sequence Controlled frames when necessary. Expedited frames are never retransmitted by the COP-P protocol.

The COP-P also supports concurrent bi-directional data transfer. In this configuration, nodes operate simultaneously as senders and receivers, as shown in Figure 2-2, COP-P Process. The protocol architecture consists of two components: the FOP-P on the send side and the FARM-P on the receive side. Each physical node in a COP-P implementation contains both the FOP-P and FARM-P protocol components, regardless of whether it is configured for unidirectional or bidirectional operation in a particular deployment.

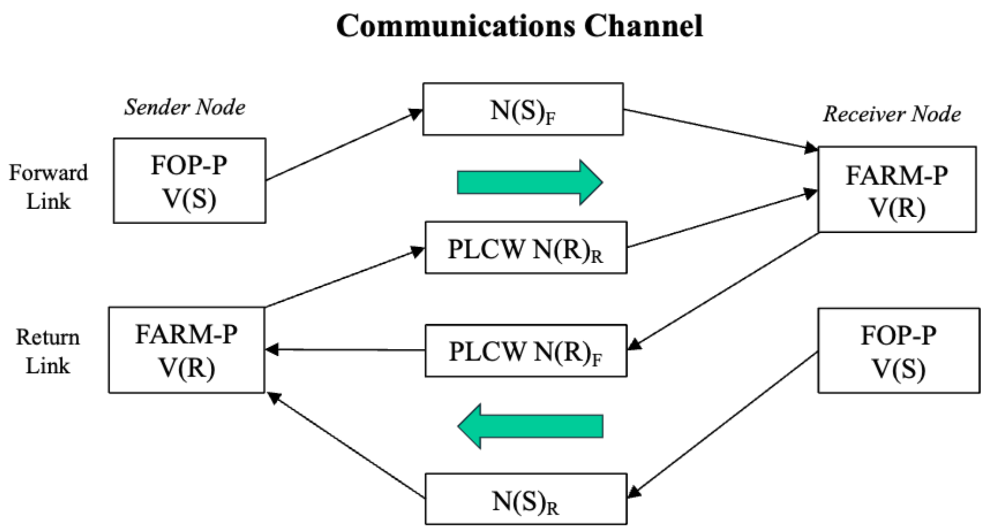

Figure 2-2: COP-P Process

NOTES

1 The User data frames (U-frames) in the forward link contain the frame sequence number N(S)F and in the return link – N(S)R.

2 The PLCW Supervisory protocol frames (P-frames) in the forward link report the return link progress and contain the frame sequence number N(R)R, while in the return link, they report the forward link progress and contain the frame sequence number N(R)F.

The FOP-P and FARM-P procedures control both Expedited and Sequence Controlled qualities of service, with distinct responsibilities:

– FOP-P actively drives the Expedited and Sequence Controlled services.

– FARM-P is data-driven: it reacts to what it receives from the FOP-P and provides appropriate feedback via the PLCW.

The FOP-P 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 management information base (MIB) parameter Synch_Timeout (see Annex F for all MIB parameters), the sender node's FOP-P notifies the local controller that it is not synchronized with the Receiver Node's FARM-P. It is the responsibility of the local controller to decide how synchronization will be re-established if the MIB parameter Resync_Local equals *false*.

Similarly, if the MIB parameter Resync_Remote equals *false*, the local transceiver will also not respond to remote resync directives via the Set V(R) directive per Table 6-2 event RE2. Otherwise, the sender node's FOP-P forces a resynchronization by executing the SET V(R) activity. FOP-P provides frame-level accounting by supplying V(S) and VE(S) values to the I/O Sublayer for every Sequence Controlled and Expedited frame that it numbers.

The FARM-P uses the services of the Coding & Synchronization (C&S) Sublayer to verify that the frame was received error-free. The FARM-P depends on the Frame Sublayer to verify that the frame is a valid Version-3 Transfer Frame and that it should be accepted for processing by Data Services. The applicability of the FOP-P and FARM-P for ersion-4 Transfer Frames is specified in reference [7].

2.3.2 SERVICE QUALITIES

2.3.2.1 General

The COP-P procedure provides Sequence Controlled and Expedited service that determines how reliably SDUs are delivered from the sender to the receiver. The procedure consists of a FOP-P (sending side) and a FARM-P (receiving side).

Each service provides data transfer with an associated service quality. Packetized data units that are larger than the maximum frame size in asynchronous frames can be transferred only by using the segmentation process.

2.3.2.2 Sequence Controlled Service

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

A sending user supplies SDUs for transfer with the sequence controlled quality of service that are inserted into Transfer Frames and transmitted on a physical channel in the order in which they are presented. SDUs are passed to the receiving user via the identified port. The retransmission mechanism ensures with a high probability of success that no SDU is lost, duplicated, or delivered out of sequence.

2.3.2.3 Expedited Service

The Expedited service is nominally used with upper-layer protocols that provide their own retransmission features or in exceptional operational circumstances, such as during spacecraft recovery operations. Expedited SDUs supplied by the sending user are transmitted without ARQ:

– At the **sending** end, Expedited SDUs are transmitted on specified physical channels independently of the Sequence Controlled SDUs waiting to be transmitted on the same physical channel.

– At the **receiving** end, the SDUs are passed to the receiving user via the identified port.

Expedited SDUs may be sent once or multiple times, but they are not sent again as a result of a request for retransmission. If such a request occurs, it is performed outside the purview of the protocol.

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

NOTE – Expedited service supports delivery of portions of user-defined data units that are greater than the maximum frame size allowed for the link.

3 SUPERVISORY PROTOCOL DATA UNITS

3.1 GENERAL

SPDUs are transmitted during persistent activities (section 4) with some exceptions, such as status reporting. When Persistence is set, it blocks the transmission of user data within the DSS, allowing only SPDU traffic. SPDUs can be fixed or variable in length:

– Fixed-length SPDUs provide status (PLCW) to the COP-P reporting mechanism (FARM, Section 6.3).

– Variable-length SPDUs contain directives/reports to establish, modify, and terminate communication sessions involving data, time, ranging.

3.1.1 SPDUs (P-frames) transmitted over the Proximity-1 data link shall only be carried over Version-3 or Version-4 frames.

NOTE – Since SPDUs may be of variable length, they require a variable length transfer frame.

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

a) SPDU Header (2 bits) consisting of:

  1) SPDU Format ID (1 bit);

  2) SPDU Type Identifier (1 bit);

b) SPDU Data field (14 or 30 bits) consisting of either a 16- or 32-bit fixed-length PLCW.

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

a) SPDU Header (1 octet) consisting of:

  1) SPDU Format ID (1 bit);

  2) SPDU Type Identifier (3 bits);

  3) Data Field Length (4 bits), representing the actual number of octets in the data field of the SPDU.

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

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

3.1.4 Implementations shall include a Directive Decoder function for processing supervisory protocol directives defined in this section and in Annexes B–E.

NOTE – The Directive Decoder is a function that decodes supervisory protocol directives received from the local link controller or the remote vehicle controller. It processes the received directives, setting the configuration (state and parameters) of PL and DLL.

3.2 FIXED-LENGTH SPDU

3.2.1 GENERAL

A '1' in the SPDU Format ID field shall identify a fixed-length SPDU. This format provides for only two SPDU types (see table 3-1), differentiated by the Type ID field:

a) '0' for (16-bit PLCW);

b) '1' for (32-bit PLCW).

Table 3-1: Fixed-Length Supervisory Protocol Data Unit

Fixed-Length SPDU (16 or 32 bits)	**SPDU Header (2 bits)**		**SPDU Data (14 or 30 bits)**
	SPDU Format ID (Bit 0)	SPDU Type ID (Bit 1)	Contains 1 protocol object, i.e., directive, report, or PLCW (Bits 2 through 15 or 31)
16-bit	'1'	'0'	14-bit Fixed Length PLCW Data (see 3.2.2.1)
32-bit	'1'	'1'	30-bit Fixed Length PLCW Data

3.2.2 FIXED-LENGTH SPDU DIRECTIVES

3.2.2.1 16-Bit Protocol Link Control Word

3.2.2.1.1 General

3.2.2.1.1.1 A '1' in the SPDU Format ID field and a '0' in the SPDU Type ID field shall identify the SPDU as a 16-bit PLCW. It's use is limited to the Proximity-1 Space Data Link Protocol, reference [6].

NOTE – The 16-bit PLCW is used for proximity operations for low data rate applications.

3.2.2.1.1.2 The PLCW shall consist of seven fields positioned contiguously in the following sequence, described from the most significant bit (MSB), Bit 0, to the least significant bit (LSB), Bit 15 (see figure 3-1):

a) SPDU Format ID (1 bit);

b) SPDU Type Identifier (1 bit);

c) Retransmit Flag (1 bit);

d) Physical Channel ID (PCID) (1 bit);

e) Reserved Spare Retransmit Flag (1 bit);

f) Expedited Frame Counter (3 bits);

g) Report Value — Frame Sequence Number (FSN) (8 bits).

Bit 0 … Bit 15

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

Figure 3-1: 16-Bit Proximity Link Control Word Fields

NOTE – The PLCW shall be transmitted using the Expedited QoS.

3.2.2.1.2 SPDU Format ID

3.2.2.1.2.1 Bit 0 of the PLCW shall contain the SPDU Format ID.

3.2.2.1.2.2 Fixed length SPDUs are identifed by a '1' in the in the SPDU Format ID field.

3.2.2.1.3 SPDU Type ID

3.2.2.1.3.1 Bit 1 of the PLCW shall contain the SPDU Type ID.

3.2.2.1.3.2 16-bit PLCWs are identified by a '0' in the SPDU Type ID field.

3.2.2.1.4 PLCW Retransmit Flag

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

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

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

3.2.2.1.5 Physical Channel Identification

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

3.2.2.1.5.2 The 1-bit PCID field shall contain the PCID of the physical channel with which this report is associated (see 5.2.2.11, 'RECEIVING_PCID_BUFFER').

3.2.2.1.6 Reserved Spare

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

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

3.2.2.1.7 Expedited Frame Counter

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

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

3.2.2.1.8 Report Value (FSN)

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

3.2.2.1.8.2 The Report Value field shall contain the value of V(R) (see 6.3.2).

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

3.2.2.2 32-Bit Protocol Link Control Word

3.2.2.2.1 A '1' in the SPDU Format ID field and a '1' in the SPDU Type Identifier field shall identify the SPDU as a 32-bit PLCW.

NOTE – The 32-bit PLCW is envisioned for proximity operations, which will have higher data rate applications than the 16-bit PLCW permit and enables the reporting of virtual channel ID (VCID). For USLP applications, the PCID field is ignored, i.e., set to 0. For Proximity-1 applications, the VCID field is ignored, i.e., set to all zeros.

3.2.2.2.2 The 32-bit PLCW including the SPDU header shall consist of seven fields positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 15 (see figure 3-2):

a) SPDU Format ID (1 bit);

b) SPDU Type ID (1 bit);

c) Reserved Spares (3 bits);

d) VCID Retransmit Flag (6 bits);

e) Retransmit Flag (1 bit);

f) PCID (1 bit);

g) Expedited Frame Counter (3 bits);

h) Report Value (FSN) (16 bits).

Bit 0 ... Bit 31

SPDU Header		SPDU Data Field					
SPDU Format ID 1 bit	SPDU Type ID 1 bit	Spares 3 bits	VCID 6 bits	Retransmit Flag 1 bit	PCID 1 bit	Expedited Frame Counter 3 bits	Report Value (FSN) 16 bits

Figure 3-2: 32-Bit Proximity Link Control Word Fields

NOTE – This PLCW shall be transmitted using the Expedited QoS.

3.2.2.2.3 SPDU Format ID

3.2.2.2.3.1 Bit 0 of the PLCW shall contain the SPDU Format ID.

3.2.2.2.3.2 Fixed length SPDUs are identifed by a ‘1’ in the in the SPDU Format ID field

3.2.2.2.4 SPDU Type ID

3.2.2.2.4.1 Bit 1 of the PLCW shall contain the SPDU Type ID.

3.2.2.2.4.2 32-bit PLCWs are identified by a ‘1’ in the SPDU Type ID field.

3.2.2.2.5 Reserved Spares

3.2.2.2.5.1 Bits 2-4 of the PLCW shall contain a Reserved Spare bit.

3.2.2.2.5.2 The Reserved Spares bit field shall be set to ‘000’.

3.2.2.2.6 VCID

3.2.2.2.6.1 Bits 5-10 of the PLCW shall contain the VCID.

NOTES

1 Each Virtual Channel in use has its own PLCW reporting activated.

2 This field does not apply to Proximity-1 applications.

3.2.2.2.7 PLCW Retransmit Flag

3.2.2.2.7.1 Bit 11 of the PLCW shall contain the PLCW Retransmit Flag.

3.2.2.2.7.2 A setting of ‘0’ in the PLCW Retransmit Flag shall indicate that there are no outstanding frame rejections in the sequence received so far, so retransmissions are not required.

3.2.2.2.7.3 A setting of ‘1’ in the PLCW Retransmit Flag shall indicate that a received frame left an FSN gap and a retransmission of the expected frame is required.

3.2.2.2.8 Physical Channel Identification

3.2.2.2.8.1 Bit 12 of the PLCW shall contain the PCID field.

3.2.2.2.8.2 The 1-bit PCID field shall contain the PCID of the physical channel with which this report is associated (see 5.2.2.11, ‘RECEIVING_PCID_BUFFER’).

NOTES

1 Each PCID in use has its own PLCW reporting activated.

2 This field does not apply to Proximity-1 applications.

3.2.2.2.9 Expedited Frame Counter

3.2.2.2.9.1 Bits 13–15 of the PLCW shall contain the EXPEDITED_FRAME_COUNTER.

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

3.2.2.2.10 Report Value (FSN)

3.2.2.2.10.1 Bits 16–31 of the PLCW shall contain the Report Value.

3.2.2.2.10.2 The Report Value field shall contain the value of V(R) (see 6.3.2).

3.2.2.2.10.3 Separate Report Values shall be reported for each VCID.

3.3 VARIABLE-LENGTH SPDU

3.3.1 GENERAL

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

NOTE – This form of SPDU uses bits 1 through 3 of the SPDU header to identify one of eight possible SPDU types, summarized in table 3-2.

Table 3-2: Variable-Length Supervisory Protocol Data Unit

Variable-Length SPDU	SPDU Header (1 octet, fixed)			SPDU Data Field (0–15 octets)
	Format ID (Bit 0)	SPDU Type Identifier (Bits 1,2,3)	Length of SPDU Data Field (Bits 4,5,6,7)	(Contains one or more protocol objects, i.e., directives, reports)
Type 1	‘0’	‘000’	Length in Octets	Fixed-Length 16-bit Directives/Reports First Generation
Type 2	‘0’	‘001’	"	Time Distribution PDU
Type 3	‘0’	‘010’	"	Status Reports
Type 4	‘0’	‘011’	"	Variable-Length Directives/Reports First Generation
Type 5	‘0’	‘100’	"	Variable-Length Directives/Reports Second Generation
Type 6	‘0’	‘101’	"	Reserved for CCSDS Use
Type 7	‘0’	‘110’	"	Reserved for CCSDS Use
Type 8	‘0’	‘111’	"	Reserved for CCSDS Use
NOTE – Directives and Reports may be concatenated within the SPDU Data Field.				

3.3.2 TYPE 1 SPDU—FIXED-LENGTH 16-BIT DIRECTIVES/REPORTS FIRST GENERATION

An SPDU Type Identifier equal to ‘000’ shall identify a Type 1 SPDU with a data field of between 0 to 15 octets containing zero, one or multiple concatenated 16-bit directives/reports.

NOTES

1 Type 1 SPDU directives/reports are defined in Annex B.

2 Type 1 SPDU format has been used for Ultra High Frequency (UHF) Mars operations, but is not limited to them.

3.3.3 TYPE 2 SPDU—TIME DISTRIBUTION DIRECTIVES

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

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

NOTE – Type 2 SPDU directives are defined in Annex C.

3.3.4 TYPE 3 SPDU—STATUS REPORT DIRECTIVES

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 left up to the implementation.

2 The protocol distinguishes when a status report is required (NEED_STATUS_REPORT) or requested by directive (see Type 1 SPDU Report Request Directive, B6).

3.3.5 TYPE 4 SPDU—VARIABLE LENGTH DIRECTIVES/REPORTS FIRST GENERATION

An SPDU Type Identifier equal to '011' shall identify a Type 4 SPDU with a data field of between 0 to 15 octets containing first generation variable length directives/reports whose lengths are defined in the MIB.

NOTE – Type 4 SPDU directives/reports are defined in ANNEX D.

3.3.6 TYPE 5 SPDU—VARIABLE LENGTH DIRECTIVES/REPORTS SECOND GENERATION

An SPDU Type Identifier equal to '100' shall identify a Type 5 SPDU with a data field of between 0 to 15 octets containing second generation variable length directives/reports whose lengths are defined in the MIB.

NOTES

1 Type 5 SPDU directives/reports are defined in ANNEX E.

2 Type 5 SPDU format is envisioned for S-band Lunar operations but is not limited to them.

3.3.7 TYPE 6 THROUGH 8 SPDUS—RESERVED FOR CCSDS USE

3.3.7.1 An SPDU Type Identifier equal to ‘101’, ‘110’, and ‘111’ shall identify Types 6, 7, and 8 SPDUs, respectively, with a data field containing from 0 to 15 octets.

3.3.7.2 Type 6 through Type 8 SPDUs are reserved for CCSDS use.

4 PERSISTENCE

4.1 OVERVIEW

A persistent activity is a process for ensuring reliable communication between a caller and a responder using the Expedited QoS while transmitting from the medium access control (MAC) queue (reference [6]). Because of the potential for frame loss due to corruption across the space link, these control activities require a persistence process to ensure that supervisory protocol directives are received and acted upon correctly.

Persistence activities can be linked in series to accomplish a task, but persistence applies to only one activity at a time. Each persistent activity is named and consists of one or more actions (e.g., issuing selective directives), followed by a WAITING_PERIOD during which a specific RESPONSE is expected. The protocol defines three persistent activities:

– hailing (i.e., session establishment; see 5.2.3 and tables 5-7 and 5-10);

– communication change (see 5.2.3 and tables 5-8 and 5-11);

– resynchronization (see 6.2.3.2 and 6.2.3.3).

4.2 PERSISTENCE ACTIVITY PARAMETERS

The following parameters are defined per activity in the MIB (see Annex F), with values varying by activity:

– Activity: the name of the persistent activity;

– waiting_period: the amount of time specified for the response to be received before the process declares that the activity is to be either repeated or aborted;

– Response: the acknowledgement by the responder that the persistent activity has been accepted;

– Notification: the message provided to the local vehicle controller, such as spacecraft Command & Data Handing (C&DH) by the caller or responder upon success or failure of the persistent activity;

– Lifetime: the period during which the persistent activity will be repeated until the expected response is detected.

NOTE – LIFETIME can be defined locally in terms of a duration or maximum number of repetitions before the activity is aborted.

4.3 PERSISTENT ACTIVITY PROCESS

4.3.1 Upon initiation of a persistent activity, the PERSISTENCE signal shall be set to *true*.

4.3.2 While PERSISTENCE is *true*, the Frame Sublayer shall select frames only from the MAC queue for output (see reference [6]).

4.3.3 The success or failure of the activity shall be determined by the detection of the expected RESPONSE within the activity's LIFETIME.

4.3.4 If the RESPONSE is not detected within the activity's LIFETIME, the activity shall be deemed failed and aborted.

4.3.5 NOTIFICATION of the activity's success or failure shall be communicated back to the vehicle controller, at which time the PERSISTENCE signal shall be set to *false*.

5 DATA SERVICES OPERATIONS

5.1 LINK OPERATIONS

This section describes how full- and half-duplex link operations (establishment, communications change, and termination) are carried out using local and remote directives. Informational ANNEX K describes how these operations can also be achieved though demand, query/response or both, using Type 5 SPDUs (see ANNEX E).

5.1.1 LINK ESTABLISHMENT AND CONTROL DIRECTIVE FUNCTIONS

Proximity-1 enables the establishment of the link via hailing and communication changes, using the generic persistent activities defined in section 4. These activities are achieved by setting the directive function field within the LINK ESTABLISHMENT & CONTROL (LEC) directive to demand or query/response (see ANNEX E).

5.1.1.1 Demand Function

Using the demand function to move to an initial working channel immediately after establishing a link on a hailing channel shall be *mandatory* for all link establishment and comm change directives.

NOTES

1 The caller expects the responder to accept the working channel parameters in the hailing directives ‘as is’ (i.e., no negotiation).

2 Since node access to hailing channels is critical, occupying hailing channels and exchanging excessive query responses must be avoided so that other nodes are not locked out.

5.1.1.2 Query/Response Function

Using the query/response function shall be *optional* for both link establishment and comm change directives. It shall be used exclusively as a mechanism to inform the caller/responder nodes of desired state changes, meaning no state changes in any Proximity-1 full-duplex or half-duplex state tables or diagrams are allowed until the caller receives an **ACK** response for the desired link direction (forward and/or return).

If the response to a query from the initiator is a(n):

– **ACK**: the responder accepts all parameters in the LEC directive with directive function = ACK per link direction (FWD and/or RTN). Next, in order to assert those changes, the caller verifies to the responder that the **ACK** was received and acted upon by transmitting an LEC directive (with direction function = demand) for the applicable link directions to the responder.

– **NACK**: the responder proposes a new modified set of parameters within the LEC directive based on what it can support. The caller might then:

  - Accept with an **ACK**; (see above)

  - Reject this proposal with a **NACK** (directive function = NACK) LEC directive and send a counter-proposal by 1) changing one or more of the parameters in the LEC directive or 2) echoing back the LEC directive with no other changes.

This negotiation continues until the MIB parameter NACKs_Allowed is exceeded. This specification does not define how such a negotiation proceeds beyond what is stated above.

NOTES

1 The user may prohibit the query/response option on the Proximity-1 link by setting the NACKs_Allowed parameter to 0.

2 Simplex-Transmit/Simplex-Receive does not use hailing to establish the link.

5.1.2 HAILING DIRECTIVES

This section establishes the constraints and requirements imposed on the hailing directives and describes how they configure the remote transceiver over the Proximity-1 link.

5.1.2.1 Requirements

5.1.2.1.1 All hailing directives shall be contained in a single transfer frame, called the hail frame.

NOTE – This requirement ensures that the hailing directives are executed as a complete set.

5.1.2.1.2 The hailing directives for SPDU Type 1 (Annex B) shall be transmitted in the following order:

1) Transmit SET PL EXTENSIONS (TX) (if present);
2) SET_TRANSMITTER_PARAMETERS;
3) SET PL EXTENSIONS (RX) (if present);
4) SET_RECEIVER_PARAMETERS.

5.1.2.1.3 The hailing directives for SPDU Types 4 (ANNEX D) and 5 (ANNEX E) shall terminate with the LEC directive.

NOTE – These two requirements ensure that the transceiver does not execute a directive before the entire hail frame is parsed.

5.1.2.2 Hailing Directives

5.1.2.2.1 Overview

Remote directives are sent over the link from the local to the remote transceiver. Several directives within the same SPDU type may be concatenated for hailing and associated PL communication changes. These directives were designed over multiple generations of radios, so their inherent capabilities vary.

- SPDU Type 1 (Annex B) includes:
  - SET_TRANSMITTER_PARAMETERS;
  - SET_RECEIVER_PARAMETERS;
  - SET_PL_EXTENSIONS.
- SPDU Type 4 (ANNEX D) includes the LEC directive, which is a 56-bit long.
- SPDU Type 5 (Annex E) includes a more advanced LEC directive, which is 96 bits long.

The following subsections below briefly describe each of these directives.

5.1.2.2.2 SET TRANSMITTER PARAMETERS

5.1.2.2.2.1 SET TRANSMITTER PARAMETERS shall be used to set the transmission parameters that control the data rate, encoding, modulation, and frequency in the transceiver receiving the directive (see Annex B).

5.1.2.2.2.2 Upon receipt, the transceiver shall use the local directive SET MODE *active* to put the receiver's MODE parameter into the *active* state.

NOTE – This directive is formulated using the values contained in the sender's COMMUNICATION VALUE BUFFER.

5.1.2.2.3 SET RECEIVER PARAMETERS

5.1.2.2.3.1 SET RECEIVER PARAMETERS shall be used to set the receiver parameters that control the data rate, decoding, modulation, and frequency in the transceiver receiving the directive (see Annex B).

5.1.2.2.3.2 Upon receipt, the transceiver shall use the local directive SET MODE *active* to put the receiver's MODE parameter into the *active* state.

NOTE – This directive is formulated using the values contained in the sender's COMMUNICATION VALUE BUFFER.

5.1.2.2.4 SET PL EXTENSIONS

SET PL EXTENSIONS shall be used to enable or disable additional PL parameters for the receive and send sides of a radio. This directive is provided for compatibility between transceivers with PL and C&S Sublayer extensions (see Annex B).

5.1.2.2.5 LINK ESTABLISHMENT & CONTROL

The LEC directive configured for transmit or receive provides the option to establish the link and move onto the comm change. See ANNEX D for the 56-bit option or ANNEX E for the 96-bit option.

NOTE – Informational ANNEX K provides use cases for the 96-bit LEC directive used in establishing the link, carrying out comm change, transferring status reports and terminating the link.

5.1.2.2.6 SET CONTROL PARAMETERS

SET CONTROL PARAMETERS provides the capability of changing zero or more session control parameters at a time (see Annex B for a complete definition). It shall be used to transmit operational control information during a session. It is used in half-duplex link establishment for Type 1 SPDUs. It includes the following fields:

a) **Token Field**: When this field is non-zero, it shall notify the recipient that the sender is relinquishing the half-duplex ‘Send Token’ and switching to receive.

b) **RNMD Field**: When this field is non-zero, it shall notify the recipient that the sending spacecraft has no more data to send, and that the session may be terminated when the recipient also has no more data to send.

c) **Duplex Field**: When this field is non-zero, it shall notify the recipient to change communication directionality (*full*, *half*, *simplex-transmit*, *simplex-receive*).

d) **Time Sample Field**: When this field is non-zero, it shall notify the recipient to capture the time, sequence number, direction, and QoS Indicator (for Version-3 frames)/Bypass Flag (for Version-4 frames) for the next *n* frames received and transmitted (where ‘*n*’ is the value, i.e., number of frames contained within the Time Sample Field).

5.1.3 LINK TERMINATION

For the Type 1 SPDU, the SET CONTROL PARAMETERS directive is used to carry out link termination. For Type 4 and Type 5 SPDUs, link termination uses a reporting/requesting directive function within the LEC directive rather than a demand or query directive function used for link establishment and communication change activities. Specifically, data-driven link termination supported in the protocol is carried out by using the LNMD local directive, setting the RNMD parameter, and sending the LEC directive. RNMD is set to *true* when either radio runs out of user data to send. Link termination may commence only when both radios have no more data to send locally (LNMD) and have received the RNMD via the LEC directive. This behavior is specified in the link termination state tables and diagrams. In addition, there may be other optional factors such as ranging active on the link which may prohibit link termination. See the informational ANNEX K for link termination use cases.

5.2 STATE TABLES

This section presents the complete set of session states organized by DUPLEX configuration. The first table (Table 5-1) defines states that apply regardless of the DUPLEX variable setting, while the subsequent tables provide state definitions specific to each duplex mode: Full duplex (Table 5-2), Half duplex (Table 5-3), and Simplex-Transmit or Simplex-Receive operations (Table 5-4).

Table 5-1: Session 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 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 5-5 are initialized. The Local SET INITIALIZE MODE directive forces entry into this state.
S2	Waiting for Hail	*on*	*off*	*connecting-L*	*off*	0	Receiving operations are enabled. FARM-P operations are enabled but only for processing received supervisory directives; that is, 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	The caller attempts to maintain the current 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 5-2: 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	The Hail activity starts with the radiation of the carrier signal.
S32	Send Hail Acquisition	*on*	*async*	*connecting-T*	*on*	2	The idle pattern is radiated to achieve symbol lock with the hailed remote unit.
S33	Send Hail Directives	*on*	*async*	*connecting-T*	*on*	3	If present, the Hail Directives SET_TRANSMITTER_PARAMETERS, SET_PL EXTENSIONS (TX and RX), SET_RECEIVER_PARAMETERS or LINK ESTABLISHMENT & CONTROL (TX and RX) are radiated in one 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	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	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	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	The receiver is *on* and processing all received data while the transmission process is trying to achieve bit lock with a potential partnered transceiver—the caller transceiver.
S40	Data services	*on*	*sync*	*active*	*on*	0	Data transfer services controlled by the COP-P protocol are conducted with a partnered transceiver.
S48	COMM_CHANGE	*on*	*sync*	*active*	*on*	6	This state is involved with the protocol actions required to perform a data rate or frequency change with a partnered transceiver. This state contains numerous sub-states whose transitions are described in table 5-7.
S45	Terminating Tail	*on*	*sync*	*active*	*on*	4	The receiver is *on* and processing all received data while the transmission process is terminating (see table 5-8.).

Table 5-3: 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	The Hail activity starts with the radiation of the carrier signal.
S12	Send Hail Acquisition	*off*	*async*	*connecting-T*	*on*	2	The idle pattern is radiated to achieve symbol lock with the hailed remote unit.
S13	Send Hail Directives	*off*	*async*	*connecting-T*	*on*	3	If present, the HAIL directives SET_TRANSMITTER_PARAMETERS, , SET_PL EXTENSIONS (TX and RX), SET_RECEIVER_PARAMETERS or LINK ESTABLISHMENT & CONTROL (TX and RX) are radiated in one 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	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	The transceiver awaits a response from the called remote unit.
S51	Radiate Carrier Only	*off*	*sync*	*active*	*on*	1	The transmission process is started with carrier radiation only.
S52	Radiate Acquisition Idle	*off*	*sync*	*active*	*on*	2	The transmission process is trying to achieve symbol lock with a potential partnered transceiver.
S50	Data Services (send)	*off*	*sync*	*active*	*on*	0	The user data transmission process functions.
S54	Terminate Reply	*off*	*sync*	*active*	*on*	3	The transmission process is sending the termination directive.
S55	Tail before Quit	*off*	*sync*	*active*	*on*	7	The transmission process is sending the terminating tail sequence bits.
S56	Token Pass or COMM_CHANGE	*off*	*sync*	*active*	*on*	6	The transmission process is sending a token or the COMM_CHANGE directive.

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	Description
S58	Tail before Switch	*off*	*sync*	*active*	*on*	4	The transmission process is sending the terminating tail sequence bits.
S60	Data Services (receive)	*on*	*off*	*active*	*off*	0	The receiver is processing received data.
S61	Awaiting First Frame	*on*	*off*	*active*	*off*	1	The receiver is *on*, awaiting receipt of the first frame for processing.
S62	Wait for Carrier	*on*	*off*	*active*	*off*	2	The receiver is *on*, waiting for the CARRIER_ACQUIRED PL signal to transition to *true*.

Table 5-4: States When DUPLEX = Simplex (Receive or Transmit)

State Name	State Description	Receive State Desc.	Send State Desc.	MODE	T	SS	Description
S71	Simplex Transmit	*off*	*on*	*active*	*on*	0	Only the transmission operations are enabled while receiving operations are inhibited.
S72	Simplex Receive	*on*	*off*	*active*	*off*	0	Only the receiving operations are enabled while transmission operations are inhibited.

5.2.1 STATE CONTROL VARIABLES

The State Tables define the following state control variables: MODE, DUPLEX, TRANSMIT, and SUB-STATE.

5.2.1.1 MODE

The MODE parameter provides control information for DLL operations Layer and PL control operations. The following states of MODE, set via the local SET MODE directive, shall be allowed:

– Inactive: in this state, the transceiver's transmitter and receiver are both turned off.

– Connecting-T: in the PL, the connecting-transmit state in full duplex dictates that the transmitter and receiver (which operates sequentially in half duplex) are powered on and enabled to process received frames, while the transmitter is enabled for asynchronous channel operations. In half duplex, only the transmitter is powered on. The Hail activity is conducted while MODE is connecting-T.

– Connecting-L: in the connecting-listen state, the receiver is powered on and enabled to process received frames while the transmitter is turned off.

– Active: in this state, when DUPLEX is 'full', the receiver is powered on and enabled to process received frames; the transmitter is enabled for synchronous channel operations responding to the control of the TRANSMIT parameter.

NOTE – The local SET INITIALIZE MODE directive puts MODE into the inactive state and initializes the COP-P variables described in 5.3.3.1.1.2, SET INITIALIZE MODE.

5.2.1.2 DUPLEX

The DUPLEX parameter identifies the characteristics of the physical channel communications so that the protocol can perform within the transceiver's operational constraints. The following values of DUPLEX, set via the local SET DUPLEX directive, shall be allowed:

– full: Both the receiver and transmitter are enabled simultaneously.

– half: Operation in a communications session switches between receiving and transmitting, with only the receiver or the transmitter enabled at one time.

– simplex transmit: The transmitter is enabled but not the receiver.

– simplex receive: The receiver is enabled but not the transmitter.

5.2.1.3 TRANSMIT

The TRANSMIT parameter is used to control PL operations when MODE is not equal to *inactive*. The following two states for TRANSMIT shall be allowed:

- off: PL is signaled to transition the transmitter to off.
- on: PL is signaled to transition the transmitter to on.

5.2.1.4 SUB-STATE

The SUB-STATE (SS) variable shall be used:

- to keep track of sequencing through protocol states in response to events and uniquely identify these states;
- to determine which data to load into the output first in, first out (FIFO) queue (see table 5-13).

5.2.2 OPERATIONAL CONTROL VARIABLES

5.2.2.1 X (Session Termination)

X (Session Termination) shall be used to track the sub-states of the termination process for full and half duplex sessions. In half duplex, it is shared between receive and transmit functionality. The values and definitions of the states of X are as follows:

- X=**0**: Bi-directional data passing in progress. Neither transceiver has declared that it is out of data to send. Used in full and half duplex.
- X=**1**: Local transceiver has been informed that there is no more data to send locally: Local_No_More_Data (LNMD). Used in half duplex only.
- X=**2**: Local transceiver has received the LNMD local directive and is sending the Remote_No_More_Data (RNMD) directive to the remote transceiver. Used in full and half duplex.
- X=**3**: Local transceiver has data to send and has received an RNMD directive from the remote transceiver. Used in half duplex only.
- X=**4**: Local transceiver has received the RNMD directive. When there is no more data to send locally, an RNMD directive is sent to the remote transceiver. Used in full and half duplex.
- X=**5**: Both local and remote transceivers have no more data to send. Once the RNMD directive is sent, the session is terminated, and X is reset to 0. Used in full and half duplex.

5.2.2.2 Y (COMM_CHANGE)

Y (COMM_CHANGE) shall be used to track the sub-states during the commanding of a PL communications change. In half duplex, it is set on the transmit side and reset on the receive side. The values and the states of Y are as follows:

- Y=**0**: No Comm_Change in progress.
- Y=**1**: Local directive received to initiate the Comm_Change.
- Y=**2**: Comm_Change directive being sent across the link.
- Y=**3**: Comm_Change directive sent, waiting for the Comm_Change acknowledgement.
- Y=**4**: Received the Remote Comm_Change Directive (RCCD). Full duplex only.
- Y=**5**: Acting upon the received RCCD. Full duplex only.

5.2.2.3 Z (SYMBOL_INLOCK_STATUS)

Z (SYMBOL_INLOCK_STATUS) shall be used during a PL communications change to track nondeterministic events within State 48 (COMM_CHANGE in Data Services), as follows:

- Z=**0**: SYMBOL_INLOCK_STATUS has **not** transitioned to false;
- Z=**1**: SYMBOL_INLOCK_STATUS has transitioned to false.

5.2.2.4 MODULATION

MODULATION is an interface variable with the PL which shall control the modulation of the transmitted carrier. When MODULATION=*on*, the coded symbols are modulated onto the radiated carrier; when MODULATION=*off*, the radiated output is not modulated (i.e., carrier only).

5.2.2.5 Persistence

Persistence is specified in section 4.

5.2.2.6 RANGING

RANGING is a PL interface variable which shall control whether ranging is modulated onto the transmitted carrier. When RANGING=*on,* the Ranging Code is modulated on to the radiated carrier; when RANGING=*off,* the Ranging Code is not modulated on to the radiated carrier.

The local node sets RANGING to *on* or *off* by using the LOCAL_SET_RANGING directive defined in 5.3.3.1.8.

The responder sets RANGING to *on* or *off* during data services operations based on the value of the Mode Type PN Ranging field in the PN_RANGING directive defined in (ANNEX E). Depending on whether ranging is active on the link, this may occur in the following states:

- S40 (Data Services) for full duplex;

– S50/S60 (Data Services) for Half-Duplex;

– S71/S72 (pseudo one way ranging) for Simplex Transmit/Receive.

The value of RANGING must be evaluated before terminating the link (see Link Termination State Table 5-8 for full-duplex and Table 5-11 for half-duplex).

5.2.2.7 NEED_PLCW and NEED_STATUS_REPORT

5.2.2.7.1 NEED_PLCW and NEED_STATUS_REPORT shall be used in the data selection for output process to determine if it should send a PLCW or status report. Where applicable, these variables shall be set to *true*:

– at initialization;

– by events in the state transition processes;

– by PLCW Timer; and

– by actions within the COP-P.

5.2.2.7.2 NEED_PLCW shall be set to *false* when a PLCW is selected for output. NEED_STATUS_REPORT shall be set to *false* when a status report is selected for output.

5.2.2.8 REMOTE_SCID_BUFFER

REMOTE_SCID_BUFFER holds the value of the spacecraft ID (SCID) that shall be used in testing all frames whose Source-or-Destination ID is set to *destination*.

5.2.2.9 COMMUNICATION_VALUE_BUFFER

COMMUNICATION_VALUE_BUFFER shall hold the communication values for the HAIL and COMM_CHANGE directives and operations.

5.2.2.10 RECEIVING_SCID_BUFFER

RECEIVING_SCID_BUFFER shall be used in frame validation to compare a received spacecraft ID value with the value stored in this buffer. This buffer may be loaded either by a directive from the local vehicle controller or with the spacecraft ID contained in the first valid received frame.

5.2.2.11 RECEIVING_PCID_BUFFER

RECEIVING_PCID_BUFFER shall be used in the frame reception process. This buffer shall be loaded with the PCID contained in the first valid received frame.

5.2.3 MIB PARAMETERS

5.2.3.1 Local_Spacecraft_ID

Local_Spacecraft_ID shall contain the value of the spacecraft ID for this local spacecraft.

5.2.3.2 Test_Source

The Test_Source parameter shall determine whether to validate the SCID field in received frames whose Source-or-Destination IDs are set to *source*:

- Test_Source=false: no test shall be performed;
- Test_Source=true: if the RECEIVING_SCID_BUFFER is
  - non-zero (i.e., it contains a valid SCID), a test shall be performed;
  - zero, the value of the SCID field in the header of the first received frame whose Source-or-Destination ID is *source* shall be loaded into RECEIVING_SCID_BUFFER and used for validation for the remainder of the session (see also related subsection 5.7.2.).

5.2.3.3 Carrier_Only_Duration

Carrier_Only_Duration represents the duration for radiating an unmodulated carrier at the beginning of a transmission.

5.2.3.4 Acquisition_Idle_Duration

Acquisition_Idle_Duration represents the duration for radiating the idle sequence pattern after the carrier-only period, enabling the receiving transceiver to achieve symbol synchronization and decoder lock.

5.2.3.5 Tail_Idle_Duration

Tail_Idle_Duration represents the duration for radiating the idle sequence pattern at the end of a transmission, enabling the receiving transceiver to process the last transmitted frame (i.e., push the data through the decoders).

NOTE – The time value for the Tail_Idle_Duration parameter can be calculated from the number of idle bits that need to be sent.

5.2.3.6 Carrier_Loss_Timer_Duration

Carrier_Loss_Timer_Duration shall contain the value loaded into the CARRIER_LOSS_TIMER based on the conditions defined in 5.3.1.3 (CARRIER_LOSS_TIMER and Associated Events).

5.2.3.7 Comm_Change_Waiting_Period

Comm_Change_Waiting_Period represents the time that the caller shall wait for the Comm_Change_Response to the COMM_CHANGE directive.

5.2.3.8 Comm_Change_Response

Comm_Change_Response shall be used by the responder to acknowledge that the persistent activity has been accepted. For the full-duplex Comm_Change_Response see table 5-7, Events E17 and E20. For the Half Duplex Comm_Change_Response, see table 5-10, Event E68.

5.2.3.9 Comm_Change_Notification

Comm_Change_Notification shall be provided by the caller and/or responder to the local vehicle controller (e.g., spacecraft C&DH) upon success or failure of the COMM_CHANGE activity (see Annex G, Notifications to Vehicle Controller).

5.2.3.10 Comm_Change_Lifetime

5.2.3.10.1 Comm_Change_Lifetime shall represent the period during which the COMM_CHANGE activity shall be repeated until the expected Comm_Change_Response is detected.

5.2.3.10.2 The Comm_Change_Lifetime may be locally defined in terms of a duration or maximum number activity repetitions before it is aborted.

5.2.3.11 Hail_Wait_Duration

Hail_Wait_Duration shall represent how long the initiating transceiver (caller) waits for a response to the Hail.

5.2.3.12 Hail_Response

Hail_Response shall be used by the responder to acknowledge that the persistent activity has been accepted. In this case, either a valid Transfer Frame has been received, or SYMBOL_INLOCK_STATUS (PL) has been set to *true* (implementation option). For full duplex, see table 5-6, Event 9; for half duplex, see table 5-9, Event 37.

5.2.3.13 Hail_Notification

Hail_Notification shall be provided by the caller and/or responder to the local vehicle controller (e.g., spacecraft C&DH) upon success or failure of the persistent activity (see also Annex G, Notifications to Vehicle Controller).

5.2.3.14 Hail_Lifetime

5.2.3.14.1 Hail_Lifetime represents the time period during which the persistent activity shall be repeated until the expected Hail_Response is detected.

5.2.3.14.2 The Hail_Lifetime may be locally defined as either a duration or maximum repetitions of activity before it is aborted.

5.2.3.15 Hailing_Data_Rate/Hailing_Symbol_Rate

Hailing_Data_Rate shall represent the data rate assigned during the Hail activity. Similarly, the Hailing_Symbol_Rate shall represent the symbol rate assigned during the Hail activity.

NOTES

1 Data rates are defined in the PL.

2 The LEC directive is defined in terms of symbol rates (see Annexes D/E).

5.2.3.16 Send_Duration

Send_Duration represents the maximum time during which the half-duplex transmitter shall send data before it relinquishes the token and transfers to receive.

5.2.3.17 Receive_Duration

Receive_Duration represents the maximum time during which the half-duplex receiver is anticipating that the sending side shall be transmitting.

5.2.3.18 PLCW_Repeat_Interval

5.2.3.18.1 PLCW_Repeat_Interval shall represent the maximum transmission time between successive PLCWs, even if PLCWs are not required for Sequence Control operations.

5.2.3.18.2 A zero value shall represent an infinite time period.

5.2.3.19 NACKs_Allowed

NACKs_Allowed defines the maximum number of NACKs that the caller may receive. Once this value is exceeded, the link negotiation process carried out via the query/response directive function between nodes is terminated.

5.3 ELEMENTS AND EVENTS AFFECTING STATE STATUS

5.3.1 TIMERS

5.3.1.1 General

5.3.1.1.1 All timers shall use the MIB parameter Interval_Clock.

NOTE – Interval_Clock is a frequency (e.g., 100 Hz) that is used for interval timing.

5.3.1.1.2 The following behavior applies to all timers:

- the timer shall count down when it is not equal to ‘zero’;
- when the timer equals ‘1’, the event associated with the timer shall occur;
- when the timer equals ‘zero’, it shall be in an inactive state;
- the timer may be reset to ‘zero’ by specific actions identified in the state transition tables.

5.3.1.2 Wait Timer and Associated Events

The values loaded into the timer shall be consistent with the Interval Clock frequency. The timer shall be loaded with the required MIB parameter value (see state tables) and counted down using the Interval_Clock. The value in the timer shall be counted down until underflow.

5.3.1.3 CARRIER_LOSS_TIMER and Associated Events

5.3.1.3.1 The CARRIER_LOSS_TIMER contains the duration during which the session shall be maintained even though the carrier is no longer present.

NOTE – This mechanism is intended to reduce complexities from momentary (short term) carrier loss due to multipath or obstacles in the communications path. When CARRIER_LOSS_TIMER counts down to 1, signaling that the spacecraft is no longer in view or the RF null was larger than expected, the vehicle controller is notified (see Annex G) and decides whether to terminate or continue the session via the reconnect process (see 1.5.1.2).

5.3.1.3.2 The CARRIER_LOSS_TIMER shall be loaded with the value contained in the MIB parameter Carrier_Loss_Timer_Duration, and down counting shall be enabled when the following conditions are simultaneously satisfied:

– the Carrier_Acquired (PL) signal is false;

– the CARRIER_LOSS_TIMER value is ‘0’;

– MODE = active;

– either [DUPLEX = full or (Duplex = half .AND. TRANSMIT = off)].

5.3.1.3.3 The CARRIER_LOSS_TIMER shall be reset to ‘zero’ when the CARRIER_ACQUIRED (PL) signal is *true*.

5.3.1.4 PLCW Timer and Associated Events

5.3.1.4.1 The PLCW TIMER shall be used periodically to request the issuance of a PLCW.

5.3.1.4.2 When the PLCW TIMER=‘1’, the NEED_PLCW variable shall be set *true*.

5.3.1.4.3 The timer shall be loaded with the value in the MIB parameter PLCW_Repeat_Interval when a PLCW is transmitted (see the COP-P state tables in section 6 for when the NEED_PLCW variable is set to *true*).

NOTE – The PLCW TIMER does not appear in the state transition tables.

5.3.2 OUTPUT FIFO

5.3.2.1 Overview

The Output FIFO is a FIFO cache for the storage of bits that are serially output to the C&S Sublayer for encoding. The channel coding options of the C&S Sublayer (e.g., convolutional coding) are applied to the data from the output FIFO before transmission by the PL.

5.3.2.2 General

The FIFO shall be filled with data per the specification defined in table 5-13. The ‘Output FIFO = empty’ state signals that the FIFO contains no data, so more data need to be provided to keep the output bitstream synchronous.

5.3.2.3 No_Frames_Pending

The No_Frames_Pending event shall occur when the Output FIFO becomes empty and there are no frames selectable for output.

5.3.3 DIRECTIVES

5.3.3.1 Local Directives

Local directives are sent internally, i.e., not across the link.

5.3.3.1.1 SET MODE

5.3.3.1.1.1 SET MODE shall assign values to the MODE parameter (5.2.1.1) as follows:

a) ***connecting-L***;

b) ***connecting-T***;

c) ***active***;

d) ***inactive*** (see 5.3.3.1.1.2).

5.3.3.1.1.2 SET MODE *inactive* shall initialize the variables in table 5-5 to the values indicated.

Table 5-5: Session Control Variable Initialization Table

Variables	Value
TRANSMIT, MODULATION, PERSISTENCE, RANGING	*off*, *off*, *false*, *off*
SS, X, Y and Z	0
WAIT TIMER (WT), CARRIER_LOSS_TIMER, PLCW TIMER	0
SEQUENCE CONTROLLED (SEQ_CTRL_FSN) AND EXPEDITED FRAME SEQUENCE COUNTERS (EXP_FSN)	0

5.3.3.1.2 SET INITIALIZE MODE

SET INITIALIZE MODE shall use SET MODE *inactive* to place MODE into the *inactive* state and trigger the COP-P events SE0 and RE0 described in the state tables in 6.2.3.3 and 6.3.1.

5.3.3.1.3 LOCAL COMM_CHANGE

LOCAL COMM_CHANGE (LCCD) shall use SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS to initiate changes in communications channel parameters. When applicable, SET PL EXTENSIONS or LEC directives may also be used for transmit and receive operations.

NOTE – RCCD employs the same parameter-setting directives as LCCD but is transmitted across the communications link to the remote transceiver.

5.3.3.1.4 LOAD COMMUNICATIONS VALUE BUFFER

LOAD COMMUNICATIONS VALUE BUFFER shall load the values for the remote transmitter and receiver associated with Hail, COMM_CHANGE, or half-duplex receiver/transmitter switching activities.

5.3.3.1.5 LOCAL_NO_MORE_DATA

LOCAL_NO_MORE_DATA shall inform the transceiver that the local data source has no more data to send.

NOTE – This directive initiates the session termination process.

5.3.3.1.6 SET DUPLEX

SET DUPLEX shall configure the local transmitter and/or receiver for full-duplex, half-duplex, or simplex operations.

5.3.3.1.7 SET RECEIVING SCID BUFFER

SET RECEIVING SCID BUFFER shall be used by the vehicle controller to load the RECEIVING_SCID_BUFFER.

5.3.3.1.8 LOCAL_SET_RANGING

LOCAL_SET_RANGING shall allow the local transceiver to set the state of the ranging channel to either *on* or *off*.

5.3.3.1.9 READ STATUS

READ STATUS shall selectively read the local status registers and buffers (including timing services) within the transceiver.

5.4 STATE TRANSITION TABLES AND DIAGRAMS

5.4.1 OVERVIEW

The following subsections contain State Transition Tables and State Transition Diagrams that should be read in conjunction with one another for completeness.

The State Transition Diagrams are intended to illustrate transitions from one state to another and the events that trigger them. States are shown in boxes. Events that cause transitions from one state to a resultant state are given in italic text beside arrows that indicate the transition between states.

In the State Transition Tables, states are assigned the letter S followed by a number, along with a descriptive title. These tables are organized as follows:

– Column 1 - event number;
– Column 2 - event that triggers the state transition;
– Column 3 - starting state;
– Column 4 - resulting state;
– Column 5 - additional actions that take place as a result of entering that state, beyond what is described in tables 5-1 through 5-4.

The diagrams do not show all possible states for reasons of simplicity and clarity. For completeness, the State Transition Tables and accompanying text contain a description of all states and events not included in the diagrams.

5.4.2 FULL DUPLEX OPERATIONS

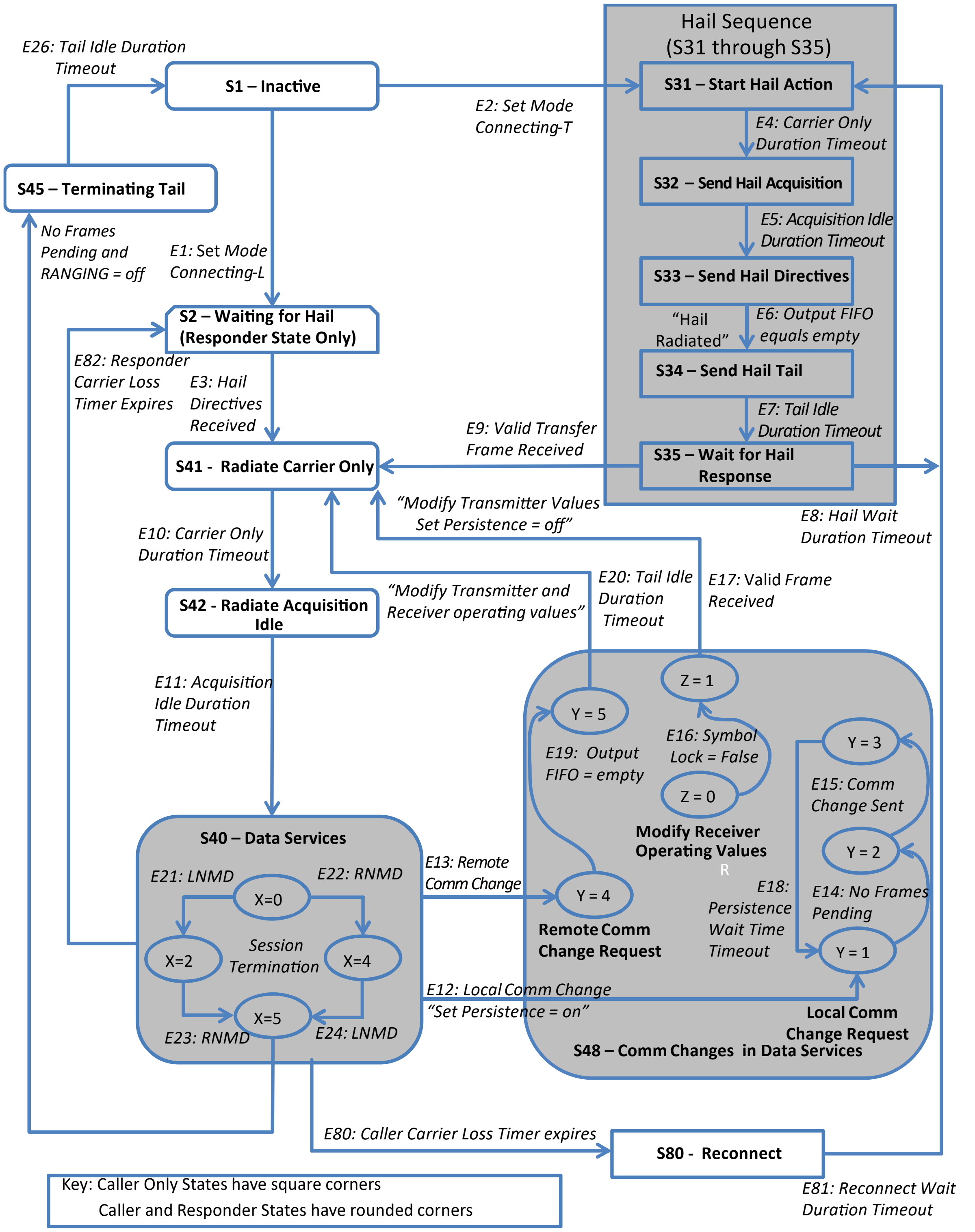

Figure 5-1: Full Duplex State Transition Diagram

Table 5-6: Full Duplex Session Establishment/Data Services State Transition Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 5-1, 5-2, and *Comments*
E1	Local Directive - SET MODE *connecting-L*	S1	S2	
E2	Local Directive - SET MODE *connecting-T*	S1	S31	- WT = Carrier_Only_Duration - Set PERSISTENCE = *true* - Form and load HAIL directives into Comm Value Buffer
E3	HAIL Directives Received	S2	S41	- WT = Carrier_Only_Duration - Set TRANSMIT = *on* - Set NEED_PLCW = *true* - Set Receiver and Transmitter parameters per HAIL directives (see 5.1.2) - Send Hail_Notification to C&DH
E4	WT = 1 Carrier_Only_Duration Timeout	S31	S32	- WT = Acquisition_Idle_Duration - Set MODULATION = *on*
E5	WT = 1 Acquisition_Idle_Duration Timeout	S32	S33	- Radiate Hail - Transmit the appropriate Receiver and Transmitter Hail directives (see 5.1.2)
E6	Output FIFO = empty	S33	S34	*Hail Radiated* - WT = Tail_Idle_Duration
E7	WT = 1 Tail_Idle_Duration Timeout	S34	S35	- WT = Hail_Wait_Duration (see 5.2.3.11) - Set TRANSMIT = *off*
E8	WT = 1 Hail_Wait_Duration Timeout	S35	S31	- WT = Carrier_Only_Duration - Set MODULATION = *off* - Set TRANSMIT = *on* - If CARRIER ONLY RECEIVED, send carrier received notification to C&DH
E9	Valid Transfer Frame Received (or SYMBOL_INLOCK_STATUS=*true*—implementation option, see Hail_Response MIB parameter)	S35	S41	- Set Transmitter values from Comm Value Buffer - WT = Carrier_Only_Duration - Set MODULATION = *off* - Set TRANSMIT = *on* - Set PERSISTENCE = *false* - Send Hail_Notification to C&DH
E10	WT = 1 Carrier_Only_Duration Timeout	S41	S42	- WT = Acquisition_Idle_Duration - Set MODULATION = *on*
E11	WT = 1 Acquisition_Idle_Duration Timeout	S42	S40	*Data Service begins*

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 5-1, 5-2, and *Comments*
E80	Caller's CARRIER_LOSS_TIMER expires	S40	S80	- WT = Reconnect_Wait_Duration - Set TRANSMIT = *off* - Reconfigure caller's Transceiver back to initial Hail settings as detailed in the initial hailing directives (see 5.1.2) - Utilize (do not reset) existing FARM-P and FOP-P variable values
E81	WT = 1 Reconnect_Wait_Duration Timeout	S80	S31	- Set TRANSMIT = *on* WT = Carrier_Only_Duration - Set PERSISTENCE = *true* - Form and load HAIL directives into Comm Value Buffer - Implementations may consider alternative values for: Carrier_Only_Duration, Acquisition_Idle_Duration, Tail_Idle_Duration, and Hail_Wait_Duration for reconnections
E82	Responder's CARRIER_LOSS_TIMER expires	S40	S2	- Set TRANSMIT = *off* - Reconfigure responder's transceiver back to initial Hail settings as detailed in the initial hailing directives(see 5.1.2) - Utilize (do not reset) existing FARM-P and FOP-P variable values
NOTE – FOP-P Data operations (6.1) occur within State 40. FARM-P operations (6.3) occur in States 40, 41, 42, and 48 whenever MODE is active and the receiver is on. Comm Value Buffer is the local buffer used for staging the transmit and receive parameters in support of the hailing and COMM_CHANGE directives. Values can be sent in locally or remotely.				

Table 5-7: Full Duplex Communication Change State Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 5-1, 5-2, and *Comments*
E12	Local COMM_CHANGE Request	S40(Y = 0)	S48(Y = 1)	- Set Y = 1 - Set PERSISTENCE = *true*
E13	Remote COMM_CHANGE Request	S40(Y = 0)	S48(Y = 4)	- Set Y = 4 - Set PERSISTENCE = *true*
E14	No Frames Pending	S48(Y = 1)	S48(Y = 2)	- Form and Send Remote COMM_CHANGE Directive (RCCD) - Set Y = 2
E15	Output FIFO = empty (COMM_CHANGE sent)	S48(Y = 2)	S48(Y = 3)	- WT = Persistence_Wait_Time - Set Y = 3
E16	Symbol Lock = *false*	S48(Y = 1 or 2 or 3)	S48(Z = 1)	- Set Z = 1 - SET_RECEIVER_PARAMETERS or equivalent directive – see 5.1.2 from Comm Value Buffer
E17	Valid Frame Received and Z = 1	S48(Z = 1)	S41	- Set Y = 0 - Set PERSISTENCE = *false*, - Set Z = 0 - SET TRANSMITTER PARAMETERS or equivalent directive – see 5.1.2 from Comm Value Buffer - WT = Carrier_Only_Duration - Set MODULATION = *off*
E18	WT = 1 Persistence_Wait_Time Timeout	S48(Y = 3)	S48(Y = 1)	- Set Y = 1 *No Response to RCCD received yet*
E19	Output FIFO = empty	S48(Y = 4)	S48(Y = 5)	- WT = Tail_Idle_Duration - Set Y = 5
E20	WT = 1 Tail_Idle_Duration Timeout	S48(Y = 5)	S41	- Set Y = 0 - Set PERSISTENCE = *false* - SET TRANSMITTER PARAMETERS & SET_RECEIVER_PARAMETERS or equivalent directives – see 5.1.2 into Comm Value Buffer - Set NEED_PLCW = *true* - WT = Carrier_Only_Duration, Set MODULATION = *off*
NOTE – X, Y, Z are sub-state variables used in the process of session termination (X) and COMM_CHANGE (Y, Z).				

Table 5-8: Full Duplex Session Termination State Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 5-1, 5-2 and *Comments*
E21	Receive LNMD (X = 0)	S40(X = 0)	S40(X = 2)	- Form and Load RNMD directive into the MAC queue (see reference [6]) - Set X = 2 - Send RNMD
E22	Receive RNMD (X = 0)	S40(X = 0)	S40(X = 4)	- Set X = 4
E23	Receive RNMD (X = 2)	S40(X = 2)	S40(X = 5)	- Set X = 5 *Begin Termination Process*
E24	Receive LNMD (X = 4)	S40(X = 4)	S40(X = 5)	- Form and Load RNMD directive into MAC queue - Set X = 5 - Send RNMD
E25	No_Frames_Pending (X = 5) and RANGING = *off*	S40(X = 5)	S45	- WT = Tail_Idle_Duration *If applicable, Ensure Ranging is inactive along with no data to send*
E26	WT = 1 Tail_Idle_Duration Timeout	S45	S1	- Local directive SET MODE *inactive* - Notify vehicle controller: End of Session (# octets received)
E28	Receive a Local SET MODE = *Inactive* Directive or SET INITIALIZE MODE Directive	Any state	S1	SET MODE *inactive* - Notify vehicle controller: End of Session (# octets received) NOTES 1 Not Shown on full-duplex transition diagram. 2 E28 initializes session control variables (see table 5-5).
NOTE – LNMD = LOCAL_NO_MORE_DATA Directive received from the local controller; RNMD is the REMOTE_NO_MORE_DATA Directive received over the link.				

5.4.3 HALF DUPLEX OPERA

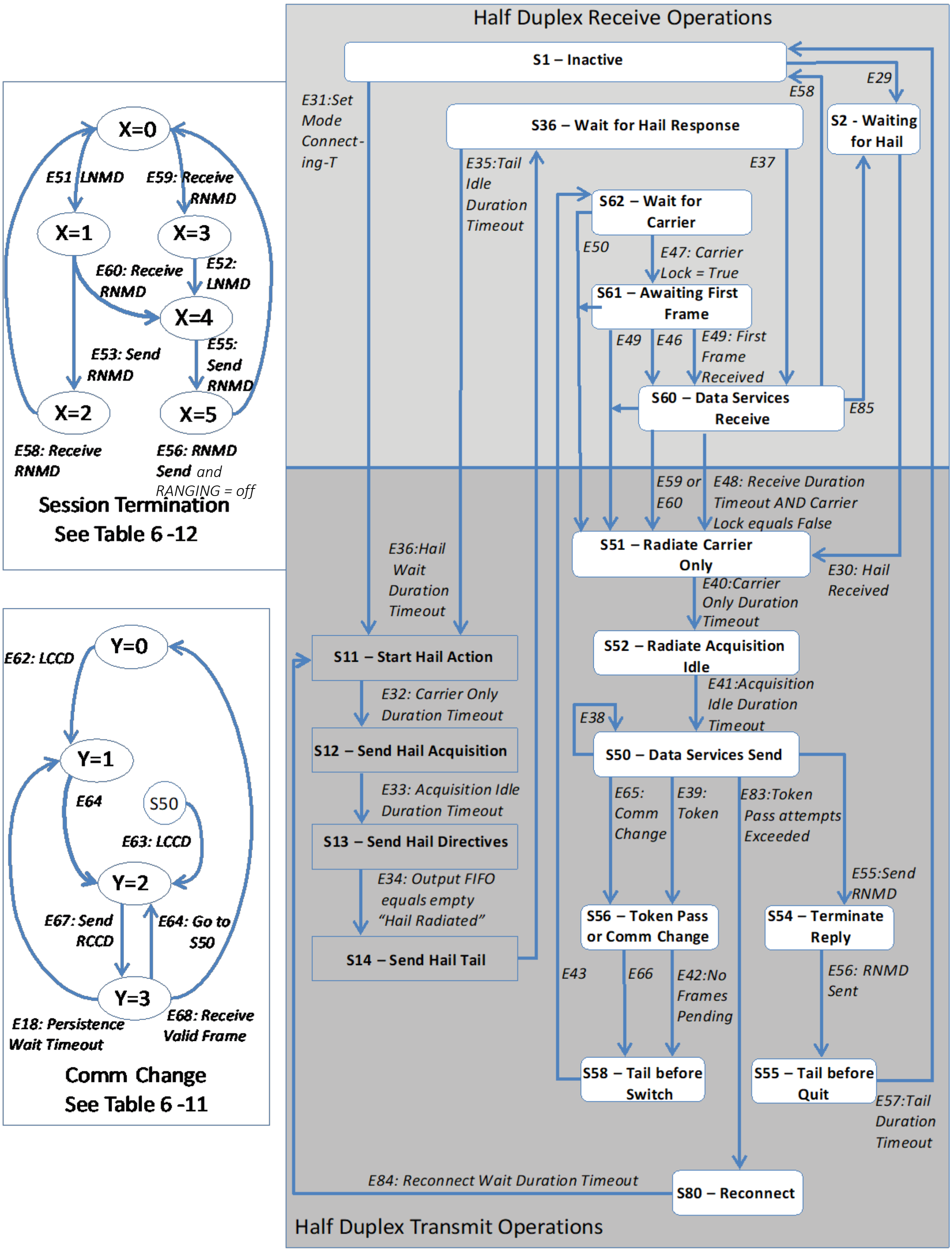

Figure 5-2: Half Duplex State Transition Diagram

Table 5-9: Half Duplex Session Establishment and Data Services

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 5-1, 5-3, and *Comments*
E29	Local Directive – SET MODE *connecting-L*	S1	S2	- Set NEED_PLCW = *true*
E30	Hail Received	S2	S51	- WT = Carrier_Only_Duration - Set Receiver and Transmitter values per HAIL directives - Set TRANSMIT = *on* - Send Hail_Notification to C&DH
E31	Local Directive – SET MODE *connecting-T*	S1	S11	- WT = Carrier_Only_Duration - Load HAIL directives to Comm Value Buffer - Set PERSISTENCE = *true* - Set Receiver Values per HAIL directive
E32	WT = 1 Carrier_Only_Duration Timeout	S11	S12	- WT = Acquisition_Idle_Duration - Set MODULATION = *on*
E33	WT = 1 Acquisition_Idle_Duration Timeout	S12	S13	- Radiate Hail - Transmit the appropriate Receiver and Transmitter Hail directives – see 5.1.2
E34	Output FIFO=empty	S13	S14	*Hail Radiated* - WT = Tail_Idle_Duration
E35	WT = 1 Tail_Idle_Duration Timeout	S14	S36	- WT = Hail_Wait_Duration (see 5.2.3.11) - Set MODULATION = *off* - Set TRANSMIT = *off*
E36	WT = 1 Hail_Wait_Duration Timeout	S36	S11	- Set TRANSMIT = *on* - WT = Carrier_Only_Duration - Set Load HAIL directives to Comm Value Buffer - If CARRIER ONLY RECEIVED, send carrier received notification to C&DH
E37	Valid Transfer Frame Received (or SYMBOL_INLOCK_STATUS = *true*)—implementation option (see Hail_Response MIB parameter)	S36	S60	- Set Transmitter values per Comm Value Buffer - Set PERSISTENCE = *false* *Get ready for next transmit contact* - WT = Receive_Duration - Send Hail_Notification to C&DH

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 5-1, 5-3, and *Comments*
E38	(Transmit Timer Event – End of Send Period) WT = 1 Send_Duration Timeout	S50	S50 Y = 0	- Set PERSISTENCE = *true* *Setting PERSISTENCE blocks the transmission of data from data services. Now only send from the MAC queue. Therefore, 'no frames pending' event occurs.*
E39	No Frames Pending AND. Y = 0 .AND. NEED_PLCW is *false*	S50 Y = 0	S56	- Form and load the token via the SET CONTROL PARAMETERS or LINK ESTABLISHMENT & CONTROL Directive into the MAC queue (see 5.1.2)
E40	WT = 1 Carrier_Only_Duration Timeout	S51	S52	- WT = Acquisition_Idle_Duration - Set MODULATION = *on*
E41	(End of Acquire) WT = 1 Acquisition_Idle_Duration Timeout	S52	S50	- WT = Send_Duration
E42	No Frames Pending (Y = 0)	S56, Y = 0	S58	- WT = Tail_Idle_Duration
E43	WT = 1 Tail_Idle_Duration Timeout .AND. Y ≠ 2	S58 Y ≠ 2	S62	- WT = Receive_Duration - Set PERSISTENCE = *false* - Set MODULATION = *off* - Switch transmit to receive
E44	WT = 1 Receive_Duration Timeout .AND. Carrier Lock = *true*	S60	S60	- WT = Receive_Duration - Notify vehicle controller: Sender exceeded prescribed transmission interval
E45	WT=1 Receive_Duration Timeout .AND. Carrier Lock = *true*	S61	S61	- WT = Receive_Duration - Notify vehicle controller: No data transferred during contact period
E46	Receive Valid frame .AND. Y ≠ 3	S61 Y≠3	S60	
E47	Carrier Lock = *true*	S62	S61	
E48	WT = 1 Receive_Duration Timeout .AND. Carrier Lock = *false*	S60	S51	- WT = Carrier_Only_Duration *Back-up action for missed token* - Switch receive to transmit
E49	Receive Token - SET CONTROL PARAMETERS Directive or LINK ESTABLISHMENT & CONTROL directive (see 5.1.2)	S60/S61	S51	- WT = Carrier_Only_Duration - Switch receive to transmit

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Action(s) in Addition to Tables 5-1, 5-3, and *Comments*
E50	WT = 1 Receive_Duration Timeout .AND. Carrier Lock = *false*	S62/S61	S51	- WT = Carrier_Only_Duration - Notify vehicle controller: S62: No carrier received for contact period S61: No data transferred during contact period - Switch receive to transmit
E83	Token Pass attempts exceeded (Maximum_Failed_Token_Passes)	S50	S80	- WT = Reconnect_Wait_Duration - Set TRANSMIT = *off* - Reconfigure caller's Transceiver back to initial Hail settings in the initial hailing directives. (see 5.1.2) - Utilize (do not reset) existing FARM-P and FOP-P variable values
E84	WT = 1 Reconnect_Wait_Duration Timeout	S80	S11	- Set TRANSMIT = *on* - WT = Carrier_Only_Duration - Set PERSISTENCE = *true* - Form and load HAIL directives into Comm Value Buffer *Implementations may consider alternative values for*: Carrier_Only_Duration, Acquisition_Idle_Duration, Tail_Idle_Duration, Hail_Wait_Duration for reconnections.
E85	Responder's CARRIER_LOSS_TIMER expires	S60	S2	- Set TRANSMIT = *off* - Utilize (do not reset) existing FARM-P and FOP-P variable values
NOTE – FOP-P Data operations occur within State 50 and are described in 6.1. FARM-P operations occur within States 60 and 61 and are described in 6.3.1.				

Table 5-10: Half Duplex Communication Change State Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Additional Action(s) and ***Comments***
E62	Receive Local COMM_CHANGE Directive (LCCD)	Any State other than State S50 Y = 0	No State Change Y = 1	- Load SET TRANSMITTER/SET RECEIVER PARAMETERS or equivalent Directives values (see 5.1.2 into Comm Value Buffer)
E63	Receive Local COMM_CHANGE Directive (LCCD)	S50	S50 Y = 2	- Set PERSISTENCE = *true* - SET RECEIVER PARAMETERS or equivalent directive (see 5.1.2 from Comm Value Buffer)
E64	Transition to State 50	Y = 1 .OR. Y = 3	S50 Y = 2	- Set Y = 2, Set PERSISTENCE = *true* - SET RECEIVER PARAMETERS or equivalent directive (see 5.1.2 from Comm Value Buffer)
E65	No Frames Pending .AND. Y = 2	S50 Y = 2	S56	- Form and load into the Comm Value Buffer the COMM_CHANGE Directives
E66	No Frames Pending	S56 Y = 2	S58 Y = 2	- WT = Tail_Idle_Duration COMM_CHANGE *Sent*
E67	WT = 1 Tail_Idle_Duration Timeout .AND. Y = 2	S58 Y = 2	S62 Y = 3	- WT = Receive_Duration - Switch transmit to receive
E47	Carrier Lock = *true*	S62	S61	*Same event - provided for clarity*
E68	Receive Valid Frame	S61 Y = 3	S60 Y = 0	- SET TRANSMITTER PARAMETERS or equivalent directive (see 5.1.2) from Comm Value Buffer) - Set Y = 0 - *PERSISTENCE = false*
E69	Receive COMM_CHANGE (Not Shown in State Transition Diagram)	S60/S61	S51	- Set Transmitter and Receiver Parameters or equivalent directives (see 5.1.2) into Comm Value Buffer) - Set NEED_PLCW = *true*

Table 5-11: Half Duplex Session Termination State Table

Event No.	Event Causing the Transition (Description)	Starting State (from)	Resulting State (to)	Additional Action(s) and *Comments*
E51	Receive LNMD (can be received at any time)	X = 0	X = 1	- Set X = 1
E52	Receive LNMD (can be received at any time)	X = 3	X=4	- Set X = 4
E53	No Frames Pending .AND. X = 1	S50 X = 1	S50 X = 2	- Form and Load RNMD into the MAC queue, - Set X = 2 - Send RNMD
E55	No Frames Pending .AND. X = 4	S50 X = 4	S54 X = 5	- Form and Load RNMD into the MAC queue, - Set X = 5; Send RNMD
E56	No Frames Pending .AND. X = 5 .AND. RANGING is *off*	S54 X = 5	S55 X = 0	- WT = Tail_Idle_Duration - Set X = 0 *Transmission of RNMD complete; if applicable, ensure ranging is inactive along with no data to send*
E57	WT = 1 Tail_Duration Timeout	S55	S1	- SET MODE Inactive - Notify vehicle controller: End of Session(# octets received)
E58	Receive RNMD .AND. X = 2 .AND. RANGING is *off*	S60/S61 X = 2	S1 X = 0	- SET MODE *Inactive* - Set X = 0 *Both nodes have no more data to send; if applicable, ensure ranging is inactive.* - Notify vehicle controller: End of Session(# octets received)
E59	Receive RNMD .AND. X = 0	S60/S61 X = 0	S51 X = 3	- Set X = 3 - WT = Carrier_Duration_Only
E60	Receive RNMD .AND. X = 1	S60/S61 X = 1	S51 X = 4	- Set X = 4 - WT = Carrier_Duration_Only
E61	Receive a Local SET MODE *Inactive* directive	any	S1	- SET MODE *Inactive* - Notify vehicle controller: End of Session(# octets received) *Not shown on half duplex state transition diagram*

5.4.4 SIMPLEX OPERATIONS

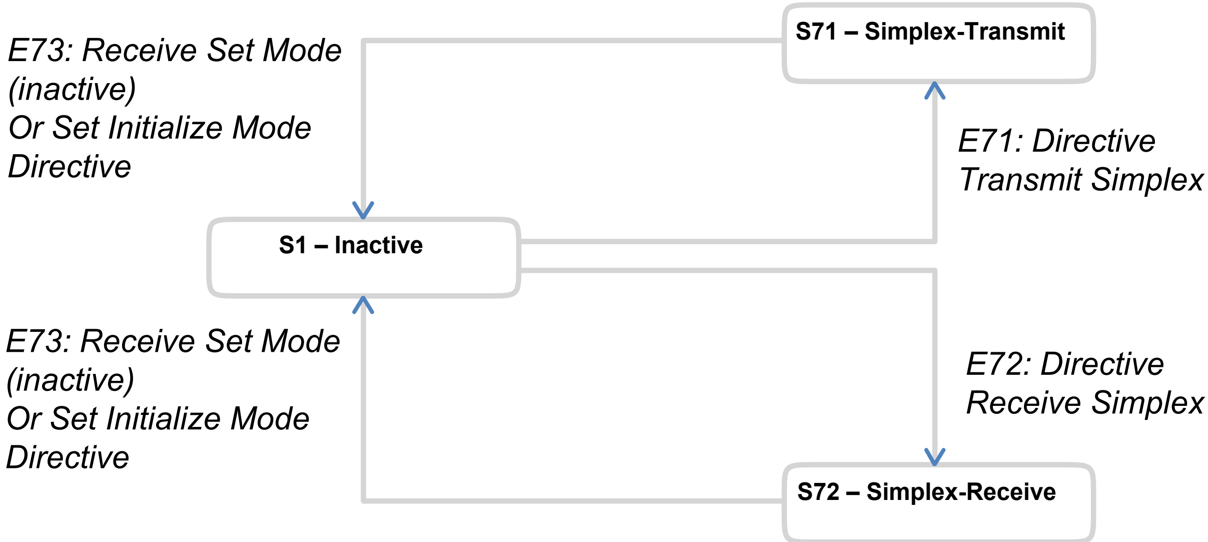

Figure 5-3: Simplex Operations

Table 5-12: Simplex State Transition Table

Event No	Starting State (from)	Resulting State (to)	Event Causing the Transition (Description)	Action(s) in addition to Tables 5-1, 5-4
E71	S1	S71	Receive Directive - Transmit Simplex	- Set DUPLEX = *Simplex transmit* - Set TRANSMIT = *on* - Local Directive SET MODE = *active*
E72	S1	S72	Receive Directive - Receive Simplex	- Set DUPLEX = *Simplex receive* - Set TRANSMIT = *off* - Local Directive SET MODE = *active*
E73	S71 or S72	S1	Receive a Local SET MODE = *Inactive* Directive	- Notify vehicle controller: End of Session(# octets received)

5.5 INTERFACES WITH THE PHYSICAL LAYER VIA CODING AND SYNCHRONIZATION SUBLAYER

5.5.1 OUTPUT INTERFACES

5.5.1.1 The TRANSMIT parameter (5.2.1.3) shall be set to *on* to signal the transceiver to turn its transmitter 'on'.

5.5.1.2 The Frame Sublayer shall output frames via the C&S Sublayer ChannelAccess.request service primitive.

5.5.1.3 The MODULATION parameter (5.2.2.4) shall be set to *on*, signaling the transceiver to modulate the carrier with the coded symbols provided on the Output coded symbol stream (see 5.6.3).

5.5.1.4 The RANGING parameter (5.2.2.6) shall be set to *on,* signaling the transceiver to modulate the carrier with the ranging code.

5.5.2 PL INPUT INTERFACES

The PL provides information about carrier and symbol lock status via the CARRIER_ACQUIRED and SYMBOL_INLOCK_STATUS parameters, respectively. The values of these parameters shall be interpreted as follows:

a) CARRIER_ACQUIRED = *true* indicates that the receiver has acquired a carrier signal;

b) SYMBOL_INLOCK_STATUS = *true* indicates that symbol synchronization has been acquired.

NOTE – The C&S layer receives a coded symbol stream from the PL and delivers frames to the Frame Sublayer.

5.6 SENDING OPERATIONS

5.6.1 SESSION ESTABLISHMENT

5.6.1.1 The following local directives shall set the physical configuration of the local transceiver:

- SET_TRANSMITTER_PARAMETERS;
- SET_RECEIVER_PARAMETERS;
- SET PL EXTENSIONS (TX) (if present);
- SET PL EXTENSIONS (RX) (if present);
- LINK ESTABLISHMENT & CONTROL (if needed).

5.6.1.2 If required for the session, the Test_Source MIB parameter shall be loaded.

5.6.1.3 A Local SET MODE (*connecting-T*) directive shall initiate the hail activity and start the session establishment process (see 5.4.2 for full-duplex operation and 5.4.3 for half-duplex operation).

5.6.2 DISCUSSION

When a frame is ready for output at the C&S Sublayer, an attached synchronization marker (ASM) is prepended, and a cyclic redundancy check (CRC) is computed and appended to the frame. The output coded symbol stream is then formulated for radiation in accordance with table 5-13.

The Idle Pattern Generator (described in reference [4]) produces an idle pattern used for acquisition periods (when no frames are available for transmission), as well as for creating a tail stream that provides the added bits required to push the data through the receiving and decoding processes at the remote terminus of the link.

5.6.3 OUTPUT CODED SYMBOL STREAM FORMULATION

Table 5-13: Data Source Selection for Output Coded Symbol Stream with TRANSMIT = *on* and MODULATION = *on*

Based Upon the Values Below, Take the Following Action					Action
SS (SUB-STATE)	SPDU Pending	PERSISTENCE	NEED_ PLCW or Status	SDU Pending	Data to load into output FIFO when it is empty
2, 4, or 7	X	X	X	X	IDLE (Acquisition or Tail)
0, 3, or 6	***true***	X	X	X	ASM + P-frame (SPDU) + CRC
0, 3, or 6	*false*	***true***	X	X	IDLE
0, 3, or 6	*false*	*false*	***true***	X	ASM + PLCW/Status + CRC
0, 3, or 6	*false*	*false*	*false*	***true***	ASM + U-frame (SDU) + CRC
0, 3, or 6	*false*	*false*	*false*	*false*	IDLE

NOTES

1 X means the value is not important.

2 SPDU Pending is *true* if there is a supervisory protocol data unit available to send.

3 SDU Pending is *true* if there is a service data unit (user data) available to send.

4 When NEED_PLCW is *true*, NEED_STATUS_REPORT can optionally be set to *true*, enabling the generation and transmission of a status report as well.

5 PERSISTENCE is a variable used for selected Supervisory protocol activities (see 4).

6 The selection of an SDU issues an extract data unit request to the FOP-P (see FOP-P data selection, described in 6.1).

7 SS = 1 indicates transmit carrier only.

8 SS = 5 indicates TX off, RX waiting for response.

5.6.4 DISCUSSION—PROVISION OF U-FRAME FOR SELECTION

The FOP-P portion of the COP-P specification (see 6.1) defines how a U-frame is selected for provision using the procedures in table 5-13. This document describes operations on a single PCID. The simultaneous use of multiple PCIDs is possible, but concurrent COP-P procedures are required, and the report shall contain the status for each PCID. How to prioritize and multiplex data into the output coded symbol stream of simultaneous multiple PCID operations (as specified above) is outside the scope of this document.

5.6.5 DISCUSSION—EVENTS RELATED TO DATA HANDLING ACTIVITIES

The following events are related to data-handling activities in Table 5-14:

Table 5-14: Data Handling Activities

Event	**Action**	**Section Reference**
NEED_PLCW is set to *false*	PLCW is chosen for output	5.2.2.7.2
NEED_STATUS_REPORT is set to *false*	status report is chosen for output	5.2.2.7.2
Output FIFO = empty is *true*	the last bit is extracted from the Output FIFO	5.3.2.2
No_Frames_Pending occurs	none of the conditions is satisfied for selecting a U-frame or SPDU (including a PLCW)	5.3.2.3

5.7 RECEIVING OPERATIONS

5.7.1 FRAME RECEPTION

5.7.1.1 Establishment of physical channel characteristics and initialization of receiving procedures shall be accomplished by a local directive SET MODE for *connecting-L* or *connecting-T* (see 5.3.3.1.1.1).

5.7.1.2 The Frame Sublayer shall accept for validation frames delivered via the C&S Sublayer ChannelAccess.indication service primitive (see reference [4], 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 length determination using the frame header length field).

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

5.7.2 FRAME VALIDATION

Frame Validation Criteria shall be as follows:

a) If the first two bits of the Transfer Frame header are:

   1) ‘00’, then the transfer frame is rejected as invalid;

   2) ‘10’, then a valid Version-3 (Proximity-1) Transfer Frame has been received from the C&S sublayer (see reference [4], subsection 3.6.4);

   3) ‘11’, then a valid Version-4 (Unified Space Data Link Protocol [USLP]) Transfer Frame has been received from the C&S sublayer.

b) When the Source-or-Destination Identifier value equals ‘1’ (*destination*), the frame is rejected as invalid if the Spacecraft ID field in the header of a Version-3 or Version-4 Transfer Frame does not match the Local_Spacecraft_ID (MIB parameter).

c) If Test_Source is *true*, frame validation depends on the RECEIVING_SCID_BUFFER value and potentially other frame contents:

   1) When Test_Source is *true* and RECEIVING_SCID_BUFFER is **zero**, then the SCID value of first received frame with Source-or-Destination ID = '0' (*source*) is loaded into RECEIVING_SCID_BUFFER and used for session validation (see also 5.2.3.2.)

   2) When Test_Source is *true* but RECEIVING_SCID_BUFFER is **non-zero**, the vehicle controller is notified of a session violation (see Annex G) if both of the following are also true:

      i) Source-or-Destination ID = '0' (*source*); and

      ii) Spacecraft ID field in Version-3 or Version-4 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).

NOTE – The Expedited_Frame_Counter increments for each validated Expedited frame received for Version-3 or Version-4 Transfer Frames.

5.7.3 VALIDATED FRAME PROCESSING

5.7.3.1 Validated U-Frames

Validated received U-frames shall be processed per the COP-P process described in section 6.

5.7.3.2 Validated P-Frames

5.7.3.2.1 Validated P-frames shall be processed by delimiting the contained SPDUs first.

5.7.3.2.2 PLCWs contained within SPDUs shall be transferred to the COP-P processor.

5.7.3.2.3 All other reports or directives shall be processed for protocol actions.

6 COP-P FOR PROXIMITY LINKS

6.1 GENERAL

This section applies to both Version-3 and Version-4 Transfer Frames. An overview of the COP-P protocol is provided in 2.3.

In the sending and receiving procedures for COP-P, the single-octet variables are modulo-256 counters. When subtracting or comparing any two of these variables, special handling is required. The math for the single-octet case is provided below.

– 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.

NOTE – Double-octet variables are modulo-16384 counters.

6.2 SENDING PROCEDURES (FOP-P)

6.2.1 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 (its 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.

6.2.2 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 send.

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 send.

c) VV(S): an 8-bit positive integer whose value shall represent the sequence number (modulo 256) to be assigned to the next Sequence Controlled frame to send. It equals V(S) unless a retransmission is in-progress.

d) N(R): an 8-bit positive integer that is a copy of the Report Value (see subsection 3.2.4, Supervisory PDU, in reference [6]) from the current PLCW. It shall represent the sequence number plus one (modulo 256) of the last Sequence Controlled frame acknowledged by the receiver.

e) NN(R): an 8-bit positive integer system variable known both inside and outside of the FOP-P state table. It shall contain a copy of the Report Value from the previously valid PLCW.

f) R(R): a Boolean variable that is a copy of the Retransmit Flag from the current PLCW. It shall indicate whether or not Sequence Controlled frames need to be retransmitted.

g) RR(R): a Boolean variable that is a copy of the Retransmit Flag from the previous valid PLCW.

h) NEED_PLCW/NEED_STATUS_REPORT: Boolean system variables known both inside and outside of the FOP-P state table (see 5.2.2.7 for complete usage). They shall indicate whether a new PLCW or status report needs to be sent (the PLCW needs to be sent when its contents change).

i) SYNCH_TIMER: a countdown timer that indicates how long a sender shall wait to receive a valid PLCW from a receiver before taking action to synchronize with it. The MIB parameter associated with this timer, Synch_Timeout (see Annex F), represents a desired time value consistent with the Interval Clock frequency (see 5.2.3.19). The SYNCH_TIMER counts down when its value is non-zero. When the SYNCH_TIMER counts down to 1, it expires and triggers the Start Local Resync Event, SE6. Subsequently, the timer then underflows to zero, which is the inactive state for the timer.

j) RESYNC: a Boolean variable that tracks the status of resynchronization within the COP-P. This variable is set to *true* when the SET V(R) activity occurs, indicating that FOP-P is resynchronizing. It is reset to *false* by the End Local Resync event, SE7.

6.2.3 FOP-P STATE TABLE EVENTS

6.2.3.1 General Procedures

6.2.3.1.1 ‘Initialize’ shall set the following variables to the indicated values:

a) V(S) = VE(S) = VV(S) = NN(R) = N(R) = 0;

b) R(R) = RR(R) = RESYNC = *false*;

c) NEED_PLCW = NEED_STATUS_REPORT = *true*;

d) CLEAR QUEUE (*Sent queue*); CLEAR QUEUE (*Seq queue*).

6.2.3.1.2 'Remove acknowledged frames from Sent queue' shall remove *n* frames from the Sent queue, where $n = N(R) - NN(R)$, i.e., the number of times that NN(R) has to be incremented to reach N(R).

6.2.3.1.3 'Start SYNCH_TIMER' shall set SYNCH_TIMER to the value of the MIB parameter Synch_Timeout if SYNCH_TIMER is equal to '0' (cf. Annex F).

NOTE – If the value of Synch_Timeout is '0', then the SYNCH_TIMER never expires.

6.2.3.1.4 'Clear SYNCH_TIMER' shall set the SYNCH_TIMER value to '0'.

NOTE – This does not trigger a resynchronization.

6.2.3.1.5 'Store this PLCW' shall:

a) assign the value of N(R) to NN(R);

b) assign the value of R(R) to RR(R).

6.2.3.1.6 'Send EXP (Expedited) Frame' shall:

a) remove frame from EXP queue;

b) assign VE(S) to the frame;

c) increment VE(S);

d) report VE(S) to the I/O Sublayer;

e) transfer this frame to the Frame Sublayer.

6.2.3.1.7 'Resend SEQ (Sequence Controlled) Frame' shall:

a) copy frame number VV(S) from the Sent queue;

b) increment VV(S);

c) transfer this frame to the Frame Sublayer.

6.2.3.1.8 'Send New SEQ Frame' shall:

a) remove frame from SEQ queue;

b) assign V(S) to the frame;

c) insert a copy of the frame to the end of the Sent queue;

d) increment V(S);

e) increment VV(S);

f) report V(S) to the I/O Sublayer;

g) transfer this frame to the Frame Sublayer.

6.2.3.2 SET V(R) Persistent Activity

The SET V(R) persistent activity (including setup of the MIB parameters before the execution of this activity) is defined below (see 4, 'Persistence', for a general overview of how the MIB parameters relate to the persistent activity).

6.2.3.2.1 Configure the SET V(R) persistent activity. The MIB Parameters (cf. Annex F) that shall be used for setup are:

a) Activity is SET V(R), i.e., Resync;

b) Resync_Waiting_Period (implementation-specific) specifies the amount of time for receiving the Resync_Response before the process repeats or aborts this activity;

c) Resync_Response acknowledges that the SET V(R) directive has been accepted by the Receiver Node, i.e., a valid PLCW with report value of N(R) = NN(R) and R(R) = *false* has been received when RESYNC = *true* (see State S2, Event SE2, FOP-P State table);

d) Resync_Notification informs the vehicle controller of success or failure of resynchronization;

e) Resync_Lifetime (implementation-specific) defines the period during which the Resynchronization activity shall be repeated until the Resync_Response is detected;

f) Resync_Local is set to *true*.

6.2.3.2.2 Execute the SET V(R) persistent activity. The following shall occur:

a) the FOP-P requests a SET V(R) Persistent Activity by setting RESYNC = *true* (see state S1, event SE4 in the FOP-P state table);

b) the MAC Sublayer builds a SET V(R) directive by copying NN(R) into the SEQ_CTRL_FSN field within the SET V(R) directive and setting the PCID field in the SET V(R) directive to the value associated with this FOP-P;

c) the MAC Sublayer loads this directive into the MAC queue for transmission and sets MAC_FRAME_PENDING = *true*;

d) the MAC Sublayer sets PERSISTENCE = *true*;

NOTE – This initiates the SET V(R) persistent activity.

e) the FOP-P terminates the SET V(R) Persistent Activity when it receives the SET V(R) Resync_Response (see parameter c) in 6.2.3.2.1) or the Resync_Lifetime expires.

6.2.3.3 FOP-P State Table

Table 6-1: FOP-P State Table

Event Number/Name	**Resulting Action in State S1 Active**	**Resulting Action in State S2 Resync**
SE0 At Session Startup (see note 1)	*Initialize* (see note 2)	N/A

SE1
Frame Sublayer needs frame to transmit
(see notes 3,4)
	If Expedited_Frame_Available = true
	Send EXP Frame
	Else if VV(S) < V(S)
	# Continue the in-progress retransmission:
	Resend SEQ Frame
	Else if (SEQUENCE_CONTROLLED_FRAME_AVAILABLE = *true* and V(S)-NN(R)<Transmission_Window)
	Send New SEQ Frame
	Else if NN(R) <V(S)
	# Initiate a Progressive Retransmission:
	VV(S) = NN(R)
	Resend SEQ Frame
	Else
	# There is no Data Services frame to send
	Endif
		N/A

SE2 Valid PLCW Received (see note 5)	If N(R) > NN(R) *Remove acknowledged frames from Sent queue* Endif If R(R) = *true* or N(R)>VV(S) VV(S) = N(R) Endif *Store this PLCW* *Clear SYNCH_TIMER*	If R(R) = false and N(R) = NN(R) Resync = false Persistence=false **State = S1** Endif
SE3 Invalid PLCW Received (see note 5)	*Start SYNCH_TIMER* VV(S) = NN(R)	Ignore
SE4 Synch-timer Expired (see note 6)	Notify vehicle controller that *SYNCH_TIMER* expired (see Annex G) If Resync_Local (MIB parameter) = *true* RR(R) = *false* Resync = *true* **State = S2** Endif	N/A
SE5 Set Transmission_Window Request	Accept Set	Accept Set
SE6 Set Synch_Timeout Request	Accept Set	Accept Set

Event Number/Name	Resulting Action in State S1 Active	Resulting Action in State S2 Resync
SE7 Reset Request	Accept *Initialize*	Accept *Initialize* **State = S1**
SE8 Invalid Request	Reject	Reject

NOTES

1 At each session startup, the FOP-P enters state S1 and triggers event SE0 before allowing any other events to occur. If subsequent reconnection is desired without starting a new session, the FOP-P can continue data services by maintaining and using the current state of the FOP-P variables.

2 Procedures are in italics and described in 6.2.3.1; comments are preceded by the ‘#’ sign.

3 ‘Progressive Retransmission’ causes the frames on the Sent queue to be retransmitted.

4 Transmission_Window (MIB parameter—cf. Annex F): The maximum number of Sequence Controlled frames that can be unacknowledged at any given time. For example, if the Transmission_Window is 10 and the sender sends 10 Sequence Controlled frames, the sender must wait for at least one of those frames to be acknowledged by the receiver before it can send any additional Sequence Controlled frames. The value of Transmission_Window cannot exceed 127. When selecting a value for this parameter, the system designer should consider the latency involved whenever frames are required to be retransmitted from the Sent queue before a new Sequence Controlled frame can be transmitted.

5 An incoming PLCW is invalid if any of these conditions is true:

a) PLCW does not match PLCW format;

b) N(R) < NN(R) ‘Invalid N(R)—too small’;

c) N(R) > V(S) ‘Invalid N(R)—too large’;

d) R(R) = *true* and N(R) = V(S) ‘Retransmit is set though all frames are acknowledged’;

e) R(R) = *false* and RR(R) = *true* and N(R) = NN(R) ‘Retransmit has cleared though no new frames are acknowledged’.

Otherwise, the PLCW is valid.

6 Setting Resync = *true* causes a Set V(R) persistent activity to be initiated (see 6.2.3.2, 4, and Annex G).

6.3 RECEIVING PROCEDURES (FARM-P)

6.3.1 FARM-P STATE TABLE

Table 6-2: 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)**	If Resync_Remote (MIB parameter) = *true*, take these actions, else ignore them: 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
NOTE – Similar to the MIB parameter, Resync_Local, the MIB parameter, Resync_Remote controls the resynchronization policy of the remote node. If Resync_Remote = false, then the local radio will also not respond to remote resync directives (Set V(R)) (Table 6-2 event RE2).		

6.3.2 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 that is copied to the PLCW, indicating whether 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 header of the 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.

6.3.3 INTERFACE TO THE I/O LAYER

FARM-P shall pass valid Expedited and valid in-sequence U-frames to the I/O Sublayer (reference [6] subsection 4.4).

NOTE – At the I/O Sublayer, these frames are buffered, assembled into packets as required, and then delivered via the specified output port.

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 *Space Communications Session Control* (CCSDS 235.1-R-1). 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.

<u>Item Column</u>

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

NOTE – The item-number prefix 'SC' = 'Session Control'.

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 SPACE COMMUNICATIONS SESSION CONTROL (CCSDS 235.1-R-1)

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 235.1-R-1	
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

A2.2.1 State Control Variables

Item	Description	Reference	Status	Values Allowed	Support
1	MODE	5.2.1.1	M	inactive, connecting-T, connecting-L, active	
2	DUPLEX	5.2.1.2	M	full, half, simplex transmit, simplex receive	
3	TRANSMIT	5.2.1.3	M	on, off	
4	SUB-STATE	5.2.1.4	M	0-7	

A2.2.2 Operational Control Variables

Item	Description	Reference	Status	Values Allowed	Support
5	Session Termination	5.2.2.1	M	0–5	
6	COMM_CHANGE	5.2.2.2	M	0–5	
7	SYMBOL_INLOCK_STATUS	5.2.2.3	M	0, 1	
8	MODULATION	5.2.2.4	M	on, off	
9	RANGING	5.2.2.6	O	on, off	
10	NEED_PLCW and NEED_STATUS_REPORT	5.2.2.7	M	true, false	
11	REMOTE_SCID_BUFFER	5.2.2.8	M	0–1023 Version-3 frames; 0-65535 Version-4 frames	
12	COMMUNICATION_VALUE_BUFFER	5.2.2.9	M		
13	RECEIVING_SCID_BUFFER	5.2.2.10	M	0–1023 Version-3 frames; 0-65535 Version-4 frames	
14	RECEIVING_PCID_BUFFER	5.2.2.11	M	0, 1	

A2.2.3 Elements and Events Affecting State Status

Item	Description	Reference	Status	Values Allowed	Support
15	Interval_Clock	5.3.1.1.1	M		
16	WT and Associated Events	5.3.1.2	M		
17	CARRIER_LOSS_TIMER and Associated Events	5.3.1.3	M		
18	PLCW TIMER and Associated Events	5.3.1.4	M		
19	OUTPUT FIFO	5.3.2.2	M	Empty is true, empty is not true	
20	NO_FRAMES_PENDING	5.3.2.3	M	true, false	

A2.2.4 Directives

Item	Description	Reference	Status	Values Allowed	Support
Local Directives					
21	SET MODE	5.3.3.1.1	M	connecting-L, connecting-T, active, inactive	
22	SET INITIALIZE MODE	5.3.3.1.2	M	inactive	
23	Local COMM_CHANGE (LCCD)	5.3.3.1.3	M		
24	LOAD COMMUNICATIONS VALUE BUFFER	5.3.3.1.4	M		
25	LOCAL_NO_MORE_DATA (LNMD)	5.3.3.1.5	M		
26	SET DUPLEX	5.3.3.1.6	M	full-duplex, half-duplex, simplex transmit, simplex receive	
27	SET RECEIVING SCID BUFFER	5.3.3.1.7	M		
28	LOCAL_SET_RANGING	5.3.3.1.8	O	on, off	
29	READ STATUS	5.3.3.1.9	O		
30	Remote directives	Annexes B,C,D,E	M		
31	16-BIT PLCW	3.2.2.1	M	Version 3 frames	
32	32-BIT PLCW	3.2.2.2	M	Version 3 or 4 frames	
33	SET TRANSMITTER PARAMETERS	5.1.2.2.2	M		
34	SET RECEIVER PARAMETERS	5.1.2.2.3	M		
35	SET PL_EXTENSIONS	5.1.2.2.4	O		
36	LEC	5.1.2.2.5	M		
37	SET CONTROL PARAMETERS	5.1.2.2.6	M		
38	Initialized values of session control variables	Table 5-5	M	off, off, false, off, 0,0,0	

A2.2.5 Duplex-Simplex Operations

Item	Description	Reference	Status	Values Allowed	Support
39	Full duplex operations	5.4.2, Tables 5-6, 5-7, 5-8	M		
40	Half duplex operations	5.4.3, Table 5-9, 5-10, 5-11	O		
41	Simplex operations	5.4.4, Table 5-12	O		

A2.2.6 Interfaces with Physical Layer

Item	Description	Reference	Status	Values Allowed	Support
Output Interfaces					
42	TRANSMIT (parameter)	5.5.1.1	M	On, Off	
43	Frame Interface to C&S sublayer	5.5.1.2	M		
44	MODULATION (parameter)	5.5.1.3	M	On, Off	
45	RANGING (parameter)	5.5.1.4	M	On, Off	
46	PL Input interfaces	5.5.2	M		
Sending Operations					
47	Session Establishment	5.6.1	M		
48	Reset NEED_PLCW or NEED_STATUS_REPORT	5.2.2.7.2	M	True, False	
49	Setting No_Frames_Pending	5.3.2.3	M	True, False	
50	Setting OUTPUT_FIFO=empty	5.3.2.2	M	True, False	
Receiving Operations					
51	Frame Reception	5.7.1	M		
52	Frame Validation Criteria	5.7.2	M		
53	Validated Frame Processing	5.7.3	M		

A2.2.7 SPDU Directive Types

Item	Description	Reference	Status	Values Allowed	Support
SPDU Type 1 Directives					
54	SET TRANSMITTER PARAMETERS	B2	M		
55	SET CONTROL PARAMETERS	B3	M		
56	SET RECEIVER PARAMETERS	B4	M		
57	SET V(R)	B5	O		
58	REPORT REQUEST	B6	M		
59	SET PL EXTENSIONS	B7	O		
60	REPORT SOURCE SPACECRAFT ID	B8	O		
SPDU Type 2 Directives					
61	TIME DISTRIBUTION	ANNEX C	O		
SPDU Type 4					

62	LEC	ANNEX D	O		
SPDU Type 5 Directives					
63	LEC	ANNEX E	M	M – Demand; O – Query/Response	
64	REPORT REQUEST	ANNEX E	M		
65	SET V(R)	ANNEX E	O		
66	REPORT SOURCE SPACECRAFT ID	ANNEX E	O		
67	SERVICE REQUEST	ANNEX E	M		
68	SET FIXED-LENGTH FRAME	ANNEX E	O		
69	PN RANGING	ANNEX E	O		

A2.2.8 Communications Operations Procedure for Proximity-1 Links

Item	Description	Reference	Status	Values Allowed	Support
70	Implement COP-P Protocol	6	M		
71	DATA SERVICES OPERATIONS (COP-P): Modulo-256 counters will be used for sequence number in the COP-P protocol	6	M		
72	DATA SERVICES OPERATIONS (COP-P): Modulo-16384 counters will be used for sequence number in the COP-P protocol	6	O		
73	SENDING PROCEDURES (FOP-P)	6.1	M		
74	The FOP-P Sent Frame Queue	6.2.1	M		

A2.2.9 FOP-P Variables

Item	Description	Reference	Status	Values Allowed	Support
75	VE(S)	6.2.2 a)	M		
76	V(S)	6.2.2 b)	M		
77	VV(S)	6.2.2 c)	M		
78	N(R):	6.2.2 d)	M		
79	NN(R):	6.2.2 e)	M		
80	R(R):	6.2.2 f)	M		
81	RR(R):	6.2.2 g)	M		
82	NEED_PLCW/NEED_STATUS_REPORT	6.2.2 h)	M		
83	SYNCH_TIMER	6.2.2 i)	M		
84	RESYNC	6.2.2 j)	M		
85	FOP-P General Procedures	6.2.3.1	M		
86	Set V(R) persistent activity	6.2.3.2	O		
87	Configure the SET V(R) persistent activity	6.2.3.2.1	O		
88	Execute the SET V(R) persistent activity	6.2.3.2.2	O		
89	FOP-P State Table	6.2.3.3	M		
90	DATA SERVICES RECEIVING OPERATIONS	6.3	M		
91	FARM-P STATE TABLE	6.3.1	M		

A2.2.10 Internal FARM-P Parameters

Item	Description	Reference	Status	Values Allowed	Support
92	V(R):	6.3.2 a)	M		
93	R(S):	6.3.2 b)	M		
94	N(S):	6.3.2 c)	M		
95	EXPEDITED_FRAME_COUNTER	6.3.2 d)	M		
96	INTERFACE TO THE I/O SUBLAYER	6.3.3	M		

A2.2.11 Management Information Base Parameters (Alphabetical)

Item	Description	Reference	Status	Values Allowed	Support
97	NACKs_Allowed	5.2.3.19	O		
98	Acquisition_Idle_Duration	5.2.3.4	M		
99	Carrier_Loss_Timer_Duration	5.2.3.6	M		
100	Carrier_Only_Duration	5.2.3.3	M		
101	Comm_Change_Lifetime	5.2.3.10	M		
102	Comm_Change_Notification	5.2.3.9	M		
103	Comm_Change_Response	5.2.3.8	M		
104	Comm_Change_Waiting_Period	5.2.3.7	M		
105	Drop_Carrier_Duration	table 5-1	M		
106	Hail_Lifetime	5.2.3.14	M		
107	Hail_Notification	5.2.3.13	M		
108	Hail_Response	5.2.3.12	M		
109	Hail_Wait_Duration	5.2.3.11	M		
110	Hailing_Channel	5.1.1.1, ANNEX H2	M		
111	Hailing_Data_Rate	5.2.3.15	M		
112	Hailing_Symbol/_Rate	5.2.3.15	M		
113	Interval_Clock	5.3.1.1.1	M		
114	Maximum_Failed_Token_Passes	5.4.3, table 5-9	O		
115	Persistence_Wait_Time	5.4.2, table 5-7	M		
116	PLCW_Repeat_Interval	5.2.3.18	M		
117	Receive_Duration	5.2.3.17	O		
118	Resync_Lifetime	6.2.3.2	O		
119	Resync_Local	6.2.3.2.1, 6.2.3.3	M		
120	Resync_Remote	6.3.1	M		
121	Resync_Notification	6.2.3.2	O		
122	Resync_Response	6.2.3.2	O		
123	Resync_Waiting_Period	6.2.3.2	O		
124	Send_Duration	5.2.3.16	O		
125	Synch_Timeout	6.2.2	M		
126	Tail_Idle_Duration	5.2.3.5	M		
127	Test_Source	5.2.3.2	M		
128	Transmission_Window	6.2.3.3	M		

A2.2.12 Notifications to Vehicle Controller

Item	Description	Reference	Status	Values Allowed	Support
129	RESULT OF PERSISTENT ACTIVITY	ANNEX G #1	M		
130	STATE CONTROL STATUS	ANNEX G #2	M		
131	INVALID FRAME SOURCE	ANNEX G #3	M		
132	TIMING SERVICES INSTANCE	ANNEX G #4	M		
133	NO CARRIER RECEIVED - HALF DUPLEX	ANNEX G #5	O		
134	NO DATA TRANSFERRED - HALF DUPLEX	ANNEX G #6	O		
135	SENDER EXCEEDED PRESCRIBED TRANSMISSION PERIOD - HALF DUPLEX	ANNEX G #7	O		
136	COP-P LOSS OF SYNCHRONIZATION	ANNEX G #8	M		
137	CARRIER_LOSS_TIMER UNDERFLOWS	ANNEX G #9	M		
138	END OF SESSION (# octets received)	ANNEX G #10	M		
139	CARRIER ONLY RECEIVED	ANNEX G #11	M		

ANNEX B

TYPE 1 SPDU—FIXED-LENGTH 16-BIT DIRECTIVES/REPORTS FIRST GENERATION

(NORMATIVE)

Variable-Length SPDU	**SPDU Header (1 octet, fixed)**			**SPDU Data Field (0–15 octets)**
	Format ID (Bit 0)	SPDU Type Identifier (Bits 1,2,3)	Length of SPDU Data Field (Bits 4,5,6,7)	(Contains one or more protocol objects, i.e., directives, reports)
Type 1	'0'	'000'	Length in Octets	Fixed-length 16-bit Directives/Reports 1st Generation
NOTE – Directives and Reports may be multiplexed within the SPDU Data Field.				

Figure B-1: Type 1 SPDU

									Directive Type 3 Bits (13, 14, 15)
Mode (0,1,2)	Data Rate (3,4,5,6)	Modulation (7)	Data Encoding (8,9)	Frequency (10,11,12)					'000' = SET TRANSMITTER PARAMETERS
Time Sample (1,2,3,4,5)	Duplex (6,7,8)	Reserved (9,10)	Remote No More Data	Token (12)					'001' = SET CONTROL PARAMETERS
Mode (0,1,2)	Data Rate (3,4,5,6)	Modulation (7)	Data Encoding (8,9)	Frequency (10,11,12)					'010' = SET RECEIVER PARAMETERS
Receiver Frame Sequence Number (SEQ_CTRL_FSN) (0,1,2,3,4,5,6,7)	Reserved (8,9,10,11,12)								'011' = SET V(R)
Reserved (0,1,2)	Status Report Request (3,4,5,6,7)	Time-Tag Request (8,9,10)	PCID 0 PLCW Request	PCID 1 PLCW Request					'100' = REPORT REQUEST
									'101' = Reserved
Direction (0)	Freq. Table (1)	Rate Table (2)	Carrier Mod. (3,4)	Data Mod. (5,6)	Mode Select (7,8)	Scrambler (9,10)	Diff. Encoding	R-S Code (12)	'110' = SET PL EXTENSIONS
Source Spacecraft ID (0.1.2.3.4.5.6.7.8.9)	Reserved (10,11,12)								'111' = REPORT SOURCE SCID

Figure B-2: Type 1 SPDU Data Field Contents

B1 GENERAL

Annex B is the **only** place in the document where the Directive Type identifier occupies Bits 13–15 (the high-order bits of the 16-bit directive word). This placement reflects a historical vendor convention and is opposite to the identifier placement used in the fixed-length directives defined in Section 3, where the Format ID begins at Bit 0. Implementors should take care not to conflate the two conventions.

B1.1 The Directive/Report/PLCW SPDU shall be used for space link supervisory configuration and control of the transceiver and its operation.

B1.2 The SPDU data field shall be a container that can hold up to seven 16-bit discrete self-delimiting and self-identifying directives:

a) each directive shall have a specific functionality;

b) each directive shall be 16 bits in length and self-identified by the value in the Directive Type field (contained in bits 13, 14, and 15 of the directive);

c) the directives shall be concatenated without intervening bits in the data field.

NOTE – Figure B-2 shows the Type 1 SPDU Data Field Contents.

B2 SET TRANSMITTER PARAMETERS DIRECTIVE

B2.1 GENERAL

The SET TRANSMITTER PARAMETERS directive shall consist of six fields, positioned contiguously in the following sequence, described from LSB, Bit 15, to MSB, Bit 0:

a) Directive Type (3 bits);

b) Transmitter Frequency (3 bits);

c) Transmitter Data Encoding (2 bits);

d) Transmitter Modulation (1 bit);

e) Transmitter Data Rate (4 bits);

f) Transmitter (TX) Mode (3 bits).

NOTE – The structural components of the SET TRANSMITTER PARAMETERS directive are visually mapped below:

Bit 0 … Bit 15

TX Mode 3 bits	TX Data Rate 4 bits	TX Modulation 1 bit	TX Data Encoding 2 bits	TX Frequency 3 bits	Directive Type 3 bits
0,1,2	3,4,5,6	7	8,9	10,11,12	13,14,15

B2.2 DIRECTIVE TYPE

B2.2.1 Bits 13–15 of the SET TRANSMITTER PARAMETERS directive shall contain the Directive Type.

B2.2.2 The 3-bit Directive Type field identifies the type of protocol control directive and shall contain the binary value ‘000’ for the SET TRANSMITTER PARAMETERS directive.

B2.3 TRANSMITTER FREQUENCY

B2.3.1 General

Bits 10–12 of the SET TRANSMITTER PARAMETERS directive shall be used to set the transmitter frequency of the partnered transceiver to the desired value.

B2.3.2 Return Transmitter Frequency

In the context of the forward link (e.g., Orbiter as Initiator; Landed Asset as Responder), this 3-bit field shall define the transmit frequency of the responder by selecting one of eight return channels (Ch0R–Ch7R) according to the mapping below. Actual frequency assignments are given in the PL (see section 5).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch0R	Ch1R	Ch2R	Ch3R	Ch4R	Ch5R	Ch6R	Ch7R

B2.4 TRANSMITTER DATA ENCODING

Bits 8–9 of the SET TRANSMITTER PARAMETERS directive shall contain the following coding options:

a) ‘00’ = low density parity check (LDPC)(2048,1024) rate 1/2 code (see reference [2]);

b) ‘01’ = Convolutional Code(7,1/2) (G2 vector inverted) with attached CRC-32 (see reference [4]);

c) ‘10’ = Bypass all codes;

d) ‘11’ = Concatenated Codes: R-S(204,188), CC(7,1/2).

NOTE – R-S(204,188) with CC(7,1/2) code is an ETSI standard. This option is not required for cross-support (see reference [J1] for more details).

B2.5 TRANSMITTER MODULATION

Bit 7 of the SET TRANSMITTER PARAMETERS directive shall contain the transmission modulation options:

a) ‘0’ = Coherent frequency Phase Shift Keying (PSK);

b) ‘1’ = Non-coherent frequency PSK.

B2.6 TRANSMITTER DATA RATE

B2.6.1 Bits 3–6 of the SET TRANSMITTER PARAMETERS directive shall contain the transmission data rates in kb/s (e.g., 4 = 4000 b/s) prior to encoding. The valid rates and bit patterns are shown below.

NOTE – Because of the NASA Mars Surveyor Project 2001 Odyssey implementation, there is an added constraint on the use of the values in the Data Rate field for 8, 32, 128, and 256 kb/s. Data rate selection is linked to the modulation field value as shown in the sections below. NC indicates non-coherent PSK, and C indicates coherent PSK. R1 through R4 indicate the field is reserved for future definition by the CCSDS. 1, 512, 1024, and 2048 kb/s data rates can only be selected using the SET PL EXTENSIONS directive (see B7).

B2.6.2 Ordered by Data Rate:

‘1000’	‘1001’	‘0000’	‘0001’	‘1100’	‘0010’	‘0011’	‘1101’	‘0100’	‘0101’	‘0110’	‘0111’	‘1010’	‘1011’	‘1110’	‘1111’
2	4	8 NC	8 C	16	32 NC	32 C	64	128 NC	128 C	256 NC	256 C	R1	R2	R3	R4

B2.6.3 Ordered by Bit Pattern:

‘0000’	‘0001’	‘0010’	‘0011’	‘0100’	‘0101’	‘0110’	‘0111’	‘1000’	‘1001’	‘1010’	‘1011’	‘1100’	‘1101’	‘1110’	‘1111’
8 NC	8 C	32 NC	32 C	128 NC	128 C	256 NC	256 C	2	4	R1	R2	16	64	R3	R4

B2.6.4 Coded symbol (R_{cs}) and data rate (R_d) table:

Table B-1: Transmitter Rate Conversion Values

Coded Symbol Rates (R_{cs})	Uncoded Data Rates (R_d) $R_d = R_{cs}$	Convolutionally Coded Data Rates (R_d) $R_d = .5 * R_{cs}$	LDPC computed data rates (R_d) $R_d = .48484 * R_{cs}$
1000	1000	N/A	N/A
2000	2000	1000	969.6969697
4000	4000	2000	1939.393939
8000	8000	4000	3878.787879
16000	16000	8000	7757.575758
32000	32000	16000	15515.15152
64000	64000	32000	31030.30303
128000	128000	64000	62060.60606
256000	256000	128000	124121.2121
512000	512000	256000	248242.4242
1024000	1024000	512000	496484.8485
2048000	2048000	1024000	992969.697
4096000	N/A	2048000	1985939.394

B2.6.5 1, 512, 1024, and 2048 kb/s data rates can be selected only by using the SET PL EXTENSIONS directive (see B7).

B2.7 TRANSMITTER MODE

Bits 0–2 of the SET TRANSMITTER PARAMETERS directive shall contain the Transmitter Mode options. This field identifies the operating mode of the transmitter:

a) ‘000’ = Mission-Specific;

b) ‘001’ = Proximity-1 Protocol;

c) ‘010’ = Mission-Specific;

d) ‘011’ = Mission-Specific;

e) ‘100’ = Mission-Specific;

f) ‘101’ = Mission-Specific;

g) ‘110’ = Reserved by CCSDS;

h) ‘111’ = Reserved by CCSDS.

B3 SET CONTROL PARAMETERS

B3.1 GENERAL

B3.1.1 The SET CONTROL PARAMETERS directive shall consist of six fields, positioned contiguously in the following sequence, described from LSB, Bit 15, to MSB, Bit 0:

a) Directive Type (3 bits);

b) Token (1 bit);

c) Remote No More Data (1 bit);

d) Reserved (2 bits);

e) Duplex (3 bits);

f) Time Sample (6 bits).

B3.1.2 This directive specifies up to four control parameters simultaneously: 1) the token for half-duplex operations; 2) the Remote No More Data condition for session termination in full or half duplex; 3) the Duplex parameter; 4) the quantity of time samples taken during timing services.

NOTE – The structural components of the SET CONTROL PARAMETERS directive are visually mapped below:

Bit 0					Bit 15
Time Sample 6 bits	Duplex 3 bits	Reserved 2 bits	Remote No More Data 1 bit	Token 1 bit	Directive Type 3 bits
0,1,2,3,4,5	6,7,8	9,10	11	12	13,14,15

B3.2 DIRECTIVE TYPE

B3.2.1 Bits 13–15 of the SET CONTROL PARAMETERS directive shall contain the Directive Type.

B3.2.2 The 3-bit Directive Type field identifies the type of protocol control directive and shall contain the binary value ‘001’ to identify the SET CONTROL PARAMETERS directive.

B3.3 TOKEN

Bit 12 of the SET CONTROL PARAMETERS directive shall contain the value of the Token field, which either indicates no change in transmit permission or specifies the transmit state for the remote node:

a) ‘0’ = No Change (i.e., ignore this field);

b) ‘1’ = Transmit.

B3.4 REMOTE NO MORE DATA

Bit 11 of the SET CONTROL PARAMETERS directive shall contain the Remote No More Data field. This field notifies the remote node either that there is no change in the remote node’s data state or that it has no more data to send, in which case the session may be terminated when the remote node also has no more data to send:

a) ‘0’ = No Change (i.e., ignore this field);

b) ‘1’ = Remote Node has No More Data to Send (RNMD).

B3.5 RESERVED

Bits 9–10 of the SET CONTROL PARAMETERS directive shall contain spares and be set to ‘all zero’.

B3.6 DUPLEX

Bits 6–8 of the SET CONTROL PARAMETERS directive shall contain the Duplex field, which notifies the remote node of any potential change in the remote node’s Duplex state:

a) ‘000’ = No Change (i.e., ignore this field);

b) ‘001’ = Full Duplex;

c) ‘010’ = Half Duplex;

d) ‘011’ = Simplex Transmit;

e) ‘100’ = Simplex Receive;

f) ‘101’ = Reserved;

g) ‘110’ = Reserved;

h) ‘111’ = Reserved.

B3.7 TIME SAMPLE

Bits 0–5 of the SET CONTROL PARAMETERS directive shall contain the Time Sample field. When this field is non-zero, it notifies the recipient to capture the time and FSN associated with the protocol timing service (see reference [6], section 5) for the next *n* frames received, where *n* is the number of Transfer Frames contained within the Time Sample Field.

B4 SET RECEIVER PARAMETERS DIRECTIVE

B4.1 GENERAL

The SET RECEIVER PARAMETERS directive shall consist of six fields, positioned contiguously in the following sequence, described from LSB, Bit 15, to MSB, Bit 0:

a) Directive Type (3 bits);

b) Receiver Frequency (3 bits);

c) Receiver Data Decoding (2 bits);

d) Receiver Modulation (1 bit);

e) Receiver Data Rate (4 bits);

f) Receiver (RX) Mode (3 bits).

NOTE – The structural components of the SET RECEIVER PARAMETERS directive are visually mapped below:

Bit 0 Bit 15

RX Mode 3 bits	RX Rate 4 bits	RX Modulation 1 bit	RX Data Decoding 2 bits	RX Frequency 3 bits	Directive Type 3 bits
0,1,2	3,4,5,6	7	8,9	10,11,12	13,14,15

B4.2 DIRECTIVE TYPE

B4.2.1 Bits 13–15 of the SET RECEIVER PARAMETERS directive shall contain the Directive Type.

B4.2.2 The 3-bit Directive Type field identifies the type of protocol control directive and shall contain the binary value ‘010’ for the SET RECEIVER PARAMETERS directive.

B4.3 RECEIVER FREQUENCY

B4.3.1 General

Bits 10–12 of the SET RECEIVER PARAMETERS directive shall be used to set the receiver frequency of the partnered transceiver to the desired value.

B4.3.2 Forward Receive Frequency

In the context of the forward link (e.g., Orbiter as Initiator, Landed Asset as Responder), this 3-bit field shall define the receive frequency of the responder by selecting one of eight forward channels (Ch0F–Ch7F) according to the mapping below. Actual frequency assignments are given in the PL (see section 5).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch0F	Ch1F	Ch2F	Ch3F	Ch4F	Ch5F	Ch6F	Ch7F

B4.4 RECEIVER DATA DECODING

Bits 8–9 of the SET RECEIVER PARAMETERS directive shall contain the following coding options:

‘00’ = LDPC (2048,1024) rate 1/2 code (see reference [2]);

‘01’ = Convolutional Code(7,1/2) (G2 vector inverted) with attached CRC-32 (see reference [4]);

‘10’ = Bypass all codes;

‘11’ = Concatenated Codes: R-S(204,188), CC(7,1/2).

NOTE – R-S(204,188) with CC(7,1/2) code is an ETSI standard. This option is not required for cross support. It is the R-S(255,239) code shortened by q = 51 (see reference [J1] for more details).

B4.5 RECEIVER MODULATION

Bit 7 of the SET RECEIVER PARAMETERS directive shall contain the following transmission modulation options:

a) ‘0’ = Coherent frequency PSK;

b) ‘1’ = Non-coherent frequency PSK.

B4.6 RECEIVER DATA RATE

B4.6.1 Bits 3–6 of the SET RECEIVER PARAMETERS directive shall contain one of the following receiver data rates in kb/s (e.g., 4 = 4000 b/s) after decoding.

NOTE – Because of the NASA Mars Surveyor Project 2001 Odyssey implementation, there is an added constraint on the use of the values in the Data Rate field for 8, 32, 128, and 256 kb/s. Data rate selection is linked to the modulation field value as shown in the tables below (‘NC’ indicates non-coherent, and c indicates coherent). Fields R1 through R4 are reserved for future definition by the CCSDS. 1, 512, 1024, and 2048 kb/s data rates can only be selected using the SET PL EXTENSIONS directive (see B7).

B4.6.2 Ordered by Data Rate:

‘1000’	‘1001’	‘0000’	‘0001’	‘1100’	‘0010’	‘0011’	‘1101’	‘0100’	‘0101’	‘0110’	‘0111’	‘1010’	‘1011’	‘1110’	‘1111’
2	4	8 NC	8 C	16	32 NC	32 C	64	128 NC	128 C	256 NC	256 C	R1	R2	R3	R4

B4.6.3 Ordered by Bit Pattern:

‘0000’	‘0001’	‘0010’	‘0011’	‘0100’	‘0101’	‘0110’	‘0111’	‘1000’	‘1001’	‘1010’	‘1011’	‘1100’	‘1101’	‘1110’	‘1111’
8 NC	8 C	32 NC	32 C	128 NC	128 C	256 NC	256 C	2	4	R1	R2	16	64	R3	R4

B4.6.4 Coded symbol (R_{cs}) and data rate (R_d) table:

Table B-2: Receiver Rate Conversion Values

Coded Symbol Rates (R_{cs})	Uncoded Data Rates (R_d) $R_d = R_{cs}$	Convolutionally Coded Data Rates (R_d) $R_d = .5 * R_{cs}$	LDPC Computed Data Rates (R_d) $R_d = .48484 * R_{cs}$
1000	1000	N/A	N/A
2000	2000	1000	969.6969697
4000	4000	2000	1939.393939
8000	8000	4000	3878.787879
16000	16000	8000	7757.575758
32000	32000	16000	15515.15152
64000	64000	32000	31030.30303
128000	128000	64000	62060.60606
256000	256000	128000	124121.2121
512000	512000	256000	248242.4242
1024000	1024000	512000	496484.8485
2048000	2048000	1024000	992969.697
4096000	N/A	2048000	1985939.394

NOTE – 1, 512, 1024, and 2048 kb/s data rates can only be selected using the SET PL EXTENSIONS directive (see B7).

B4.7 RECEIVER MODE

Bits 0–2 of the SET RECEIVER PARAMETERS directive shall contain the receiver mode options. This field identifies the operating mode of the receiver:

a) ‘000’ = Mission-Specific;

b) ‘001’ = Proximity-1 Protocol;

c) ‘010’ = Mission-Specific;

d) ‘011’ = Mission-Specific;

e) ‘100’ = Mission-Specific;

f) ‘101’ = Mission-Specific;

g) ‘110’ = Reserved by CCSDS;

h) ‘111’ = Reserved by CCSDS.

B5 SET V(R) DIRECTIVE

B5.1 GENERAL

The SET V(R) directive shall consist of three fields, positioned contiguously in the following sequence, described from LSB, Bit 15, to MSB, Bit 0:

a) Directive Type (3 bits);

b) Spare (5 bits);

c) Receiver FSN (SEQ_CTRL_FSN) (8 bits).

NOTE – The structural components of the SET V(R) directive are visually mapped below:

Bit 0 Bit 15

Receiver Frame Sequence Number SEQ_CTRL_FSN 8 bits	Spare 5 bits	Directive Type 3 bits
0,1,2,3,4,5,6,7	8,9,10,11,12	13,14,15

B5.2 DIRECTIVE TYPE

B5.2.1 Bits 13–15 of the SET V(R) directive shall contain the Directive Type.

B5.2.2 The 3-bit Directive Type field identifies the type of protocol control directive and shall contain the binary value ‘011’ to identify the SET V(R) directive.

B5.3 SPARE

Bits 8–12 of the SET V(R) directive shall contain spare bits, set to ‘all zero’.

B5.4 RECEIVER FRAME SEQUENCE NUMBER

Bits 0–7 of the SET V(R) directive shall contain the value of the FSN (SEQ_CTRL_FSN) to which the receiving unit of the partnered transceiver is to be set.

B6 REPORT REQUEST DIRECTIVE

B6.1 GENERAL

The REPORT REQUEST directive is the mechanism by which either (1) a status report, (2) a time-tag, or (3) a PLCW per PCID can be requested of a protocol node. It shall consist of seven fields, positioned contiguously in the following sequence, described from LSB, Bit 15, to MSB, Bit 0:

a) Directive Type (3 bits);

b) PCID 1 PLCW Request (1 bit);

c) PCID 0 PLCW Request (1 bit);

d) Time-Tag Request (3 bits);

e) Status Request (5 bits);

f) Spare (3 bits).

NOTE – The structural components of the REPORT REQUEST directive are shown in figure B-3.

Bit 0 … Bit 15

Spare 3 bits	Status Report Request 5 bits	Time-Tag Request 3 bit	PCID 0 PLCW Request 1 bit	PCID 1 PLCW Request 1 bit	Directive Type 3 bits
0,1,2	3,4,5,6,7	8,9,10	11	12	13,14,15

Figure B-3: Report Request

B6.2 DIRECTIVE TYPE

B6.2.1 Bits 13–15 of the REPORT REQUEST directive shall contain the Directive Type.

B6.2.2 The 3-bit Directive Type field identifies the type of protocol control directive and shall contain the binary value ‘100’.

B6.3 PHYSICAL CHANNEL ID 1 PLCW REPORT REQUEST FIELD

Bit 12 of the REPORT REQUEST directive shall indicate whether a PLCW report for PCID 1 is required:

a) ‘1’ = PLCW report is needed for PCID 1; transmit this report on the same PCID that carried the report request.

b) ‘0’ = PLCW report is not required.

B6.4 PHYSICAL CHANNEL ID 0 PLCW REPORT REQUEST FIELD

Bit 11 of the REPORT REQUEST directive shall indicate whether a PLCW report for PCID 0 is required:

a) ‘1’ = PLCW report is needed for PCID 0; transmit this report on the same PCID that carried the report request.

b) ‘0’ = PLCW report is not required.

B6.5 TIME-TAG REQUEST FIELD

Bits 8–10 of the directive shall indicate a request to the remote transceiver to initiate a protocol time-tag exchange when set to a value other than ‘000’ (see reference [6], section 5).

B6.6 STATUS REPORT REQUEST

B6.6.1 The value contained in bits 3–7 of the REPORT REQUEST directive shall indicate the type of status report desired.

B6.6.2 A value of ‘00000’ indicates that a status report is not required.

B6.6.3 All status report types are reserved for CCSDS use.

B6.7 SPARES

Bits 0–2 of the REPORT REQUEST directive shall contain spare bits set to ‘all zero’.

B7 SET PL EXTENSIONS

B7.1 OVERVIEW

The SET PL EXTENSIONS directive is the mechanism by which additional PL parameters can be enabled or disabled. It is transferred across the space link from the local to the remote transceiver. This directive is provided for compatibility between transceivers with extensions in addition to those discussed in this Recommended Standard.

B7.2 GENERAL

The SET PL EXTENSIONS directive shall consist of ten fields, positioned contiguously in the following sequence, described from LSB, Bit 15, to MSB, Bit 0:

a) Directive Type (3 bits);

b) R-S Code (1 bit);

c) Differential Mark Encoding (1 bit);

d) Scrambler (2 bits);

e) Mode Select (2 bits);

f) Data Modulation (2 bits);

g) Carrier Modulation (2 bits);

h) Rate Table (1 bit);

i) Frequency Table (1 bit);

j) Direction (1 bit).

NOTE – The structural components of the SET PL EXTENSIONS directive are shown in figure B-4.

Bit 0 … Bit 15

Direction 1 bit	Freq Table 1 bit	Rate Table 1 bit	Carrier MOD 2 bits	Data MOD 2 bits	Mode Select 2 bits	Scrambler 2 bits	Differential Mark Encoding 1 bit	R-S Code 1 bit	Directive Type 3 bits
0	1	2	3,4	5,6	7,8	9,10	11	12	13,14,15

Figure B-4: SET PL EXTENSIONS

B7.3 DIRECTIVE TYPE

B7.3.1 Bits 13–15 of the SET PL EXTENSIONS directive shall contain the Directive Type.

B7.3.2 The 3-bit Directive Type field identifies the directive type and shall contain the binary value ‘110’.

B7.4 REED-SOLOMON CODE

B7.4.1 Bit 12 of the SET PL EXTENSIONS directive shall indicate which R-S Code is used:

a) ‘0’ = R-S(204,188) code;

b) ‘1’ = R-S(255,239) code.

B7.4.2 Neither of these R-S Codes is specified by CCSDS in other Recommended Standards, therefore, they are not required for cross-support.

B7.5 DIFFERENTIAL MARK ENCODING

Bit 11 of the SET PL EXTENSIONS directive shall indicate whether Differential Mark Encoding is enabled:

a) ‘0’ = No differential encoding;

b) ‘1’ = Differential encoding enabled. The current data bit undergoes an exclusive OR operation with the previously transmitted bit to determine the value of the current transmitted bit. When the current data bit is a ‘1’, then the current encoder output bit level changes relative to the previous output value. If the data bit is a ‘0’, then the current encoder output bit level remains constant relative to the previous output value (see table below).

NOTE – Differential coding must be enabled only for missions that interoperate with NASA Mars Reconnaissance Orbiter (MRO).

B7.6 SCRAMBLER

B7.6.1 Bits 9–10 of the SET PL EXTENSIONS directive shall indicate whether digital bit scrambling is used, and if so – which type:

a) ‘00’ = Bypass all bit scrambling;

b) ‘01’ = Consultative Committee for International Telephony and Telegraphy (CCITT) bit scrambling enabled (see reference [J2]);

c) ‘10’ = Bypass all bit scrambling;

d) ‘11’ = Intelsat Earth Station Standards (IESS) bit scrambling enabled (see reference [J3]).

B7.6.2 These Scrambler options are not specified by CCSDS in other Recommended Standards and not required for cross-support.

B7.7 MODE SELECT

Bits 7–8 of the SET PL EXTENSIONS directive shall indicate the type of carrier suppression used:

a) ‘00’ = Suppressed Carrier (requires Modulation Index of 90° on transmit side and Differential Mark Encoding/Decoding on transmit/receive sides);

b) ‘01’ = Residual Carrier;

c) ‘10’ = Reserved;

d) ‘11’ = Reserved.

NOTE – Option a) is required only for missions that interoperate with NASA MRO.

B7.8 DATA MODULATION

Bits 5–6 of the SET PL EXTENSIONS directive shall indicate the type of data modulation used:

a) ‘00’ = non-return to zero-level (NRZ-L);

b) ‘01’ = Bi-Phase-Level (Manchester);

c) ‘10’ = Reserved;

d) ‘11’ = Reserved.

NOTE – NRZ-L is required only for missions that interoperate with NASA MRO.

B7.9 CARRIER MODULATION

Bits 3–4 of the SET PL EXTENSIONS directive shall indicate the type of carrier modulation to be used:

a) ‘00’ = No Modulation;

b) ‘01’ = PSK;

c) ‘10’ = Frequency Shift Keying (FSK);

d) ‘11’ = Quadrature Phase Shift Keying (QPSK).

NOTE – FSK and QPSK are not required for cross-support.

B7.10 RATE TABLE

Bit 2 of the SET PL EXTENSIONS directive shall indicate which set of data rates shall be used prior to encoding.

a) ‘0’ = Default Set defined in the Data Rate Field of the SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS Directives in this Annex;

b) ‘1’ = Extended PL Data Rate Set defined below.

‘0000’ = 1000 b/s	‘0100’ = 16000 b/s	‘1000’ = 256000 b/s	‘1100’ = Reserved
‘0001’ = 2000 b/s	‘0101’ = 32000 b/s	‘1001’ =512000 b/s	‘1101’ = Reserved
‘0010’ = 4000 b/s	‘0110’ = 64000 b/s	‘1010’ = 1024000 b/s	‘1110’ = Reserved
‘0011’ = 8000 b/s	‘0111’ = 128000 b/s	‘1011’ = 2048000 b/s	‘1111’ = Reserved

NOTE – Option a) is required for cross-support and option b) – for cross-support with data rates less than 2000 b/s and greater than 256000 b/s.

B7.11 CODED SYMBOL (R_{CS}) AND DATA RATES (R_D)

The values in this table indicate the coded symbol and effective data rates resulting from the application of different coding schemes to the Extended PL Data Rate Set.

Table B-3: Rate Conversion Values

Coded Symbol Rates (R_{cs})	Uncoded Data Rates (R_d) $R_d = R_{cs}$	Convolutionally Coded Data Rates (R_d) $R_d = .5 * R_{cs}$	LDPC Computed Data Rates (R_d) $R_d = .48484 * R_{cs}$
1000	1000	N/A	N/A
2000	2000	1000	969.6969697
4000	4000	2000	1939.393939
8000	8000	4000	3878.787879
16000	16000	8000	7757.575758
32000	32000	16000	15515.15152
64000	64000	32000	31030.30303
128000	128000	64000	62060.60606
256000	256000	128000	124121.2121
512000	512000	256000	248242.4242
1024000	1024000	512000	496484.8485
2048000	2048000	1024000	992969.697
4096000	N/A	2048000	1985939.394

B7.12 FREQUENCY TABLE

B7.13 GENERAL

Bit 1 of the SET PL EXTENSIONS directive shall indicate which set of frequencies to use:

a) ‘0’ = Channels 0-7 are defined in the Frequency Field of the SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS directives and specifically in the PL;

b) ‘1’ = Channels 8-15 are defined in the Extended PL Frequency Set specified below.

B7.13.1 Forward Link

In the context of the forward link (e.g., Orbiter as Initiator; Landed Asset as Responder), this 3-bit field shall define the receive frequency of the responder. Actual frequency assignments are given in the PL (see section 5).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch8F	Ch9F	Ch10F	Ch11F	Ch12F	Ch13F	Ch14F	Ch15F

B7.13.2 Return Link

In the context of the return link (e.g., Orbiter as Initiator; Landed Asset as Responder), this 3-bit field shall define the transmit frequency of the responder. Actual frequency assignments are given in the PL (see section 5).

‘000’	‘001’	‘010’	‘011’	‘100’	‘101’	‘110’	‘111’
Ch8R	Ch9R	Ch10R	Ch11R	Ch12R	Ch13R	Ch14R	Ch15R

B7.13.3 Direction

Bit 0 of the SET PL EXTENSIONS directive shall indicate if the fields in this directive apply to the transmit or receive side of the transceiver:

a) ‘0’ = transmit side;

b) ‘1’ = receive side.

B8 REPORT SOURCE SPACECRAFT ID

B8.1 GENERAL

The REPORT SOURCE SPACECRAFT ID is the mechanism by which the local transceiver can provide status of its source spacecraft ID to the remote transceiver across the link. It shall consist of three fields, positioned contiguously in the following sequence, described from LSB, Bit 15, to MSB, Bit 0:

a) Directive Type (3 bits);

b) Reserved (3 bits);

c) Source Spacecraft ID (10 bits).

NOTE – The structural components of the REPORT SOURCE SPACECRAFT ID are shown in figure B-5.

Bit 0 Bit 15

Source Spacecraft ID 10 bits	Reserved 3 bits	Directive Type 3 bits
0,1,2,3,4,5,6,7,8,9	10,11,12	13,14,15

Figure B-5: Report Source Spacecraft ID

B8.1.1 Directive Type

B8.1.1.1 Bits 13–15 of the REPORT SOURCE SPACECRAFT ID status report shall contain the Directive Type.

B8.1.1.2 The 3-bit Directive Type field identifies the type of status report and shall contain the binary value ‘111’.

B8.1.2 Reserved

Bits 10–12 of the REPORT SOURCE SPACECRAFT ID status report shall contain reserved bits, set to ‘all zero’.

B8.1.3 Source Spacecraft ID

Bits 0–9 of the REPORT SOURCE SPACECRAFT ID status report shall contain the SCID of the source of the Transfer Frame.

ANNEX C

TYPE 2 SPDU—TIME DISTRIBUTION

(NORMATIVE)

Variable-Length SPDU	**SPDU Header (1 octet, fixed)**			**SPDU Data Field (0–15 octets)**
	Format ID (Bit 0)	SPDU Type Identifier (Bits 1,2,3)	Length of SPDU Data Field (Bits 4,5,6,7)	(Contains one or more protocol objects, i.e., time distribution)
Type 2	‘0’	‘001’	Length in Octets	Time Distribution

Figure C-1: Type 2 SPDU

C1 GENERAL

C1.1 The TIME DISTRIBUTION SPDU data field is the container that describes both the type and value of the time entity for distribution.

C1.2 A single TIME DISTRIBUTION directive shall be contained within a TIME DISTRIBUTION SPDU.

C1.3 The format of the TIME DISTRIBUTION SPDU data field shall consist of four fields, positioned contiguously, in the following sequence:

a) TIME DISTRIBUTION Directive Type (1 octet);

b) Transceiver Clock (8 octets);

c) Send Side Delay (3 octets);

d) One-Way-Light-Time (3 octets).

C1.4 All time code fields in this directive shall comply with the CCSDS Unsegmented Time Code format (reference [3]).

NOTE – The structural components of the TIME DISTRIBUTION SPDU data field are shown in Figure C-2.

Octet 0			Octet 14
Directive Type 1 Octet	Transceiver Clock 8 Octets	Send Side Delay 3 Octets	One-Way-Light-Time 3 Octets

Figure C-2: Type 2 SPDU Time Distribution Data Field Contents

C2 TIME DISTRIBUTION DIRECTIVE

C2.1 GENERAL

C2.1.1 Octet 0 of the TIME DISTRIBUTION SPDU data field shall contain the TIME DISTRIBUTION Directive Type field indicating the function to be performed (if any) with the time contents.

C2.1.2 TIME DISTRIBUTION Types are:

a) ‘00000000’ = NULL;

b) ‘00000001’ = TIME TRANSFER;

c) all others = Reserved for CCSDS use.

C2.2 TRANSCEIVER CLOCK

C2.2.1 When the Time Distribution Type equals TIME TRANSFER,

a) octet 1 through octet 8 shall contain the value of the clock corresponding to when the trailing edge of the last bit of the ASM of the transmitted PLTU crosses the clock capture point within the transceiver;

b) this time code field shall be divided into 5 octets of coarse time and 3 octets of fine time (see reference [3]).

C2.2.2 Otherwise, this field shall contain reserved bits, set to ‘all zero’.

C2.3 SEND SIDE DELAY

C2.3.1 When the Time Distribution Type equals TIME TRANSFER,

a) octet 9 through octet 11 shall contain the delay time between the transceiver internal clock capture point and when the trailing edge of the last bit of the Sync-Marked Transfer Frame (SMTF) crossed the time reference point;

b) this time code field shall be divided into 1 octet of coarse time and 2 octets of fine time (see reference [3]).

C2.3.2 Otherwise, this field shall contain reserved bits, set to ‘all zero’.

C2.4 ONE WAY LIGHT TIME

C2.4.1 When the Time Distribution Type equals TIME TRANSFER and the mission has decided that one-way light time (OWLT) calculation should be used:

a) octet 12 through octet 14 shall contain the calculated OWLT from the instant when the trailing edge of the transmitted SMTF's final ASM bit crosses the time reference point of the initiator node to the destination node's time reference point;

b) this OWLT time code field shall be divided into 1 octet of coarse time and 2 octets of fine time (see reference [3]).

C2.4.2 Otherwise, this field shall contain reserved bits, set to 'all zero'.

ANNEX D

TYPE 4 SPDU—VARIABLE-LENGTH DIRECTIVES/REPORTS FIRST GENERATION

(NORMATIVE)

Variable-Length SPDU	**SPDU Header (1 octet, fixed)**			**SPDU Data Field (0–15 octets)**
	Format ID (Bit 0)	SPDU Type Identifier (Bits 1,2,3)	Length of SPDU Data Field (Bits 4,5,6,7)	(Contains one or more protocol objects, i.e., directives, reports)
Type 4	‘0’	‘011’	Length in Octets	Variable Length Directives/Reports 1st Generation

Figure D-1: Type 4 SPDU

Directive Name	Link Direction	Demand/Query	Query Response	RNMD	Token	Duplex/Simplex	Frequency	Polarization	Mod Index	Modulation	Spares	Coding	Inst. Link SNR	Symbol Rate
‘000’ = Link Establishment & Control Size = 56 bits														
3	1	1	1	1	1	3	5	1	3	4	2	6	8	16

Directive Name	PCID 0 - PLCW Request	PCID 1 - PLCW Request	Time-Tag Sample Request	Status Report Request
‘001’ = Report Request Size = 16 bits				
3	1	1	6	5

Directive Name	Reserved	Frame Sequence Number
‘010’ = Set V(R) Size = 16 bits		
3	5	8

Directive Name	Reserved	Source SCID
‘011’ = Report Source Spacecraft ID Size = 32 bits		
3	13	16

Directive Name
‘100’ = Reserved
3
‘101’ = Reserved
3
‘110’ = Reserved
3
‘111’ = Reserved
3

Figure D-2: Type 4 SPDU Data Field Contents

D1 GENERAL

D1.1 Type 4 SPDU directives shall be used for space link supervisory configuration and control of the transceiver and its operation at S-band.

D1.2 The SPDU data field shall contain 0 to 15 octets of supervisory data.

D1.3 Each directive shall perform a specific function.

D1.4 Each directive shall not exceed bits (15 octets × 8 bits) in length and shall be self-identified by the value in the directive name field (contained in bits 0 through 2 of the directive).

D1.5 Concatenation of the directives shall be allowed without intervening bits within the data field of the Type 4 SPDU as long as the total SPDU data field length does not exceed 120 bits.

D1.6 The size of each directive is defined in the MIB in ANNEX F.

NOTE – Figure D-2 shows the SPDU Type 4 directive contents. The size of each field in bits is given below the field names.

D2 LINK ESTABLISHMENT & CONTROL DIRECTIVE

D2.1 OVERVIEW

The LEC directive initiates communication via hailing, establishes a working channel, and enables follow-on link control changes between partnered transceivers. A *caller* transceiver initiates the link establishment process and manages the negotiation of the link session if required. A *responder* transceiver typically receives link establishment parameters from the caller. The caller initiates communication with a responder on a prearranged communications (hailing) channel using predefined controlling parameters. The caller and responder may negotiate the controlling parameters for the session with flexibility to operate between fully controlled (demand) and completely adaptive (negotiated by query). These roles are invariant throughout the link session.

To accomplish hailing, this directive is transmitted back-to-back within the same transfer frame to establish both the forward and return link initial communication conditions. Similarly, once the link is established, the same approach is used to move to the selected working channel. This directive is used in lieu of either the SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS or SET PL EXTENSIONS directives for SPDU Type 1 applications.

D2.2 SPECIFICATION

D2.2.1 General

The LEC directive shall consist of 15 fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 55 (see Figure D-3):

a) Directive Name (3 bits);

b) Link Direction (1 bit);

c) Demand/Query (1 bit);

d) Query Response (1 bit);

e) Remote No More Data (RNMD) (1 bit);

f) Token (1 bit);

g) Duplex/Simplex (3 bits);

h) Frequency (5 bits);

i) Polarization (1 bit);

j) Modulation Index (3 bits);

k) Modulation (4 bits);

l) Spares (2 bits);

m) Coding (6 bits);

n) Instantaneous Link Signal-to-Noise Ratio (SNR) (8 bits);

o) Symbol Rate (16 bits);

NOTE – The structural components of the LEC directive are shown in Figure D-3.

Directive Name	Link Direction	Demand/ Query	Query Response	RNMD	Token	Duplex/ Simplex	Frequency	Polarization	Mod Index	Modulation	Spares	Coding	Inst. Link SNR	Symbol Rate
3 bits	1 bit	1 bit	1 bit	1 bit	1 bit	3 bits	5 bits	1 bit	3 bits	4 bits	2 bits	6 bits	8 bits	16 bits
0–2	3	4	5	6	7	8–10	11-15	16	17-19	20–23	24-25	26–31	32–39	40–55

Figure D-3: LINK ESTABLISHMENT & CONTROL Directive

D2.2.2 Directive Name

D2.2.2.1 Bits 0–2 of the LEC directive shall contain the Directive Name.

D2.2.2.2 The 3-bit Directive Name field identifies the name of SPDU Type 4 protocol control directive and shall contain the binary value ‘000’ for the LEC directive.

D2.2.3 Link Direction

Bit 3 of the LEC directive shall indicate the link direction (Forward or Return):

a) ‘0’ = Return Link: the responder transmits, and the caller receives (typically a telemetry link). This directive sets the responder’s transmitter parameters.

b) ‘1’ = Forward Link: the caller transmits, and the responder receives (typically a command link). The caller (i.e., link initiator) is the node that transmits the Hail Directive. This directive sets the responder’s receiver parameters.

D2.2.4 Demand/Query

Bit 4 of the LEC directive shall contain either a Demand (caller expects the responder to accept the parameters in this directive 'as is') or as a Query to negotiate these link parameters specified in this directive between the caller and the responder. Used in hailing, moving onto a working channel, link control, and link termination.

a) '0' = Demand (Command);

b) '1' = Query (Link Negotiation).

D2.2.5 Query Response

Bit 5 of the LEC directive shall indicate whether the demand or the query was accepted or rejected by the responder.

a) '0' = ACK;

b) '1' = NACK.

D2.2.6 Remote No More Data

Bit 6 of the LEC directive shall contain the Remote No More Data (RNMD) field that plays a role in link termination. It notifies the caller either that there is no change in the responder's data state or that it has no more data to send, in which case the link may be terminated when the responder has no more data to send locally:

a) '0' = No Change (i.e., ignore this field);

b) '1' = Remote Node has No More Data to Send (RNMD).

D2.2.7 Token

Bit 7 of the LEC directive shall contain the value of the Token field, which either notifies the remote node that there is no change in transmit permission or commands the responder remote node to the transmit state:

a) '0' = No Change (i.e., ignore this field);

b) '1' = Transmit.

D2.2.8 Duplex/Simplex

Bits 8–10 of the LEC directive shall contain the Duplex/Simplex field, which notifies the remote node of any potential change in the directionality of its communication:

a) '000' = No Change;

b) '001' = Full Duplex;

c) '010' = Half Duplex;

d) '011' = Simplex Transmit;

e) '100' = Simplex Receive;

f) '101' = Reserved;

g) '110' = Reserved;

h) '111' = Reserved.

D2.2.9 Frequency

D2.2.9.1 General

Bits 11–15 of the LEC directive shall be used to set the frequency of the partnered transceiver to the desired value (either receive or transmit frequency based upon the value of the Link Direction field defined in D2.2.3).

D2.2.9.2 Forward Link

In the context of the forward link (i.e., forward direction defined by the caller which transmits the Hail—initiator/link manager), this 5-bit field shall define the receive frequency of the responder. Actual frequency assignments per channel are defined in the Proximity-1 PL (see reference [5]).

00000	00001	00010	00011	00100	00101	00110	00111	01000	01001	01010	01011	01100	01101	01110	01111	10000	10001	10010	10011	10100	10101	10110	10111	11000	11001	11010	11011	11100	11101	11110	11111
Ch0F	Ch1F	Ch2F	Ch3F	Ch4F	Ch5F	Ch6F	Ch7F	Ch8F	Ch9F	Ch10F	Ch11F	Ch12F	Ch13F	Ch14F	Ch15F	Ch16F	Ch17F	Ch18F	Ch19F	Ch20F	Ch21F	Ch22F	Ch23F	Ch24F	Ch25F	Ch26F	Ch27F	Ch28F	Ch29F	Ch30F	Ch31F

NOTE – Forward Hailing Channel 0 and 9 are identified in red text.

B3.2.9.3 Return Link

In the context of the return link (i.e., return direction defined by the responder that receives the Hail), this 5-bit field shall define the transmit frequency of the responder. Actual frequency assignments per channel are defined in the Proximity-1 PL (see reference [5]).

00000	00001	00010	00011	00100	00101	00110	00111	01000	01001	01010	01011	01100	01101	01110	01111	10000	10001	10010	10011	10100	10101	10110	10111	11000	11001	11010	11011	11100	11101	11110	11111
Ch0R	Ch1R	Ch2R	Ch3R	Ch4R	Ch5R	Ch6R	Ch7R	Ch8R	Ch9R	Ch10R	Ch11R	Ch12R	Ch13R	Ch14R	Ch15R	Ch16R	Ch17R	Ch18R	Ch19R	Ch20R	Ch21R	Ch22R	Ch23R	Ch24R	Ch25R	Ch26R	Ch27R	Ch28R	Ch29R	Ch30R	Ch31R

NOTE – Return Hailing Channel 0 and 9 are identified in red text.

D2.2.10 Polarization

Bit 16 of the LEC directive shall contain the Polarization field as follows:

a) '0' = Left Hand Circular Polarization;

b) '1' = Right Hand Circular Polarization.

D2.2.11 Modulation Index

Bits 17–19 of the LEC directive shall set the modulation index based on the values below:

a) '000' = 0 rad/pk (No Modulation);

b) '001' = 0.4 rad/pk;

c) '010' = 0.6 rad/pk;

d) '011' = 0.8 rad/pk;

e) '100' = π/3 rad/pk (60 degrees);

f) '101' = 1.15 rad/pk;

g) '110' = 1.3 rad/pk;

h) '111' = 1.4 rad/pk.

D2.2.12 Modulation

Bits 20–23 of the LEC directive shall contain the modulation options based on the values below:

a) ‘0000’ = PCM/PM/Bi-phase-L (filtered);

b) ‘0001’ = GMSK;

c) ‘0010’ = RESERVED BY CCSDS;

d) ‘0011’ = RESERVED BY CCSDS;

e) ‘0100’ = RESERVED BY CCSDS;

f) ‘0101’ = RESERVED BY CCSDS;

g) ‘0110’ = RESERVED BY CCSDS;

h) ‘0111’ = RESERVED BY CCSDS;

i) ‘1000’ = RESERVED BY CCSDS;

j) ‘1001’ = RESERVED BY CCSDS;

k) ‘1010’ = RESERVED BY CCSDS;

l) ‘1011’ = RESERVED BY CCSDS;

m) ‘1100’ = RESERVED BY CCSDS;

n) ‘1101’ = RESERVED BY CCSDS;

o) ‘1110’ = RESERVED BY CCSDS;

p) ‘1111’ = RESERVED BY CCSDS.

D2.2.13 Spares

Bits 24-25 of the LEC directive shall contain 2 spare bits reserved by the CCSDS.

D2.2.14 Coding

Bits 26–31 of the LEC directive shall contain the following coding options:

a) ‘000000’ = Uncoded;

b) ‘000001’ = LDPC(2048,1024);

c) ‘000010’ = Reserved by CCSDS;

d) ‘000011’ = Reserved by CCSDS;

e) ‘000100’ = Reserved by CCSDS;

f) ‘000101’ = LDPC(6144,4096);

g) ‘000110’ = Reserved by CCSDS;

h) ‘000111’ = Reserved by CCSDS;

i) ‘001000’ = Reserved by CCSDS;

j) ‘001001’ = Reserved by CCSDS;

k) ‘001010’ = LDPC(8160,7136);

l) ‘001011’ through ‘111111’ = Reserved by CCSDS.

D2.2.15 Instantaneous Link Signal-to-Noise Ratio

Bits 32–39 of the LEC directive shall contain the link SNR ratio, i.e., Eb/No in dB Hz. This value is an integer.

D2.2.16 Symbol Rate

Bits 40-55 of the LEC directive shall indicate the symbol rate in symbols per second. This value is a binary16-bit number with format specified by the IEEE 754 standard for half-precision floating point numbers: 1 sign bit (always positive), 5 bits exponent, and 10 bits mantissa/significand. When this number is multiplied by 2^16, then the range of supported symbol rates is between 1/256 symbol/sec and 2^31 (4,292,870,144) symbols/sec, with a precision of 0.1%. The sign bit is always transmitted as a positive value and the all-ones, i.e., ‘11111’ exponent value is excluded.

D2.3 REPORT REQUEST DIRECTIVE

D2.3.1 General

The REPORT REQUEST directive is the mechanism by which (1) a status report, (2) time-tag sample collection, or (3) a PLCW per PCID can be requested of a Proximity-1 node. It shall consist of five fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 15:

a) Directive Name (3 bits);

b) PCID 0 PLCW Request (1 bit);

c) PCID 1 PLCW Request (1 bit);

d) Time-Tag Sample Request (6 bits);

e) Status Report Request (5 bits).

NOTE – The structural components of the REPORT REQUEST directive are shown in Figure D-4.

Directive Name 3 bits	PCID 0 PLCW Request 1 bit	PCID 1 PLCW Request 1 bit	Time-Tag Sample Request 6 bits	Status Report Request 5 bits
0–2	3	4	5–10	11–15

Bit 0 … Bit 15

Figure D-4: Report Request Directive

D2.3.2 Directive Name

D2.3.2.1 Bits 0–2 of the REPORT REQUEST directive shall contain the Directive Name.

D2.3.2.2 The 3-bit Directive Name field identifies the type of protocol control directive and shall contain the binary value ‘001’.

D2.3.3 Physical Channel ID 0 PLCW Report Request Field

Bit 3 of the REPORT REQUEST directive shall indicate whether a PLCW report for PCID 0 is required:

a) ‘1’ = PLCW report is needed for PCID 0; transmit this report on the same PCID that the report request arrived on.

b) ‘0’ = PLCW report is not required.

D2.3.4 Physical Channel ID 1 PLCW Report Request Field

Bit 4 of the REPORT REQUEST directive shall indicate whether a PLCW report for PCID 1 is required:

a) ‘1’ = PLCW report is needed for PCID 1; transmit this report on the same PCID that the report request arrived on.

b) ‘0’ = PLCW report is not required.

D2.3.5 Time-Tag Sample Request Field

Bits 5–10 of this directive shall contain the Time-Tag Sample Request field. When this field is non-zero, it notifies the recipient to capture the time and FSN (associated with the Proximity timing service; see reference [6], section 5) for the next *n* frames received, where *n* is the number of Proximity Transfer Frames contained within the Time Sample Field.

D2.3.6 Status Report Request

D2.3.6.1 The value contained in bits 11–15 of the REPORT REQUEST directive shall indicate the type of status report requested.

D2.3.6.2 If set to ‘00000’, a status report is not required.

D2.3.6.3 The types of status reports are reserved for CCSDS use as SPDU Type 3 directives.

D2.4 SET V(R) DIRECTIVE

D2.4.1 General

The SET V(R) directive used in the COP-1 (Reference X) and COP-P (Reference Y) procedures shall consist of three fields, positioned contiguously in the following sequence, described from MSB, Bit 0 to LSB, Bit 15:

a) Directive Name (3 bits);

b) Spare (5 bits);

c) Receiver FSN (SEQ_CTRL_FSN) (8 bits).

NOTE – The structural components of the SET V(R) directive are shown in Figure D-5.

Bit 0 ... Bit 15

Directive Name 3 bits	Spare 5 bits	Receiver FSN SEQ_CTRL_FSN 8 bits
0–2	3–7	8–15

Figure D-5: SET V(R) Directive

D2.4.2 Directive Name

D2.4.2.1 Bits 0–2 of the SET V(R) directive shall contain the Directive Name.

D2.4.2.2 The 3-bit Directive Name field identifies the type of protocol control directive and shall contain the binary value ‘010’ to identify the SET V(R) directive.

D2.4.3 Spare

Bits 3–7 of the SET V(R) directive shall contain spare bits, set to ‘all zero’.

D2.4.4 Receiver Frame Sequence Number

Bits 8–15 of the SET V(R) directive shall contain the value of the FSN (SEQ_CTRL_FSN) to which the receiving unit of the partnered transceiver is to be set.

D2.5 REPORT SOURCE SPACECRAFT ID DIRECTIVE

D2.5.1 Overview

The REPORT SOURCE SPACECRAFT ID is the mechanism by which the local transceiver can provide status of its source spacecraft ID to the remote transceiver across the Proximity link. This directive is provided because the verification test of the spacecraft ID performed by the protocol is by default based on the destination spacecraft ID. However, there is an option to include a test of the source spacecraft ID in the protocol as well. This directive allows the caller to query the responder for its Source Spacecraft ID.

D2.5.2 General

The REPORT SOURCE SPACECRAFT ID directive shall consist of three fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 31:

a) Directive Name (3 bits);

b) Reserved (13 bits);

c) Source Spacecraft ID (16 bits).

NOTE – The structural components of the REPORT SOURCE SPACECRAFT ID are shown in Figure D-6.

Bit 0 ... Bit 31

Directive Name 3 bits	Reserved 13 bits	Source Spacecraft ID 16 bits
0–2	3–15	16–31

Figure D-6: Report Source Spacecraft ID

D2.5.3 Directive Name

D2.5.3.1 Bits 0–2 of the REPORT SOURCE SPACECRAFT ID status report shall contain the Directive Name.

D2.5.3.2 The 3-bit Directive Name field identifies the name of the Report Source Spacecraft ID directive and shall contain the binary value ‘011’.

D2.5.4 Reserved

Bits 3–15 of the REPORT SOURCE SPACECRAFT ID status report shall contain reserved bits, set to ‘all zero’.

D2.5.5 Source Spacecraft ID

Bits 16–31 of the REPORT SOURCE SPACECRAFT ID directive shall contain the SCID of the source of the Transfer Frame. The version 3 SCID for Proximity-1 transfer frames is 10 bits long and the version 4 SCID for USLP transfer frames is 16 bits long.

ANNEX E

TYPE 5 SPDU—VARIABLE-LENGTH DIRECTIVES/REPORTS SECOND GENERATION

(NORMATIVE)

Variable-Length SPDU	**SPDU Header (1 octet, fixed)**			**SPDU Data Field (0–15 octets)**
	Format ID (Bit 0)	SPDU Type Identifier (Bits 1,2,3)	Length of SPDU Data Field (Bits 4,5,6,7)	(Contains one or more protocol objects, i.e., directives, reports)
Type 5	‘0’	‘100’	Length in Octets	Variable Length Directives/Reports 2nd Generation

Figure E-1: Type 5 SPDU

Directive Name

‘0000’ = Link Establishment & Control Size = 96 bits	Link Direction	Directive Function	RNMD	Token	Duplex/Simplex	Polarization	Coherent/Noncoherent	MODCOD Overlay	Modulation	Coding	Spare	Modulation Index	Spare	Frame Type	Instantaneous Link SNR	Time Sample	Spares	Symbol Rate	Frequency
4	1	3	1	1	3	1	1	1	4	5	1	3	1	2	8	6	2	16	32

‘0001’ = Report Request Size = 16 bits	PCID 0 - PLCW Request	PCID 1 - PLCW Request	Report/Request LEC Values	Status Report Request	Spares
4	1	1	1	5	4

‘0010’ = Set V(R) Size = 24 bits	Spares	Frame Sequence Number
4	4	16

‘0011’ = Report Source Spacecraft ID Size = 24 bits	Spares	Source SCID
4	4	16

‘0100’ = Service Request Size = 16 bits	Mission Defined Event Code	Spares	Event Priority
4	6	5	1

‘0101’ = Set Fixed-length Frame Size = 24 bits	Frame Alignment	Spares	Link Direction	Transfer Frame Length
4	1	2	1	16

‘0110’ = PN Ranging Size = 96 bits	Mode Type	Ranging Code	Chip Rate	Ranging Mod	PN Epoch	Status Report Request	Spare
4	2	2	31	3	48	5	1

‘0111’ – ‘1111’ = Reserved by CCSDS
4

Figure E-2: Type 5 SPDU Data Field Contents

E1 GENERAL

E1.1 Type 5 SPDU directives shall be used for space link supervisory configuration as well as control of the transceiver and its operation at S-band.

E1.2 The SPDU data field shall contain 0 to 15 octets of supervisory data.

E1.3 Each directive shall perform a specific function.

E1.4 Each directive shall not exceed 120 bits (15 octets × 8 bits) in length and shall be self-identified by the value in the directive name field, contained in bits 0 through 2 of the directive.

E1.5 Concatenation of the directives shall be allowed without intervening bits within the data field of the Type 5 SPDU as long as the total SPDU data field length does not exceed 120 bits.

E1.6 The size of each directive is defined in the MIB in Annex F.

NOTE – Figure E-2 shows the SPDU Type 5 directive contents. The size of each field in bits is given below the field names.

E2 LINK ESTABLISHMENT & CONTROL DIRECTIVE

E2.1 OVERVIEW

The LEC directive is used to initiate communication via hailing, move to a working channel to enable follow-on link control changes between partnered transceivers, and terminate the link. A *caller* transceiver is the initiator of the link establishment process and manager of negotiation of the link session, if required. A *responder* transceiver typically receives link establishment parameters from the caller. The caller initiates communication between itself and a responder on a prearranged communications (hailing) channel with predefined controlling parameters. The caller and responder may negotiate the controlling parameters for the session with flexibility to operate between fully controlled (demand) and completely adaptive (negotiated by query). These roles are invariant throughout the link session.

To accomplish hailing, this directive is transmitted back-to-back within the same transfer frame to establish both the forward and return link initial communication conditions. Similarly, once the link is established, the same approach is used to move to the selected working channel. This directive is used in lieu of the SET TRANSMITTER PARAMETERS, SET RECEIVER PARAMETERS and/or SET PL EXTENSIONS directives for SPDU Type 1 applications.

E2.2 SPECIFICATION

E2.2.1 General

The LEC directive shall consist of 20 fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 95 (see

Bit 0 Bit 95

Directive Name	Link Direction	Directive Function	RNMD	Token	Duplex/ Simplex	Polarization	Coherent/Non-Coherent	MODCOD Overlay	Modulation	Coding	Spare	Modulation Index	Spare	Frame Type	Inst. Link SNR	Time Sample	Spares	Symbol Rate	Frequency
4 bits	1 bit	3 bits	1 bit	1 bit	3 bits	1 bit	1 bit	1 bit	4 bits	5 bits	1 bit	3 bits	1 bit	2 bits	8 bits	6 bits	2 bits	16 bits	32 bits
0–3	4	5-7	8	9	10–12	13	14	15	16–19	20–24	25	26–28	29	30–31	32–39	40-45	46-47	48–63	64–95

Figure E-3):

a) Directive Name (4 bits);

b) Link Direction (1 bit);

c) Direction Function (3 bits);

d) Remote No More Data (RNMD) (1 bit);

e) Token (1 bit);

f) Duplex/Simplex (3 bits);

g) Polarization (1 bit);

h) Coherent/Non-coherent (1 bit);

i) MODCOD Overlay (1 bit);

j) Modulation (4 bits);

k) Coding (5 bits);

l) Spare (1 bit);

m) Modulation Index (3 bits);

n) Spare (1 bit);

o) Frame Type (2 bits);

p) Instantaneous Link SNR (8 bits);

q) Time Sample (6 bits);

r) Spares (2 bits);

s) Symbol Rate (16 bits);

t) Frequency (32 bits).

NOTE – The structural components of the LEC directive are shown in

Bit 0 Bit 95

Directive Name	Link Direction	Directive Function	RNMD	Token	Duplex/ Simplex	Polarization	Coherent/Non-Coherent	MODCOD Overlay	Modulation	Coding	Spare	Modulation Index	Spare	Frame Type	Inst. Link SNR	Time Sample	Spares	Symbol Rate	Frequency
4 bits	1 bit	3 bits	1 bit	1 bit	3 bits	1 bit	1 bit	1 bit	4 bits	5 bits	1 bit	3 bits	1 bit	2 bits	8 bits	6 bits	2 bits	16 bits	32 bits
0–3	4	5-7	8	9	10–12	13	14	15	16–19	20–24	25	26–28	29	30–31	32–39	40-45	46-47	48–63	64–95

Figure E-3.

Bit 0 Bit 95

Directive Name	Link Direction	Directive Function	RNMD	Token	Duplex/ Simplex	Polarization	Coherent/Non-Coherent	MODCOD Overlay	Modulation	Coding	Spare	Modulation Index	Spare	Frame Type	Inst. Link SNR	Time Sample	Spares	Symbol Rate	Frequency
4 bits	1 bit	3 bits	1 bit	1 bit	3 bits	1 bit	1 bit	1 bit	4 bits	5 bits	1 bit	3 bits	1 bit	2 bits	8 bits	6 bits	2 bits	16 bits	32 bits
0–3	4	5-7	8	9	10–12	13	14	15	16–19	20–24	25	26–28	29	30–31	32–39	40-45	46-47	48–63	64–95

Figure E-3: LINK ESTABLISHMENT & CONTROL Directive

E2.2.2 Directive Name

E2.2.2.1 Bits 0–3 of the LEC directive shall contain the Directive Name.

E2.2.2.2 The 4-bit Directive Name field identifies the name of SPDU Type 5 protocol control directive and shall contain the binary value ‘0000’ for the LEC directive.

E2.2.3 Link Direction

Bit 4 of the LEC directive shall indicate the link direction (Forward or Return).

a) ‘0’ = Return Link: the responder transmits, and the caller receives (typically a telemetry link). This directive sets the responder’s transmitter parameters.

b) ‘1’ = Forward Link: the caller transmits, and the responder receives (typically a command link). The caller (i.e., link initiator) is the node that transmits the Hail Directives. This directive sets the responder’s receiver parameters.

E2.2.4 Directive Function

Bits 5 through 7 of the LEC directive shall define its function. See section 5.1 for a further description of the functions below.

a) ‘000’ = Demand (Command): caller expects the responder to accept the parameters in this directive ‘as is’;

b) ‘001’ = Query Request (Link Negotiation): allows the caller and responder to negotiate these link parameters;

c) ‘010’ = Query Response (ACK): indicates acceptance by the responder/partnered node;

d) ‘011’ = Query Response (NACK): indicates rejection by the responder/partnered node;

e) ‘100’ – ‘111’ = Reserved by CCSDS.

E2.2.5 Remote No More Data

Bit 8 of the LEC directive shall contain the Remote No More Data (RNMD) field, which plays a role in link termination. It notifies the caller that either there is no change in the remote nodes’ data state or that the remote node has no more data to send, so the link may be terminated when the remote node has no more data to send locally:

a) ‘0’ = No Change (i.e., ignore this field);

b) ‘1’ = Remote Node has No More Data to Send (RNMD).

E2.2.6 Token

Bit 9 of the LEC directive shall contain the value of the Token field as follows:

a) ‘0’ = No Change;

b) ‘1’ = Transmit.

E2.2.7 Duplex/Simplex

Bits 10–12 of the LEC directive shall contain the Duplex/Simplex field, which notifies the remote node of any potential change in the directionality of its communication:

a) ‘000’ = No Change (i.e., ignore this field);

b) ‘001’ = Full Duplex;

c) ‘010’ = Half Duplex;

d) ‘011’ = Simplex Transmit;

e) ‘100’ = Simplex Receive;

f) ‘101’ = Reserved;

g) ‘110’ = Reserved;

h) ‘111’ = Reserved.

E2.2.8 Polarization

Bit 13 of the LEC directive shall contain the Polarization field as follows:

a) ‘0’ = Left Hand Circular Polarization;

b) ‘1’ = Right Hand Circular Polarization.

E2.2.9 Coherent/Non-coherent

Bit 14 of the LEC directive shall contain the transceiver coherent or non-coherent option as per below:

a) ‘0’ = Coherent;

b) ‘1’ = Non-coherent.

E2.2.10 MODCOD Overlay

Bit 15 of the LEC directive shall contain the Modulation/Coding Overlay field. This value is used to interpret bits 16-24 of the LEC directive. MODCOD is a placeholder for the ability to table drive the combined settings of both the Modulation and Coding fields.

a) ‘0’ = treat these bits as two separate fields: Modulation followed by Coding;

b) ‘1’ = Combine these bits into a single field called MODCOD.

E2.2.11 Modulation

Bits 16–19 of the LEC directive shall contain the modulation options based on the values below:

a) ‘0000’ = PCM/PM/Bi-phase-L (filtered);

b) ‘0001’ = GMSK;

c) ‘0010’ = OQPSK (filtered);

d) ‘0011’ = BPSK (filtered);

e) ‘0100’ = PCM/PSK/PM;

f) ‘0101’ = PCM/PM/NRZ-L (filtered);

g) ‘0110’ = RESERVED BY CCSDS;

h) ‘0111’ = RESERVED BY CCSDS;

i) ‘1000’ = RESERVED BY CCSDS;

j) ‘1001’ = RESERVED BY CCSDS;

k) ‘1010’ = RESERVED BY CCSDS;

l) ‘1011’ = RESERVED BY CCSDS;

m) ‘1100’ = RESERVED BY CCSDS;

n) ‘1101’ = RESERVED BY CCSDS;

o) ‘1110’ = RESERVED BY CCSDS;

p) ‘1111’ = RESERVED BY CCSDS.

NOTE – Only options a) and b) are supported by Proximity-1 PL reference [5].

E2.2.12 Coding

Bits 20–24 of the LEC directive shall contain the following coding options:

a) ‘00000’ = Uncoded;
b) ‘00001’ = LDPC(2048,1024);
c) ‘00010’ = LDPC(8192,4096);
d) ‘00011’ = LDPC(32768, 16384);
e) ‘00100’ = Reserved by CCSDS;
f) ‘00101’= LDPC(6144,4096);
g) ‘00110’= LDPC(24576, 16384);
h) ‘00111’= Reserved by CCSDS;

i) ‘01000’= Reserved by CCSDS;

j) ‘01001’= LDPC(20480, 16384);

k) ‘01010’ = LDPC(8160,7136);

l) ‘01011’ = Convolutional Code(7,1/2);

m) ‘01100’ through ‘11111’ = Reserved by CCSDS.

NOTES

1 Only options a, b, f, and k are supported by the Proximity-1 C&S sublayer, reference [4]. For options c, d, g, j, and l, see reference [2].

2 The uncoded option with suppressed carrier modulation and without randomization cannot guarantee sufficient bit transitions resulting in an unreliable link.

E2.2.13 Spare

Bit 25 of the LEC directive shall contain 1 spare bit reserved by the CCSDS with the binary value ‘0’.

E2.2.14 Modulation Index

Bits 26–28 of the LEC directive shall set the modulation index based upon the values below:

a) ‘000’ = 0 rad/pk (No Modulation);

b) ‘001’ = 0.4 rad/pk;

c) ‘010’ = 0.6 rad/pk;

d) ‘011’ = 0.8 rad/pk;

e) ‘100’ = $\pi/3$ rad/pk (60 degrees);

f) ‘101’ = 1.15 rad/pk;

g) ‘110’ = 1.3 rad/pk;

h) ‘111’ = 1.4 rad/pk.

NOTE – This field is ignored when using suppressed carrier modulation.

E2.2.15 Spare

Bit 29 of the LEC directive shall contain 1 spare bit reserved by the CCSDS with the binary value ‘0’.

E2.2.16 Frame Type

Bits 30–31 of the LEC directive shall contain the transfer frame options:

a) ‘00’ = Mission Specific ;

b) ‘01’ = Proximity-1;

c) ‘10’ = USLP;

d) ‘11’ = AOS (U-frames only).

NOTE – See reference [2] for the AOS coding options: sliced (octet stream of Sync-Marked AOS transfer frames) or non-sliced AOS transfer frames.

E2.2.17 Instantaneous Link Signal-to-Noise Ratio

Bits 32–39 of the LEC directive shall contain the link SNR, E_s/N_0, in dB. The unit of the step size is defined by the LINK_SNR_STEP managed parameter (see ANNEX F). This value is a 2s complement signed integer multiplied by the step size.

NOTE – If the step size is 0.1dB, 0x01 = 0.1dB, 0xff = -0.1dB, 0x81 = -12.7dB, 0x80 = unavailable or invalid.

E2.2.18 Time Sample

Bits 40–45 of the LEC directive shall contain the 6-bit Time Sample field. When this field is non-zero, it notifies the recipient node to capture the time and frame sequence numbers (FSN) associated with the protocol timing service (see reference [6], section 5) for the next *n* transfer frames received, where *n* is the number of samples contained within the Time Sample Field.

NOTE – When this field is set to zero, no time samples are requested from the remote node.

E2.2.19 Spares

Bits 46–47 of the LEC directive shall contain spare bits set to ‘all zero’.

E2.2.20 Symbol Rate

E2.2.20.1 Bits 48–63 of the LEC directive shall indicate the symbol rate in symbols per second. This value is a binary16-bit whose format is specified by the IEEE 754 standard for half-precision floating point numbers, i.e., 1 sign bit (always positive), 5 bits exponent, and 10 bits mantissa/significand.

E2.2.20.2 To derive the value of this field, the symbol rate in symbols per second shall be divided by 2^{16} and then converted to IEEE 754 half-precision floating point.

E2.2.20.3 To derive the symbol rate value from the field value, the opposite operation shall be done, i.e., the floating point value shall be multiplied by 2^{16}.

E2.2.20.4 The sign bit is always transmitted as a positive value and the 'all ones' ('11111') exponent value is excluded.

NOTES

1 Symbol Rate assignment must take into consideration the actual spectrum available.

2 The default hailing symbol rate in S-band is 2,000 symbols/s, which is LDPC (2048,1024) encoded.

3 Symbol rate values in the range from 1,000 symbols/s to 4,096,000 symbols/s are represented with a precision of 0.1% from the defined Proximity-1 channel symbol rates as measured at the output of the transmitter.

4 Minimum and maximum symbol rates are based upon the selected Proximity-1 PL [5] and Coding & Synchronization Sublayer [4] parameter options.

E2.2.21 Frequency

Bits 64-95 of the LEC directive shall be used to set the frequency of the partnered transceiver to the desired value (either receive or transmit based on the value of the Link Direction field defined in E2.2.3). The format of this value is a binary32-bit specified by the IEEE 754 standard for single precision floating point numbers, i.e., 1 sign bit (always positive), 8 bits exponent, and 24 bits mantissa/significand.

NOTE – Frequency channel assignments including hailing channels are defined in the Proximity-1 PL Blue Book (reference [5]).

E2.3 REPORT REQUEST DIRECTIVE

E2.3.1 General

The REPORT REQUEST directive is the mechanism for requesting three types of outputs from a Proximity-1 node: status report, time-tag sample collection, or PLCW per PCID. It shall consist of five fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 15:

a) Directive Name (4 bits);

b) PCID 0 PLCW Request (1 bit);

c) PCID 1 PLCW Request (1 bit);

d) Report/Request LEC Values (1 bit);

e) Status Report Request (5 bits);

f) Spares (4 bits).

NOTE – The structural components of the REPORT REQUEST directive are shown in Figure E-4.

Bit 0 … Bit 15

Directive Name 4 bits	PCID 0 PLCW Request 1 bit	PCID 1 PLCW Request 1 bit	Report/ Request LEC Values 1 bit	Status Report Request 5 bits	Spares 4 bits
0–3	4	5	6	7–11	12-15

Figure E-4: Report Request Directive

E2.3.2 Directive Name

E2.3.2.1 Bits 0–3 of the REPORT REQUEST directive shall contain the Directive Name.

E2.3.2.2 The 4-bit Directive Name field identifies the type of protocol control directive and shall contain the binary value ‘0001’.

E2.3.3 Physical Channel ID 0 PLCW Report Request Field

Bit 4 of the REPORT REQUEST directive shall indicate whether a PLCW report for PCID 0 is required:

a) ‘1’ = PLCW report is needed for PCID 0; transmit this report on the same PCID on which the report request arrived.

b) ‘0’ = PLCW report is not required.

E2.3.4 Physical Channel ID 1 PLCW Report Request Field

Bit 5 of the REPORT REQUEST directive shall indicate whether a PLCW report for PCID 1 is required:

a) ‘1’ = PLCW report is needed for PCID 1; transmit this report on the same PCID on which the report request has arrived.

b) ‘0’ = PLCW report is not required.

E2.3.5 Report/Request LEC Directive Values

Bits 6 of the REPORT REQUEST directive shall indicate whether the LEC directive values are being reported or requested.

a) '1' = LEC directive values are requested by the remote transceiver;

b) '0' = LEC directive values are reported to the remote transceiver.

E2.3.6 Status Report Request

E2.3.6.1 The value contained in bits 7–11 of the REPORT REQUEST directive shall indicate the type of status report desired.

E2.3.6.2 If set to '00000', a status report is not required.

E2.3.6.3 The types of status report formats are reserved for CCSDS use as SPDU Type 3 directives.

E2.3.7 Spares

The value contained in bits 12–15 of the REPORT REQUEST directive shall contain spare bits set to 'all zero'.

E2.4 SET V(R) DIRECTIVE

E2.4.1 General

The SET V(R) directive used in COP-P (section 6) procedures shall consist of three fields, positioned contiguously in the following sequence, described from MSB, Bit 0 to LSB, Bit 23:

a) Directive Name (4 bits);

b) Spare (4 bits);

c) Receiver FSN (SEQ_CTRL_FSN) (16 bits).

NOTE – The structural components of the SET V(R) directive are shown in Figure E-5. Frame Sequence Number may be either an 8-bit or a 16-bit number based upon the size of the Transmission Window (see Annex F) in the COP-P.

Bit 0 ... Bit 23

Directive Name 4 bits	Spare 4 bits	Receiver SEQ_CTRL_FSN 16 bits
0–3	4–8	9–23

Figure E-5: SET V(R) Directive

E2.4.2 Directive Name

E2.4.2.1 Bits 0–3 of the SET V(R) directive shall contain the Directive Name.

E2.4.2.2 The 4-bit Directive Name field identifies the type of protocol control directive and shall contain the binary value '0010' to identify the SET V(R) directive.

E2.4.3 Spare

Bits 4–8 of the SET V(R) directive shall contain spare bits set to 'all zero'.

E2.4.4 Receiver Frame Sequence Number

Bits 9–23 of the SET V(R) directive shall contain the value of the FSN (SEQ_CTRL_FSN) to which the receiving unit of the partnered transceiver is to be set.

E2.5 REPORT SOURCE SPACECRAFT ID DIRECTIVE

E2.5.1 Overview

The REPORT SOURCE SPACECRAFT ID is the mechanism by which the local transceiver can provide status of its source spacecraft ID to the remote transceiver across the Proximity link. The protocol's default verification tests only the destination spacecraft ID, but an optional source spacecraft ID test is available. This directive allows the caller to query the responder for its Source Spacecraft ID.

E2.5.2 General

The REPORT SOURCE SPACECRAFT ID directive shall consist of three fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 31:

a) Directive Name (4 bits);

b) Reserved (12 bits);

c) Source Spacecraft ID (16 bits).

NOTE – The structural components of the REPORT SOURCE SPACECRAFT ID are shown in Figure E-6.

Bit 0		Bit 31
Directive Name 3 bits	Reserved 12 bits	Source Spacecraft ID 16 bits
0–3	4–15	16–31

Figure E-6: Report Source Spacecraft ID

E2.5.3 Directive Name

E2.5.3.1 Bits 0–3 of the REPORT SOURCE SPACECRAFT ID status report shall contain the Directive Name.

E2.5.3.2 The 4-bit Directive Name field identifies the name of the Report Source Spacecraft ID directive and shall contain the binary value ‘0011’.

E2.5.4 Reserved

Bits 4–15 of the REPORT SOURCE SPACECRAFT ID status report shall contain reserved bits, set to ‘all zero’.

E2.5.5 Source Spacecraft ID

Bits 16–31 of the REPORT SOURCE SPACECRAFT ID directive shall contain the SCID of the source of the Transfer Frame. The version 3 SCID for Proximity-1 transfer frames is 10 bits long and the version 4 SCID for USLP transfer frames is 16 bits long.

E2.6 SERVICE REQUEST DIRECTIVE

E2.6.1 Overview

The SERVICE REQUEST directive is the mechanism by which a node may request a service request to the partnered node based upon mission specific events with a nominal or emergency priority associated with them. It shall consist of four fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 15:

a) Directive Name (4 bits);

b) Mission Specific Event (6 bits);

c) Spares (5 bits);

d) Event Priority (1 bit).

NOTE – The structural components of the SERVICE REQUEST directive are shown in Figure E-7.

Bit 0

Directive Name 4 bits	Mission Specific Event 6 bits	Spares 5 bits	Event Priority 1 bit
0 - 3	4-9	10-14	15

Figure E-7: Service Request

E2.6.2 Directive Name

E2.6.2.1 Bits 0–3 of the SERVICE REQUEST directive shall contain the Directive Type.

E2.6.2.2 The 4-bit Directive Type field identifies the type of protocol control directive and shall contain the binary value ‘0100’.

E2.6.3 Mission Specific Event

Bits 4-9 of the SERVICE REQUEST directive shall describe the mission specific event that generated the service request. These values will be supplied by the mission.

E2.6.4 Spares

Bits 10-14 of the SERVICE REQUEST directive shall contain reserved bits, set to ‘all zero’.

E2.7 SET FIXED-LENGTH FRAME DIRECTIVE

E2.7.1 General

The SET FIXED-LENGTH FRAME directive configures the remote node to transmit/receive fixed-length transfer frames. In this case, the C&S Sublayer operates in accordance with the TM Synchronization and Channel Coding standard (reference [2]), which requires a fixed-length frame interface. Furthermore, the alignment between codewords and frames allows for slicing or non-slicing of the symbol stream. This directive shall precede the LEC directive in the SPDU. It shall consist of five fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 23:

a) Directive Name (4 bits);

b) Frame Alignment (1 bit);

c) Spares (2 bits);

d) Link Direction (1 bit);

e) Transfer Frame Length (16 bits).

NOTE – The structural components of the SET FIXED-LENGTH FRAME directive are shown in Figure E-8.

Bit 0 ... Bit 23

Directive Name 4 bits	Frame Alignment 1 bit	Spares 2 bits	Link Direction 1 bit	Transfer Frame Length 16 bits
0–3	4	5-6	7	8–23

Figure E-8: Set Fixed-Length Frame Directive

E2.7.2 Directive Name

E2.7.2.1 Bits 0–3 of the SET FIXED-LENGTH FRAME directive shall contain the Directive TypeName.

E2.7.2.2 The 4-bit Directive NameType field identifies the type of protocol control directive and shall contain the binary value ‘0101’.

E2.7.3 Frame Alignment

Bit 4 of the SET FIXED-LENGTH FRAME directive shall indicate how the transfer frame aligns with the codeword. When the frame aligns with the codeword(s) then the input stream presented to the C&S Sublayer is not sliced. However, without transfer frame/codeword alignment, the input stream is sliced. In that case, the input stream presented to the C&S sublayer consists of a stream of SMTFs:

c) ‘0’ = No slicing (Transfer Frame and Codewords align);

d) ‘1’ = Slicing (No alignment).

NOTE – Since AOS reference [8] is a DLL protocol that exclusively uses fixed-length transfer frames, the remote node must know the frame alignment for proper link configuration.

E2.7.4 Spares

Bits 5–6 of the SET FIXED-LENGTH FRAME directive shall contain reserved bits set to ‘00’.

E2.7.5 Link Direction

Bit 7 of the SET FIXED-LENGTH FRAME directive shall indicate the link direction (Forward or Return):

a) ‘0’ = Return Link: the responder transmits, and the caller receives (typically a telemetry link). This directive sets the responder’s transmitter parameters.

b) ‘1’ = Forward Link: the caller transmits, and the responder receives (typically a command link). The caller (i.e., link initiator) is the node that transmits the Hail Directive. This directive sets the responder’s receiver parameters.

E2.7.6 Transfer Frame Length

The value contained in bits 8–23 of the SET Fixed-length Frame directive shall indicate the length in octets of the fixed-length transfer frame.

E2.8 PSEUDORANDOM NOISE RANGING DIRECTIVE

E2.8.1 Overview

The following assumptions and requirements are associated with the Pseudo-Noise (PN) RANGING directive:

- The PN RANGING directive should support one-way (pseudo-range) and two-way ranging.
- Only a single PN ranging code sequence will be specified for Proximity-1 use.
- The PN RANGING directive will follow the SPDU Type 5 format for second generation lunar use.

It is assumed that the link has already been established prior to sending the PN RANGING directive, so the link direction, antenna polarization, frequency channel, etc. have been agreed upon between the two radios. To start the Proximity-1 ranging session, the initiator sends the PN RANGING directive to establish the ranging parameters for use with the responder. These parameters include chip rate, PN code type, PN ranging mode (coherent, non-coherent, regenerative, non-regenerative), ranging mod index, and the epoch time-tag for the start of the PN sequence. The PN RANGING directive can also be used to request the status of the PN ranging configuration, calibration delay, or ranging observables from the responder prior or after the ranging session.

E2.8.2 General

The PN RANGING directive is the mechanism by which the PN ranging for a Proximity-1 node is initiated and configured. It can also be used to request a status report on the PN ranging configuration of a Proximity-1 node.

This directive assumes that the link between the nodes has already been established using the LINK ESTABLISHMENT AND CONTROL directive. As such, the forward and return directions and channel carrier frequencies have already been established for each node, and are not repeated as part of this directive.

The PN RANGING DIRECTIVE shall consist of eight fields, positioned contiguously in the following sequence, described from MSB, Bit 0, to LSB, Bit 95:

a) Directive Name (3 bits);

b) PN Ranging Mode Type (2 bits);

c) Ranging Code (2 bits);

d) Chip Rate (31 bits);

e) Ranging Modulation Index (3 bits);

f) PN Epoch Time-Tag (48 bits);

g) Status Report Request (5 bits);

h) Spares (2 bits).

NOTE – The structural components of the PN RANGING directive are shown in figure Figure E-9.

Bit 0 — Bit 95

Directive Name 4bits	Mode Type 2 bits	Ranging Code 2 bits	Chip Rate 31 bits			Ranging Mod Index 3 bits	PN Epoch Time-Tag 48 bits		Status Report Request 5 bits	Spare 1 bit
			k	*l*	m		day	ms of day		
0-3	4-5	6-7	8-10	11-24	25-38	39-41	42-57	58-89	90-94	95

Figure E-9: PN RANGING Directive

E2.8.3 Directive Name

E2.8.3.1 Bits 0-3 of the PN RANGING directive shall contain the Directive Name.

E2.8.3.2 The 4-bit Directive Name field identifies the type of protocol control directive and shall contain the binary value ‘1100’ for PN RANGING.

E2.8.4 Mode Type PN Ranging Field

Bits 4-5 of the PN RANGING directive shall indicate the PN ranging type:

a) ‘00’ = Ranging Off;

b) ‘01’ = One-way Ranging (pseudo-range);

c) ‘10’ = Two-way Non-Regenerative Ranging (turnaround ranging);

d) ‘11’ = Two-way Regenerative Ranging.

E2.8.5 Ranging Code

Bits 6-7 of the PN RANGING directive shall indicate the PN ranging code type:

a) ‘00’ = Maximum Length (PN18) code;

b) ‘01’ = T2B;

c) ‘10’ = T4B;

d) ‘11’ = Reserved.

NOTE – Only option a) is supported by the Proximity-1 PL reference [5]. For options b) and c), reference [9] applies.

E2.8.6 Chip Rate PN Ranging Field

Bits 8-38 of the PN RANGING directive shall indicate the transmit PN Chip rate. The chip rate is dependent on the forward link carrier frequency and defined by three parameters (*l*, *k*, and *m*). Bits 8-10 indicate the value of *k*, Bits 11-24 indicate the valve of *l,* and Bits 25-38 indicate the value of *m*. The formula to calculate the S-band chip rate is shown below:

$$F_{chip} = 2\, F_{clock} = \frac{m}{l} \cdot \frac{f_{s-band}}{128 \cdot 2^{k}}$$

The values of *l*, *k*, and *m* should be chosen such that multiples of the PN code sequence align with the second boundary while the forward and return coherent link frequencies align closely with the nominal Prox-1 channel center frequencies. This can be accomplished by choosing values of *l* and *m* using factors of the PN code length, while *k* is selected to increase or decrease the chip rate by factors of 2.

Table 1 shows the recommended values for *k, l,* and *m* for an assumed maximum length PN ranging code of 2^18-1 = 262143 chips. For this PN code length, *m* is recommended to be 9709 (= 7 x 19 x 73) and the corresponding values of *l* and *k* for the frequency channels 1-8 are shown in the table. Other values for *m*, *l*, and *k* are possible depending on the ranging needs.

Ideally, the values of *l*, *k*, and *m* should be chosen such that multiples of the PN code sequence align with the second boundary, and the forward and return coherent link frequencies align closely with the nominal Prox-1 channel center frequencies. This can be accomplished by choosing values of *l* and *m* such that the F_{chip} is an integer multiple of the PN code length, while *k* is selected to increase or decrease the chip rate by factors of 2.

Table 1 shows the recommended values for *k, l,* and *m* for an assumed maximum length PN ranging code of 2^18-1 = 262143 chips. For this PN code length, *m* is recommended to be 9709 (= 7 x 19 x 73) and the corresponding values of *l* and *k* for the frequency channels 1-8 are shown in the table. Other values for *m*, *l*, and *k* are possible, depending on the ranging needs.

Table E-1: Recommended Values for *m*, *l*, *k* for the Frequency Channels 1 thru 8

Channel No.	$f_{s\text{-}band}$ (Forward Link)	f_{return} (Return Link)	m	l	k	F_{chip} (kchips/s)	PN Code Period (sec)
1	2085.765120	2265.084293	9709	9430	6	262.143	1
					5	524.286	0.5
					4	1048.572	0.25
					3	2097.144	0.125
2	2086.649856	2266.045092	9709	9434	6	262.143	1
					5	524.286	0.5
					4	1048.572	0.25
					3	2097.144	0.125
3	2087.534592	2267.005892	9709	9438	6	262.143	1
					5	524.286	0.5
					4	1048.572	0.25
					3	2097.144	0.125
4	2088.419328	2267.966691	9709	9442	6	262.143	1
					5	524.286	0.5
					4	1048.572	0.25
					3	2097.144	0.125
5	2095.718400	2275.893285	9709	9475	6	262.143	1
					5	524.286	0.5

Channel No.	***$f_{s\text{-}band}$ (Forward Link)***	***f_{return} (Return Link)***	***m***	***l***	***k***	***F_{chip} (kchips/s)***	***PN Code Period (sec)***
					4	1048.572	0.25
					3	2097.144	0.125
6	2096.824320	2277.094284	9709	9480	6	262.143	1
					5	524.286	0.5
					4	1048.572	0.25
					3	2097.144	0.125
7	2097.709056	2278.055083	9709	9484	6	262.143	1
					5	524.286	0.5
					4	1048.572	0.25
					3	2097.144	0.125
8	2098.593792	2279.015883	9709	9488	6	262.143	1
					5	524.286	0.5
					4	1048.572	0.25
					3	2097.144	0.125

E2.8.7 Ranging Modulation Index PN Ranging Field

Bits 39-41 of the PN RANGING directive shall indicate the PN ranging modulation index:

a) ‘000’ = 8.75 degrees;

b) ‘001’ = 17.5 degrees;

c) ‘010’ = 35 degrees;

d) ‘011’ = 45 degrees;

e) ‘100’ = 60 degrees;

f) ‘101’ = 70 degrees;

g) ‘110’ = Reserved;

h) ‘111’ = Reserved

E2.8.8 Epoch Time PN Ranging Field

E2.8.8.1 The value contained in bits 42–89 of the PN Ranging directive shall indicate the epoch of the PN ranging code. The epoch is the time-tag of when the leading edge of first chip of the transmit PN sequence crosses the clock capture point (defined by the implementation) within the transceiver. Similar to the Proximity-1 timing services defined in CCSDS 211.0-B-6, the reference point for all timing calculation shall be defined by the enterprise.

E2.8.8.2 The PN range code epoch shall be transmitted using the CCSDS Day Segmented (CDS) time code format defined in CCSDS 301.0-B-4. Bits 42-57 presents the number of days from 1958 January 1 starting with 0. Bits 58-89 represent the milliseconds of the day. Ideally the start of the PN range code will align with an integer number of seconds. Since this time code format is UTC-based, the leap second correction must be made.

E2.8.9 Status Report Request

E2.8.9.1 The value contained in bits 90–94 of the PN RANGING directive shall indicate the type of ranging status report desired:

a) ‘00000’ = No status report is required;

b) ‘00001’ = Ranging configuration report;

c) ‘00010’ = Ranging delay calibration report;

d) ‘00011’ = Position, Velocity, and Time report;

e) ‘00100’ = Ranging observable report;

f) Other values = Reserved.

E2.8.9.2 The types of status reports are reserved for CCSDS use as SPDU Type 3 directives.

E2.8.10 Spare

The value contained in bit 95 of the PN RANGING directive shall be reserved by the CCSDS and set to ‘0’.

ANNEX F

MANAGEMENT INFORMATION BASE PARAMETERS

(NORMATIVE)

This table lists each MIB parameter in the document along with how it is used and in which layer or sublayer. 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-duplex, half-duplex, and simplex session establishment and COMM_CHANGE. Session static (see 5.2.3.4).	P, M
Carrier_Loss_Timer_Duration	Mandatory. Used in full- and half-duplex operations. Session static (see 5.2.3.6).	D
Carrier_Only_Duration	Mandatory. Used in full-duplex, half-duplex, and simplex session establishment and COMM_CHANGE. Session static (see 5.2.3.3).	P, M
Comm_Change_Lifetime	Mandatory. Used in the COMM_CHANGE persistent activity. Session static (see 5.2.3.10).	M
Comm_Change_Notification	Mandatory. Used in the COMM_CHANGE persistent activity. Session static (see 5.2.3.9).	M
Comm_Change_Response	Mandatory. Used in the COMM_CHANGE persistent activity. Session static (see 5.2.3.8).	M
Comm_Change_Waiting_Period	Mandatory. Used in the COMM_CHANGE persistent activity. Session static (see 5.2.3.7).	M
Hail_Lifetime	Mandatory. Used in the hailing persistent activity. Session static (see 5.2.3.14).	M
Hail_Notification	Mandatory. Used in the hailing persistent activity. Session static (see 5.2.3.13).	M
Hail_Response	Mandatory. Used in the hailing persistent activity. Session static (see 5.2.3.12).	M
Hail_Wait_Duration	Mandatory. Used in the hailing persistent activity. Session static (see 5.2.3.11).	M

Parameter	Use	Layer
Hailing_Channel	Mandatory. Channel assignment used in the hailing persistent activity during link establishment. Session static (see 5.1.1.1 and ANNEX H).	P, M
Hailing_Data_Rate	Mandatory. Data rate used in the hailing persistent activity during link establishment. Session static (see 5.2.3.15).	P, M
Hailing_Symbol_Rate	Mandatory. Symbol rate used in the hailing persistent activity during link establishment. Session static (see 5.2.3.15).	P, M
NACKs_Allowed	Mandatory. Defines the maximum number of negative acknowledgements (NACKs) that the caller can receive from the responder. Once this value is exceeded, the link negotiation process carried out via the query/response directive function with the responder is terminated. Session static.	M
Interval_Clock	Mandatory. A frequency (e.g., 100 Hz) that is used for interval timing. Session static (see reference [4], subsection 5.2).	C
Link_SNR_Step	Mandatory. Used to establish the step size in fractions of a dB reporting the instantaneous link SNR by the radio. Session Static.	P
Local_PCID	Optional. Used to set the value of the local receiver's PCID. Session Static.	M
Local_Spacecraft_ID	Mandatory. Used as a frame validation check when Source-or-Destination ID equals *source*. Session static (see reference [6] subsection 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). Session Static.	D
Default Frame Type	Mandatory. Defines the default transfer frame type in use by the transceiver at setup. Values are: "00"(Mission-Specific), '01'(Proximity-1), '10'(USLP), '11'(N/A). Session Static.	F, U

Parameter	Use	Layer
Maximum_Frame_Length	Mandatory. Defines the maximum size Transfer Frame transferred between nodes. Link efficiency at various data rates may require varying frame lengths (see reference [6] subsection 3.2.3.1 for Version-3 Transfer Frames and reference [7], subsection 5.2 for Version-4 Transfer frames). The maximum value allowed for this parameter depends on the Frame Type 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 reference [6] subsection 4.4.2.1).	I
Persistence_Wait_Time	Mandatory. Defines the maximum amount of time the initiating transceiver stays in persistence until either (1) it receives an acknowledgement from the remote transceiver that the COMM_CHANGE was acted upon, or (2) the wait timer times out (see table 5-7, 'Full Duplex Communication Change State Table'). Session Static.	M
PLCW_Repeat_Interval	Mandatory. Used in COP-P. Session static (see 5.2.3.18).	D
Receive_Duration	Mandatory. Used in half-duplex data services. Session static (see 5.2.3.17).	D
Drop_Carrier_Duration	Mandatory. Used in full- and half-duplex data services. The caller drops the carrier for this defined amount of time. Used to force the responder to lose carrier lock and therefore transition to State S2: Waiting for Hail. Session static (see table 5-1).	D
Remote_PCID	Mandatory. Used to identify the powered receiver used by the remote transceiver. Session Static.	M
Remote_Spacecraft_ID	Mandatory. Used to address one or several remote spacecraft, as opposed to the local spacecraft. Session dynamic (see reference [6] subsection 3.2.2.9.3).	F, M, D, I
Resync_Local	Optional. If Resync_Local equals *false*, it is the responsibility of the local controller to decide how synchronization will be re-established. Otherwise, if *true*, the Sender Node's FOP-P forces synchronization by requesting a SET V(R) persistent activity. Session static (see 6.2.3.2, 'SET V(R) Persistent Activity').	D

Parameter	Use	Layer
Resync_Remote	Optional. Similar to Resync_Local. It controls the resynchronization policy of the remote node. If Resync_Remote = false, then the local radio will also not respond to remote resync directives (Set V(R)) (Table 6-2 event RE2). Session Static.	D
Resync_Lifetime	Optional. Used in the FOP-P SET V(R) persistent activity. Session static (see 6.2.3.2).	M, D
Resync_Notification	Optional. Used in the FOP-P SET V(R) persistent activity. Session static (see 6.2.3.2).	M, D
Resync_Response	Optional. Used in the FOP-P SET V(R) persistent activity. Session static (see 6.2.3.2).	M, D
Resync_Waiting_Period	Optional. Used in the FOP-P SET V(R) persistent activity. Session static (see 6.2.3.2).	M, D
Send_Duration	Mandatory. Used in half-duplex data services. Session static (see 5.2.3.16).	D
Source_Destination_ID	Mandatory. ‘0’= Source SCID; ‘1’=Destination SCID. Session Static (see reference [6] subsection 3.2.2.9).	M
Synch_Timeout	Mandatory. Defines the value to which the SYNCH_TIMER is initialized or reinitialized. Session static (see 6.2.2).	D
Tail_Idle_Duration	Mandatory. Used in full-duplex, half-duplex, and simplex session establishment and COMM_CHANGE. Session static (see 5.2.3.5).	P, M
Test_Source	Mandatory. Used in the verification of the spacecraft ID when the Source-or-Destination ID is *source*. Session static (see 5.2.3.2).	F
Transmission_Window	Mandatory. Sets the maximum size of the transmission window for the COP-P. Session static (see 6.2.3.3, note 3).	D
LEC_Length	Mandatory. Size of the LEC directive (ANNEX E) in octets. Session Static.	M
Report_Request_Length	Mandatory. Size of the Report_Request directive (ANNEX E) in octets. Session Static.	M
Set_V(R)_Length	Mandatory. Size of the Set V(R) directive (ANNEX E) in octets. Session Static.	M

Parameter	Use	Layer
Report_Source_SCID_Length	Mandatory. Size of the Report_Source_SCID directive (ANNEX E) in octets. Session Static.	M
Set_Fixed_Length_Frame_Length	Mandatory. Size of the Set Fixed Length Frame directive (ANNEX E) in octets. Session Static.	M
PN_Ranging_Length	Mandatory. Size of the PN Ranging directive (ANNEX E) in octets. Session Static.	M

ANNEX G

NOTIFICATIONS TO VEHICLE CONTROLLER

(NORMATIVE)

This table summarizes all of the conditions throughout the document under which the vehicle controller is notified from within the protocol.

Number	Condition	Reference
1	RESULT OF PERSISTENT ACTIVITY Notification of the success or failure of a persistent activity.	See 4, ‘Persistence’.
2	STATE CONTROL STATUS Status of the State Control Variables.	See state tables contained in section 5.
3	INVALID FRAME SOURCE When the SCID field and RECEIVING_SCID_BUFFER disagree, and Test_Source is *true*, then a session violation has occurred, and the vehicle controller shall be notified.	See 5.7, ‘RECEIVING OPERATIONS’.
4	TIMING SERVICES INSTANCE At the end of receiving the SET CONTROL PARAMETERS (*time sample*) directives, the recipient transceiver notifies its vehicle controller that time tags and FSNs are available.	See reference [6] section 5, ‘Proximity-1 Timing Services’.
5	NO CARRIER RECEIVED—HALF DUPLEX	State table 5-9, Event 50.
6	NO DATA TRANSFERRED—HALF DUPLEX	State table 5-9, Event 45, E50
7	SENDER EXCEEDED PRESCRIBED TRANSMISSION PERIOD—HALF DUPLEX	State table 5-9, Event 44.
8	COP-P LOSS OF SYNCHRONIZATION When FOP-P detects out-of-synchronization condition (SYNCH_TIMER Expires).	See 6.2.3.3, ‘FOP-P State Table’, Event SE4.
9	CARRIER_LOSS_TIMER UNDERFLOWS	State table 5-8, Event 27.

Number	Condition	Reference
10	END OF SESSION (# octets received) Caller notifies the vehicle controller of the number of octets received during the session.	State table 5-8, Events E26, E27, E28. State table 5-11, Events E57, E58, E61. State table 5-12, Event E73.
11	CARRIER ONLY RECEIVED Caller notifies vehicle controller that only a carrier was detected immediately after the ‘Wait for Hail Response’ state terminated.	State table 5-6, Event E8. State table 5-9, Event E36.

ANNEX H

DEFAULT HAILING PARAMETERS FOR SPACE ENTERPRISES

(NORMATIVE)

H1 OVERVIEW

This normative Annex documents the default hailing (session establishment) parameters used for hailing a partnered transceiver for specific Space Enterprises, such as Mars or Lunar operations. This Annex provides the parameter values to carry out both a demand and a negotiated hail.

H2 HAILING CHANNEL PARAMETERS

H2.1 UHF-BAND HAILING CHANNEL PARAMETERS

Hailing-channel parameters for UHF-Band (Martial environment) shall be:

– Hailing Channel Number: Channel 1 forward and return link;[1]

– Hailing Symbol Rate: 8,000 symbols/second;

– Coding: Uncoded;

– Modulation: Bi-Phase-L;

– Polarization: Right Hand Circular;

– Transceiver Mode: Proximity-1;

– Physical Channel ID (PCID): 0;[2]

– Coherency: Non-coherent.

H2.2 S BAND HAILING CHANNEL PARAMETERS

Haling-channel parameters for S Band (lunar environment) shall be:

[1] Hailing is performed between pre-configured transceivers, so it is nominally performed on the hailing channel. However, if transceivers are compatibly configured, hailing can occur on an agreed-to channel. Several first generation transceivers in the Mars Enterprise at UHF operate at fixed frequency and use Channel 0 instead.

[2] PCID is a “don’t care” value unless an implementation treats the two PCID values as separately independent entities, in which case each physical channel shall have a completely separate set of MIB parameters and all state machines, including COP-P.

- Default Hailing Channel Number: 0;[3]
- Optional Hailing Channel Number: 9;[3]
- Hailing Coded Symbol Rate: 2000 symbols/second
- Coding: LDPC (n=2048,k=1024) rate 1/2 code defined in reference [4];
- Modulation: Bi-phase-L;
- Polarization:
  - Left Hand Circular for Default Hailing Channel 0;
  - Right Hand Circular for Optional Hailing Channel 9;
- Transceiver Mode: USLP;
- Physical Channel ID (PCID): 0;[2]
- Coherency: Non-coherent.

[3] Specific frequency channel assignments are defined in the Proximity-1 Space Link Protocol - Physical Layer (reference [5]).

ANNEX I

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

I1 SECURITY CONSIDERATIONS

I1.1 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 (see reference [J4] for implementation guidance), a brief overview of the three available services is provided below:

– **Confidentiality**: Protects payload data from unauthorized access. Without this service, sensitive or private information might be disclosed to eavesdroppers, and data flowing to or from a spacecraft might be visible to unauthorized entities.

– **Integrity**: Protects payload data from undetected modification during transit. Without this service, corrupted/erroneous commands or software might be uploaded to a spacecraft, or corrupted telemetry might be retrieved from a spacecraft, potentially resulting in incorrect course of action or loss of the mission.

– **Authentication**: Verifies the source of payload data (e.g., for command data). Without this service, unauthorized commands or software might be uploaded/loaded onto a spacecraft, or data retrieved from a source masquerading as the spacecraft.

A single datagram may require all three security services to ensure that the payload is confidential, unaltered, and authentic.

I1.2 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 DLL;

– Data **integrity** protection: Any layer (Application, Network, or Data Link);

– Data **confidentiality**: Any layer (Application, Network, or Data Link).

Reference [J4] provides more information regarding the choice of service and where it can be implemented.

I1.3 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.

I1.4 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.

I2 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.

I3 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 J

INFORMATIVE REFERENCES

(INFORMATIVE)

NOTE – References [J1]-[J3] 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.

[J1] *Digital Video Broadcasting (DVB); Framing Structure, Channel Coding and Modulation for 11/12 GHz Satellite Services*. ETSI EN 300 421 V1.1.2 (1997-08). Sophia-Antipolis: ETSI, 1997.

[J2] *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.

[J3] *Performance Characteristics for Intermediate Data Rate Digital Carriers Using Convolutional Encoding/Viterbi Encoding*. Rev. 10. IESS 308. Washington, DC: INTELSAT, 2000.

[J4] *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.

[J5] *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 K

LINK ESTABLISHMENT, COMM CHANGE, AND LINK TERMINATION USE CASES

(INFORMATIVE)

This Annex defines representative LEC operational use cases. It describes how directive exchanges between Caller and Responder evolve across hailing and working channel conditions, including negotiation, configuration changes, and link termination. All entries in this Annex use the LEC directive family.

K1 LEC DIRECTIVE BIT FIELD DEFINITION

This table defines the fixed 96-bit structure of all LEC directives used throughout this Annex. Field definitions apply uniformly across hailing, working channel, and termination scenarios.

Table K-1: LEC Directive Bit Field Definition

Directive Name	Link Direction	Directive Function	RNMD	Token	Duplex/Simplex	Polarization	Coherent/Non-	MODCOD Overlay	Modulation	Coding	Spare	Modulation Index	Spare	Frame Type	Inst. Link SNR	Time Sample	Spares	Symbol Rate	Frequency
4 bits	1 bit	3 bits	1 bit	1 bit	3 bits	1 bit	1 bit	1 bit	4 bits	5 bits	1 bit	3 bits	1 bit	2 bits	8 bits	6 bits	2 bit	16 bits	32 bits
0–3	4	5–7	8	9	10–12	13	14	15	16–19	20–24	25	26–28	29	30–31	32-39	40-45	46-47	48–63	64–95

K2 USE CASES AND ACTIVITY SEQUENCES

The table below illustrates the sequential directive exchanges between the Caller and Responder across various communication scenarios. It maps nodes, directives, functions, configuration parameters, and resulting state changes for each step, with shaded values highlighting actively negotiated parameters.

Table K-2: LEC Directive Use Cases

				Bits 5–7	**Bit 8**	**Bit 9**	**Bits 16–19**	**Bits 20–24**	**Bits 48–63**	**Bits 64–95**	
Use Case	Activity	Src → Dest	Channel	Function	RNMD	Token	Modulation	Coding	Symbol Rate	Freq	State Change
Hailing, no negotiation	Caller demands FWD link	C → R	ch0	Demand	0	0	SP-L/PM	LDPC 1/2	8k	2085.6875	Idle → Working
	Caller demands RTN link	C → R	ch0	Demand	0	0	GMSK	LDPC 1/2	128k	2265	Config applied
Hailing with negotiation	Caller sends FWD query	C → R	ch0	Query	0	0	SP-L/PM	LDPC 1/2	8k	2085.6875	Negotiation
	Caller sends RTN query	C → R	ch0	Query	0	0	GMSK	LDPC 1/2	128k	2265	Negotiation
	Responder sends FWD ACK	R → C	ch0	ACK	0	0	SP-L/PM	LDPC 1/2	8k	2085.6875	Partial accept
	Responder sends RTN NACK	R → C	ch0	NACK	0	0	GMSK	LDPC 1/2	128k	2265	Retry required
	Caller sends revised RTN query	C → R	ch0	Query	0	0	SP-L/PM	LDPC 1/2	128k	2265	Negotiation
	Responder sends RTN ACK	R → C	ch0	ACK	0	0	SP-L/PM	LDPC 1/2	128k	2265	Accepted
	Caller demands FWD link	C → R	ch0	Demand	0	0	SP-L/PM	LDPC 1/2	8k	2085.6875	Finalizing
	Caller demands RTN link	C → R	ch0	Demand	0	0	SP-L/PM	LDPC 1/2	128k	2265	Working

				Bits 5–7	Bit 8	Bit 9	Bits 16–19	Bits 20–24	Bits 48–63	Bits 64–95	
Use Case	Activity	Src → Dest	Channel	Function	RNMD	Token	Modulation	Coding	Symbol Rate	Freq	State Change
Working channel ADR	Caller requests RTN rate change	C → R	ch1	Demand	0	0	SP-L/PM	LDPC 1/2	256k	2265	Rate increase
	Caller queries high RTN rate	C → R	ch1	Query	0	0	GMSK	LDPC 1/2	500k	2265	Negotiation
	Responder sends RTN NACK	R → C	ch1	NACK	0	0	GMSK	LDPC 1/2	500k	2265	Retry required
	Caller queries medium RTN rate	C → R	ch1	Query	0	0	GMSK	LDPC 1/2	350k	2265	Negotiation
	Responder sends RTN ACK	R → C	ch1	ACK	0	0	GMSK	LDPC 1/2	350k	2265	Accepted
	Caller demands RTN link change	C → R	ch1	Demand	0	0	GMSK	LDPC 1/2	350k	2265	Working
Report SNR	Caller requests SNR report	C → R	ch1	report-rqst	0	0	SP-L/PM	LDPC 1/2	256k	2265	Polling
	Responder reports SNR (3.3) bits 32-39	R → C	ch1	report	0	0	SP-L/PM	LDPC 1/2	256k	2265	Monitoring (SNR 3.3)
Data Driven Link Termination	Responder indicates no data	R → C	ch1	report-rqst	1	0	-	-	-	-	Terminating
	Responder polls Caller status	R → C	ch1	report-rqst	1	0	-	-	-	-	Polling
	Caller indicates active data	C → R	ch1	report-rqst	0	0	-	-	-	-	Active
	Caller indicates no data	C → R	ch1	report-rqst	1	0	-	-	-	-	Terminated

NOTE – The following bitfields have been omitted from this summary for brevity because they remain constant or are marked as "don't care" (invalid/0) across these scenarios. See the full bitfield map above for the complete telemetry structure:

- Directive Name bits 0-3 =LEC

• Duplex/Simplex	bits 10–12	=FD or 0
• Polarization	bit 13	= LHCP
• Coherent/Non-coherent	bit 14	= Non coh
• MODCOD Overlay	bit 15	= 0
• Spares	bits 25, 29, 46–47	= 0 or blank
• Modulation Index	bits 26–28	= 100 (pi/3)
• Frame Type	bits 30–31	= USLP or invalid
• Inst. Link SNR	bits 32–39	= invalid (except for Report SNR, where its value of 3.3 is captured in the activity description)
• Time Sample	bits 40–45	= 0 or invalid

ANNEX L

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

Term	Meaning
ACK	acknowledge
ADR	adaptive data rate
AOS	advanced orbiting systems
ARQ	automatic repeat queuing
ASM	attached synchronization marker
C&DH	command and data handling
C&S	coding and synchronization
CCSDS	Consultative Committee for Space Data Systems
COP-P	communication operations procedure-P
CRC	cyclic redundancy check
DLL	Data Link Layer
DSS	Data Services Sublayer
ETSI	European Telecommunications Standards Institute
FARM-P	frame acceptance and reporting mechanism-P
FD	full duplex
FIFO	first in, first out
FOP-P	frame operations procedure-P
FSK	frequency shift keying
FSN	frame sequence number
FWD	forward
GMSK	gaussian minimum shift keying
I/O	input/output
ITU	International Telecommunications Union

LCCD	local COMM_CHANGE directive
LDPC	low density parity check
LEC	LINK ESTABLISHMENT & CONTROL directive
LHCP	left hand circular polarization
LNMD	LOCAL_NO_MORE_DATA
LSB	least significant bit
MAC	media access control
MIB	management information base
MODCOD	modulation/coding overlay
MRO	Mars Reconnaissance Orbiter
MSB	most significant bit
NACK	negative acknowledge
NRZ-L	non-return to zero-level
OSI	Open Systems Interconnection
OWLT	one-way light time
PCID	physical channel identifier
PDU	protocol data unit
P-frame	supervisory/protocol frame
PL	Physical Layer
PLCW	protocol link control word
PLTU	Proximity Link Transmission Unit
PN	Pseudo-Noise
PSK	phase shift keying
QoS	quality of service
QPSK	quadrature phase shift keying
RCCD	remote COMM_CHANGE directive
RF	radio frequency
R-S	Reed-Solomon
RNMD	REMOTE_NO_MORE_DATA

RTN	return
RX	receive/receiver
SANA	Space Assigned Numbers Authority
SCID	spacecraft identifierSDU service data unit
SMTF	Sync-Marked Transfer Frame
SNR	signal-to-noise ratio
SPDU	supervisory protocol data unit
SP-L/PM	Split-Phase-Level/Phase Modulation
SS	sub-state
TX	transmit/transmitter
U-frame	user data frame
UHF	Ultra High Frequency
USLP	Unified Space Data Link Protocol
VCID	virtual channel identifier
WT	Wait Timer