



CCSDS

The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

**PROXIMITY-1 SPACE LINK
PROTOCOL—CODING AND
SYNCHRONIZATION
SUBLAYER**

RECOMMENDED STANDARD

CCSDS 211.2-B-2

BLUE BOOK

December 2013

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

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 211.0-B-1	Proximity-1 Space Link Protocol	October 2002	Original issue, superseded
CCSDS 211.2-B-1	Proximity-1 Space Link Protocol— Coding and Synchronization Sublayer	April 2003	Superseded
CCSDS 211.2-B-2	Proximity-1 Space Link Protocol— Coding and Synchronization Sublayer, Recommended Standard, Issue 2	December 2013	Current issue: This update includes several improvements and clarifications— accomplishing better alignment and consistency with the other Proximity-1 Blue Books—and the addition of an option for Low-Density Parity-Check (LDPC) codes.

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

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommended Standard is to specify synchronization and channel coding schemes used with the Proximity-1 Data Link Protocol (reference [3]) and Physical Layer (reference [4]). Proximity space links are defined to be short-range, bi-directional, fixed or mobile radio links, generally used to communicate among probes, landers, rovers, orbiting constellations, and orbiting relays. These links are characterized by short time delays, moderate (not weak) signals, and short, independent sessions.

1.2 SCOPE

This Recommended Standard defines synchronization and channel coding schemes for Proximity-1 links in terms of:

- a) the services provided to the users of this specification;
- b) data formats; and
- c) the procedures performed to generate and process the data formats.

It does not specify:

- a) individual implementations or products;
- b) the methods or technologies required to perform the procedures; or
- c) the management activities required to configure and control the protocol.

The Coding and Synchronization Sublayer is part of the Data Link Layer. The rest of the Data Link Layer is defined in the separate CCSDS Recommended Standard entitled, *Proximity-1 Space Link Protocol—Data Link Layer* (reference [3]). The Physical Layer is defined in the separate CCSDS Recommended Standard entitled, *Proximity-1 Space Link Protocol—Physical Layer* (reference [4]).

1.3 APPLICABILITY

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

The Recommended Standard specified in this document is to be invoked through the normal standards programs of each CCSDS Agency and is applicable to those missions for which cross support based on capabilities described in this Recommended Standard is anticipated. Where mandatory capabilities are clearly indicated in sections of the 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. Concept and rationale behind the decisions that formed the basis for Proximity-1 is documented in the CCSDS Proximity-1 Space Link Green Book (reference [E1]).

1.5 DOCUMENT STRUCTURE

This document is divided into three numbered sections and four annexes:

- a) section 1 presents the purpose, scope, applicability and rationale of this Recommended Standard and lists the conventions, definitions, and references used throughout the document;
- b) section 2 provides an overview of Proximity-1 synchronization and channel coding;
- c) section 3 specifies convolutional coding;
- d) annex A contains the Protocol Implementation Conformance Statement (PICS) proforma for this specification;
- e) annex B defines the service provided to the users;
- f) annex C defines CRC-32 Coding Procedure;
- g) annex D discusses security, SANA, and patent considerations;
- h) annex E contains informative references;
- i) annex F contains a list of abbreviations and acronyms.

1.6 CONVENTIONS AND DEFINITIONS

1.6.1 DEFINITIONS

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

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

- a) Data Link Layer;
- b) Physical Layer;
- c) protocol data unit;
- d) real system;
- e) service;
- f) service data unit.

1.6.1.2 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.

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

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

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

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

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

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

1.6.2 NOMENCLATURE

1.6.2.1 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.

1.6.2.2 INFORMATIVE TEXT

In the normative section of this document (section 3 and annexes B and C), informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

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

1.6.3 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) shall be the first transmitted bit of the field, i.e., ‘Bit 0’, as shown in figure 1-1.

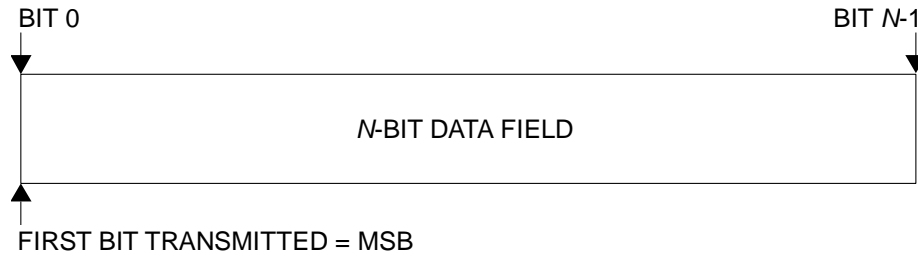


Figure 1-1: Bit Numbering Convention

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

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

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

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

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

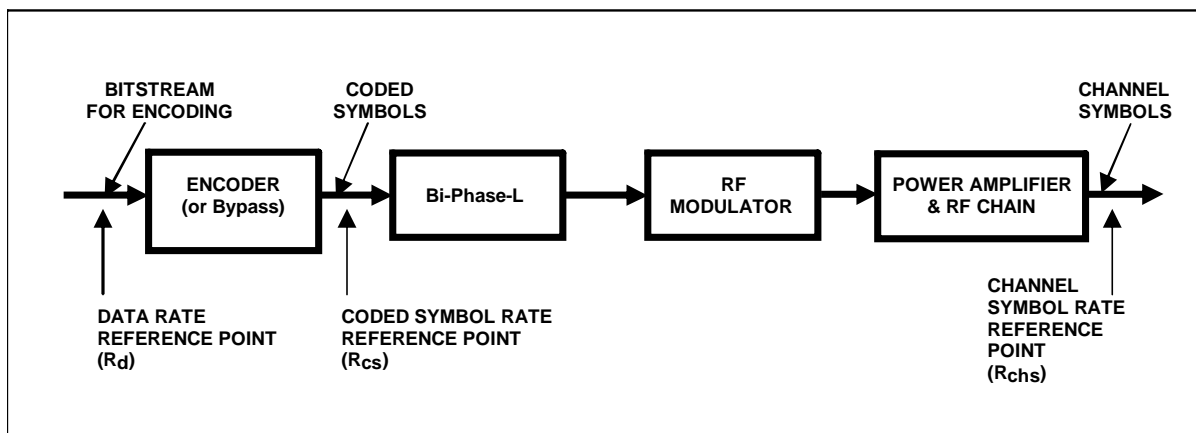


Figure 1-2: Proximity-1 Rate Terminology

1.7 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. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.
- [2] *TM Synchronization and Channel Coding*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.0-B-2. Washington, D.C.: CCSDS, August 2011.
- [3] *Proximity-1 Space Link Protocol—Data Link Layer*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.0-B-5. Washington, D.C.: CCSDS, December 2013.
- [4] *Proximity-1 Space Link Protocol—Physical Layer*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.1-B-4. Washington, D.C.: CCSDS, December 2013.

2 OVERVIEW

2.1 LAYERS OF THE PROTOCOL

Proximity-1 is a bi-directional Space Link Layer protocol for use by space missions. It has been designed to meet the requirements of space missions for efficient transfer of space data over various types and characteristics of Proximity space links. The protocol consists of a Data Link Layer (reference [3]) and a Physical Layer (reference [4]). The Coding and Synchronization (C&S) Sublayer defined in this document is part of the Data Link Layer.

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

Figure 2-1 gives a simplified view of the Proximity-1 layered structure.

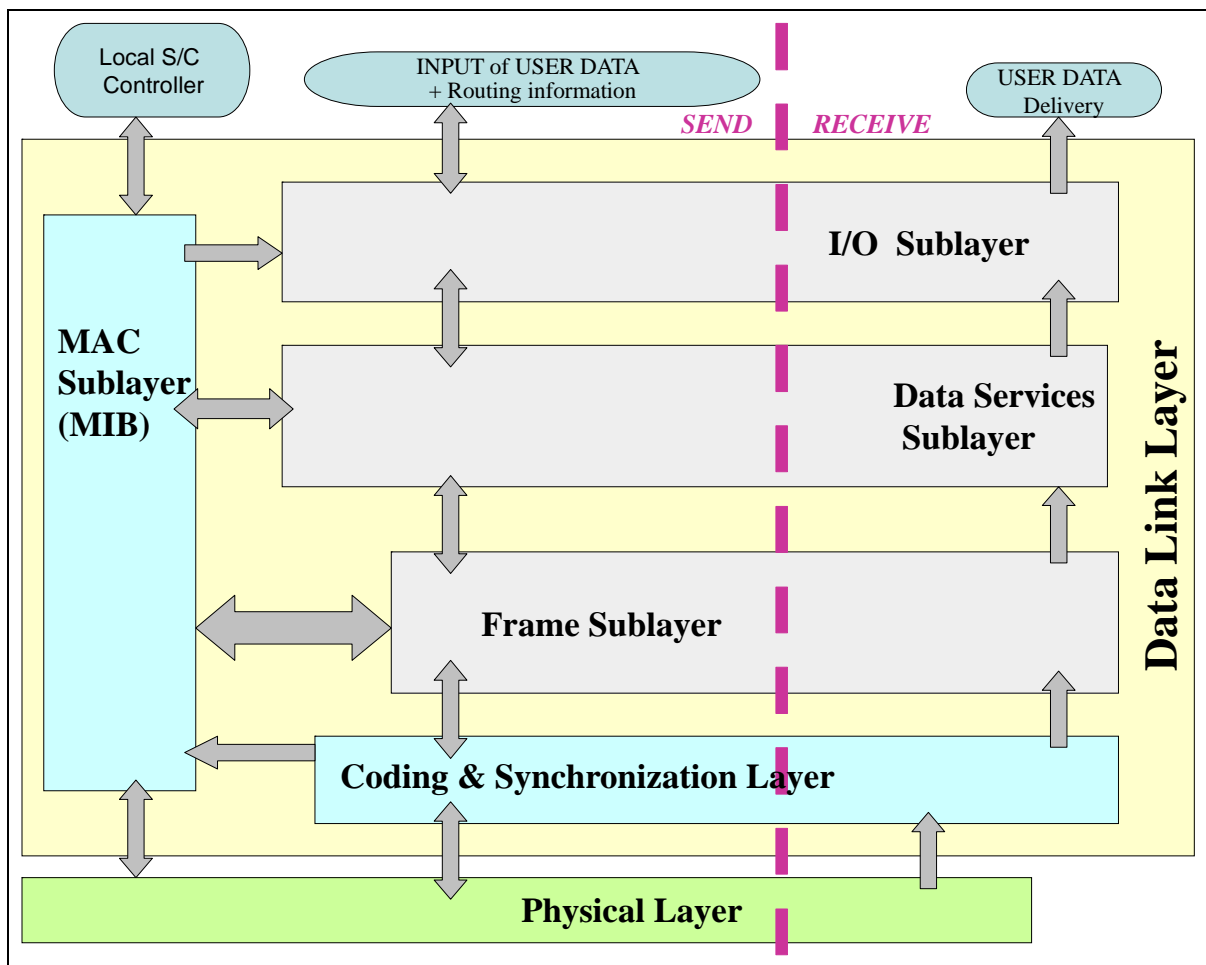


Figure 2-1: Simplified Overview of Proximity-1 Layers

2.2 PHYSICAL LAYER

On the send side, the Physical Layer:

- accepts control variables from the Data Link Layer for control of the transceiver;
- accepts a stream of Proximity-1 coded symbols from the Data Link Layer for modulation onto the radiated carrier.

On the receive side, the Physical Layer

- provides the serial stream output of Proximity-1 coded symbols from the receiver to the Data Link Layer:
- provides status signals (CARRIER_ACQUIRED and SYMBOL_INLOCK_STATUS) to the Data Link Layer.

2.3 DATA LINK LAYER

This subsection provides a brief overview of the Data Link Layer, with emphasis on the features relevant to the C&S Sublayer. Reference [3] contains a more complete description of the overall Proximity-1 system, of the Data Link Layer, and of its sublayers.

On the send side, the Data Link Layer is responsible for providing data to be transmitted by the Physical Layer. On the receive side, the Data Link Layer accepts the serial coded symbol stream output from the receiver in the Physical Layer and processes the protocol data units contained in it.

Within the Data Link Layer, the Medium Access Control (MAC) Sublayer and the Frame Sublayer have interfaces to the C&S Sublayer.

The Medium Access Control (MAC) Sublayer controls the establishment, maintenance and termination of communications sessions for point-to-point communications between Proximity entities. It controls the operational state of the Data Link and Physical Layers, using control variables. It accepts Proximity-1 directives both from the local vehicle controller and across the Proximity link to control its operations. The MAC Sublayer is also responsible for the storage and distribution of the Management Information Base (MIB) parameters.

The Frame Sublayer includes the processing associated with the fields contained in the Frame Header of the Version-3 Transfer Frame. On the send side, the Frame Sublayer determines the order of frame transmission and delivers frames to the C&S Sublayer. On the receive side, the Frame Sublayer receives and validates frames from the C&S Sublayer and delivers them to the Data Services Sublayer or to the MAC Sublayer, depending on their contents.

2.4 CODING AND SYNCHRONIZATION SUBLAYER

On the send side, the actions of the C&S Sublayer include:

- constructing PLTUs, where each PLTU contains a Version-3 Transfer Frame received from the Frame Sublayer;
- generation of the bitstream for encoding, inserting Idle data as required;
- channel coding;
- provision of the coded symbols stream at a constant rate (R_{cs}), to the Physical Layer for modulation onto the radiated carrier.

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

- reception of the coded symbols stream from the receiver in the Physical Layer at a constant rate (R_{cs});
- channel decoding;
- delimiting of each PLTU, including validation;
- for each valid PLTU, delivering the delimited transfer frame to the Frame Sublayer.

On both the send and receive sides, the C&S Sublayer supports Proximity-1 timing services defined in reference [3] by capturing the values of the clock, frame sequence number, Quality of Service (QOS) Indicator, and direction (ingress or egress) associated with each Proximity-1 transfer frame.

The (simplified) interaction of the Coding & Synchronization Sublayer with the other (sub) layers at the transmitting (i.e., encoding) side of Proximity-1 is shown in figure 2-2.

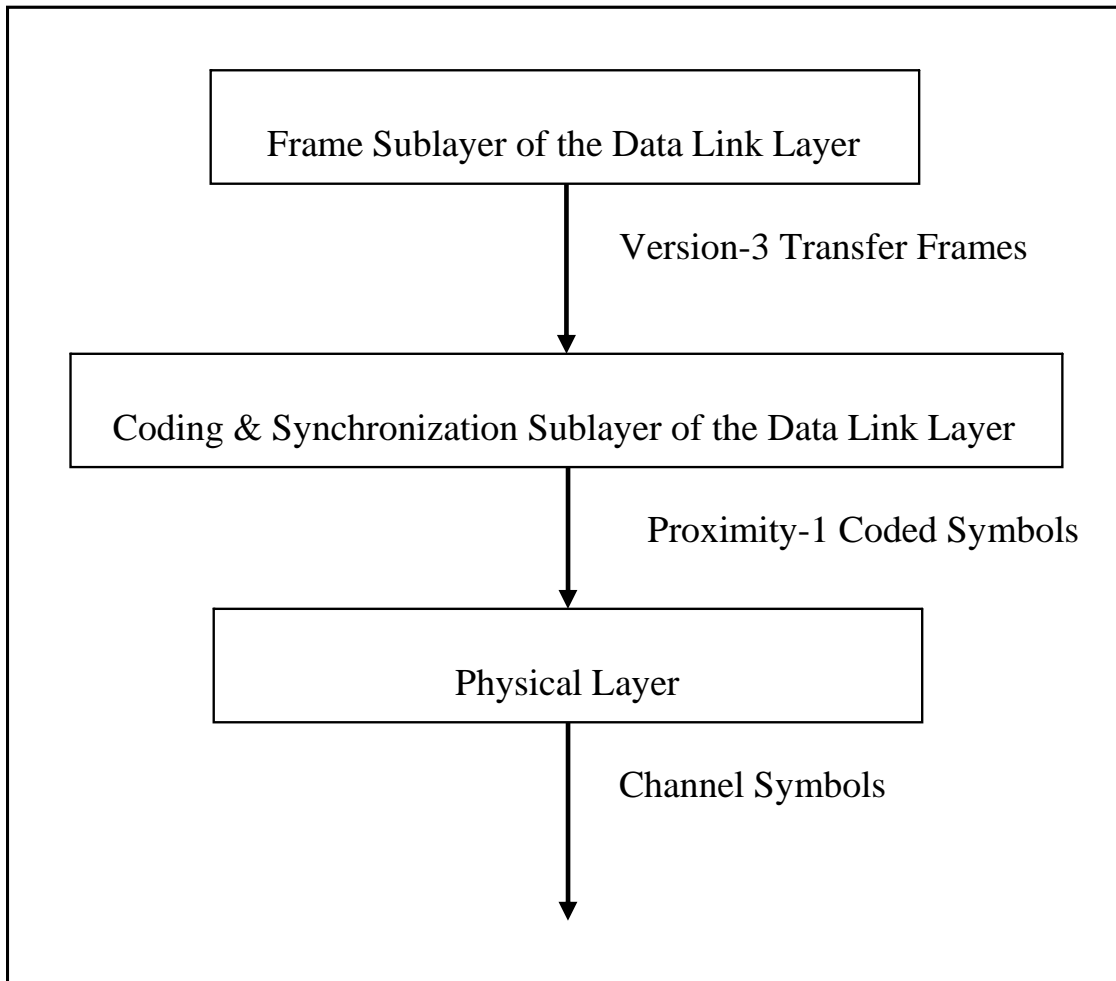


Figure 2-2: Coding & Synchronization Sublayer Send Side Interactions

3 CODING AND SYNCHRONIZATION SUBLAYER

3.1 OVERVIEW

On the send side, the C&S Sublayer generates the output coded symbols stream (including PLTUs and Idle data) to be delivered to the Physical Layer for modulation onto the radiated carrier. The PLTU is specified in 3.2. Each PLTU contains a Version-3 Transfer Frame specified in reference [3] that also defines an Output Bitstream FIFO, which holds coded symbol-stream data ready for delivery to the Physical Layer.

The PLTUs form a non-continuous serial stream, consisting of a sequence of variable-length PLTUs, which can have a delay between the end of one PLTU and the start of the next. While establishing a Proximity-1 session for a full- or half-duplex link, synchronization is reacquired for each PLTU and Idle data is provided for the acquisition process. When no PLTU is available, Idle data is transmitted to maintain synchronization. Idle data is specified in 3.3. The procedures for the session establishment, data services, and session termination phases of a Proximity-1 session are specified in reference [3].

The channel coding options for Proximity-1 are specified in 3.4. The send side and receive side procedures in the C&S Sublayer are specified in 3.5 and 3.6.

3.2 PROXIMITY LINK TRANSMISSION UNIT (PLTU)

3.2.1 PLTU OVERVIEW

The C&S Sublayer handles the PLTU specified here and the Version-3 Transfer Frame specified in reference [3]. The PLTU and the transfer frame are variable-length data structures.

For the sending end of a link, the C&S Sublayer constructs PLTUs, where each PLTU contains a transfer frame. For the receiving end, the C&S Sublayer processes each PLTU and delimits the transfer frame.

3.2.2 PLTU STRUCTURE

A PLTU shall encompass the following three fields, positioned contiguously, in the following sequence:

- a) 24-bit Attached Synchronization Marker (ASM);
- b) a Version-3 Transfer Frame;
- c) 32-bit Cyclic Redundancy Check.

NOTES

- 1 The length of a PLTU depends on the length of the transfer frame it contains. A PLTU can have a length up to 2055 octets (3 octets ASM + 2048 octets maximum transfer frame + 4 octets CRC).
- 2 The structural components of the PLTU are shown in figure 3-1.

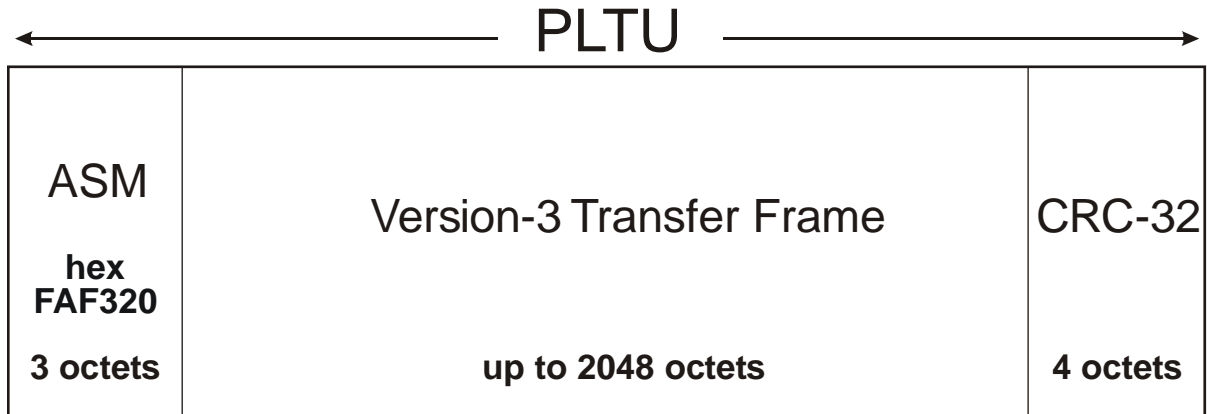


Figure 3-1: Proximity-1 Link Transmission Unit (PLTU)

3.2.3 ATTACHED SYNCHRONIZATION MARKER (ASM)

3.2.3.1 The Attached Synchronization Marker (ASM) shall occupy the first 24 bits of the PLTU.

3.2.3.2 The ASM shall consist of the following bit pattern (in hexadecimal): FAF320.

NOTE – At the receiving end, the ASM is used to detect the start of a PLTU.

3.2.4 VERSION-3 TRANSFER FRAME

The Version-3 Transfer Frame (defined in 3.2) in a PLTU shall immediately follow the ASM.

NOTE – Specification of the Version-3 Transfer Frame is contained in reference [3]. The PLTU is not designed for use with any other type of transfer frame.

3.2.5 CYCLIC REDUNDANCY CHECK (CRC-32)

3.2.5.1 The Cyclic Redundancy Check (CRC-32) shall occupy the last 32 bits of the PLTU.

3.2.5.2 The CRC-32 shall immediately follow the Version-3 Transfer Frame.

3.2.5.3 The CRC-32 shall be calculated by applying the encoding procedure specified in annex C to the Version-3 Transfer Frame.

3.2.5.4 The ASM shall NOT be a part of the encoded data space of the CRC-32.

NOTE – As shown in figure 3-1, the CRC is part of the PLTU but it is not part of the Version-3 Transfer Frame. In this respect, Proximity-1 differs from other CCSDS space data link protocols.

3.3 IDLE DATA

3.3.1 OVERVIEW

Idle data are included in the bitstream for encoding:

- for the purpose of data acquisition (Acquisition sequence);
- when no PLTU is available (Idle sequence); and
- prior to terminating transmission (Tail sequence).

A Pseudo-Noise (PN) sequence defines the bit pattern used for the Idle data in each of these sequences. The PN sequence is cyclic and is repeated as needed.

Reference [3] specifies the uses of the Acquisition sequence, Idle sequence, and Tail sequence in the phases of a Proximity-1 session. It also specifies the MIB parameters *Acquisition_Idle_Duration* and *Tail_Idle_Duration*, which represent the time that is used to radiate the Acquisition sequence and the Tail sequence.

3.3.2 GENERAL

3.3.2.1 Idle data shall be included in the bitstream for encoding as follows:

- a) an Acquisition sequence (defined in 3.3.3) shall be inserted when transmission commences;
- b) Idle sequence(s) (defined in 3.3.2 and 3.3.4) shall be inserted when no PLTU is available; and
- c) a Tail sequence (defined in 3.3.5) shall be inserted prior to terminating transmission.

3.3.2.2 Idle data shall consist of the PN sequence 352EF853 (in hexadecimal), repeated as needed.

3.3.2.3 When LDPC coding is used, the Acquisition sequence shall start on the first bit of the PN sequence.

NOTE – The requirement to start the Acquisition sequence on the first bit of the PN sequence applies only when LDPC coding is used.

3.3.2.4 Whenever the end of the PN sequence is reached, the sequence shall be repeated starting from the first bit of the PN sequence.

NOTE – An Idle Data Generator can be used to generate Idle data for insertion into the bitstream to be encoded.

3.3.3 ACQUISITION SEQUENCE

3.3.3.1 Overview

The Physical Layer provides the modulation necessary for the partners in a session to acquire and process each other's transmission. When transmission commences, the transmitter's modulation is sequenced (first carrier only followed by an Acquisition Sequence) such that the receiving unit can acquire the signal and achieve a reliable channel symbol stream in preparation for acceptance of the transmitted data units. If convolutional code is applied (see 3.4) the Acquisition Sequence is also used to achieve node synchronization in the decoder (reference [E1]). If LDPC code is used, the acquisition sequence duration is set long enough for a valid CSM to be detected after symbol synchronization is established and before the first PLTU begins.

3.3.3.2 Requirements

3.3.3.2.1 The Acquisition sequence shall consist of data as specified by the requirements in 3.3.3.2 above.

3.3.3.2.2 The Acquisition sequence shall be transmitted for the duration specified by the MIB parameter Acquisition_Idle_Duration specified in reference [3].

3.3.4 IDLE SEQUENCE

3.3.4.1 Overview

While in the data transfer phase of a Proximity-1 session, (encoded) PLTUs are transmitted within a continuous stream of channel symbols from the transmitter to the receiver. When no PLTU is available, the Idle sequence is injected into the bit stream to be encoded in order to keep the channel symbols stream flowing and to enable the receiver to maintain synchronization.

3.3.4.2 Requirements

3.3.4.2.1 The Idle sequence shall consist of data as specified by the requirements in 3.3.3.2 above.

3.3.4.2.2 During the data services phase, if no PLTU is ready for transfer, then the Idle sequence shall be transmitted.

3.3.5 TAIL SEQUENCE

3.3.5.1 Overview

Prior to terminating transmission (removing modulation) the transmitter transmits a series of idle bits (Tail sequence) for a fixed period. This can help the receiving unit to maintain bit lock and convolutional decoding while it completes the processing of the final received data unit.

3.3.5.2 Requirements

3.3.5.2.1 The Tail sequence shall consist of data as specified by the requirements in 3.3.3.2 above.

3.3.5.2.2 The Tail sequence shall be transmitted for the duration specified by the MIB parameter Tail_Idle_Duration, specified in reference [3].

3.4 CHANNEL CODING

3.4.1 OVERVIEW OF PROXIMITY-1 CHANNEL CODING

This document defines two channel codes for use on Proximity-1 links: an optional convolutional code, and an optional LDPC code.

NOTE – Some transceivers implement additional channel codes to those defined in the Proximity-1 recommended standards. The additions include a pair of Reed-Solomon codes, which can be enabled or disabled by the SET PL EXTENSIONS directive defined in annex A of reference [3]. The Reed-Solomon codes are not specified in the CCSDS Proximity-1 space link Recommended Standards and their use is not intended for cross-support applications.

3.4.2 CODING OPTIONS

3.4.2.1 The C&S Sublayer shall process the incoming Version-3 Transfer Frames and produce a bitstream for encoding (including PLTUs and Idle Data) at data rate R_d .

NOTE – The current data rate is configured using the SET TRANSMITTER PARAMETERS and SET PL EXTENSIONS directives defined in annex A of reference [3] and it is selected among the following discrete data rates, shown in bits per second: 1000, 2000, 4000, 8000, 16000, 32000, 64000, 128000, 256000, 512000, 1024000, 2048000. When LDPC codes are used, these R_d values are approximated and the true values can be found in annex A of reference [3].

3.4.2.2 The C&S Sublayer shall generate the output stream of Proximity-1 coded symbols applying only one of the following coding options:

- a) no coding;
- b) convolutional code (see 3.4.3);
- c) LDPC code (see 3.4.4).

NOTES

- 1 The convolutional and LDPC codes are optional. The use of the convolutional or LDPC code by the transmitter is configured using the SET TRANSMITTER PARAMETERS directive. The use by the receiver is configured by the SET RECEIVER PARAMETERS directive. The directives are defined in annex A of reference [3]. The MAC Sublayer configures the C&S Sublayer according to received directives.
- 2 The directives SET TRANSMITTER PARAMETERS and SET RECEIVER PARAMETERS include an option to concatenate the convolutional code with one of the Reed-Solomon codes. Neither the Reed-Solomon code nor the concatenation with the convolutional code is specified here.

Figure 3-2 below shows the principal behavior of the C&S Sublayer.

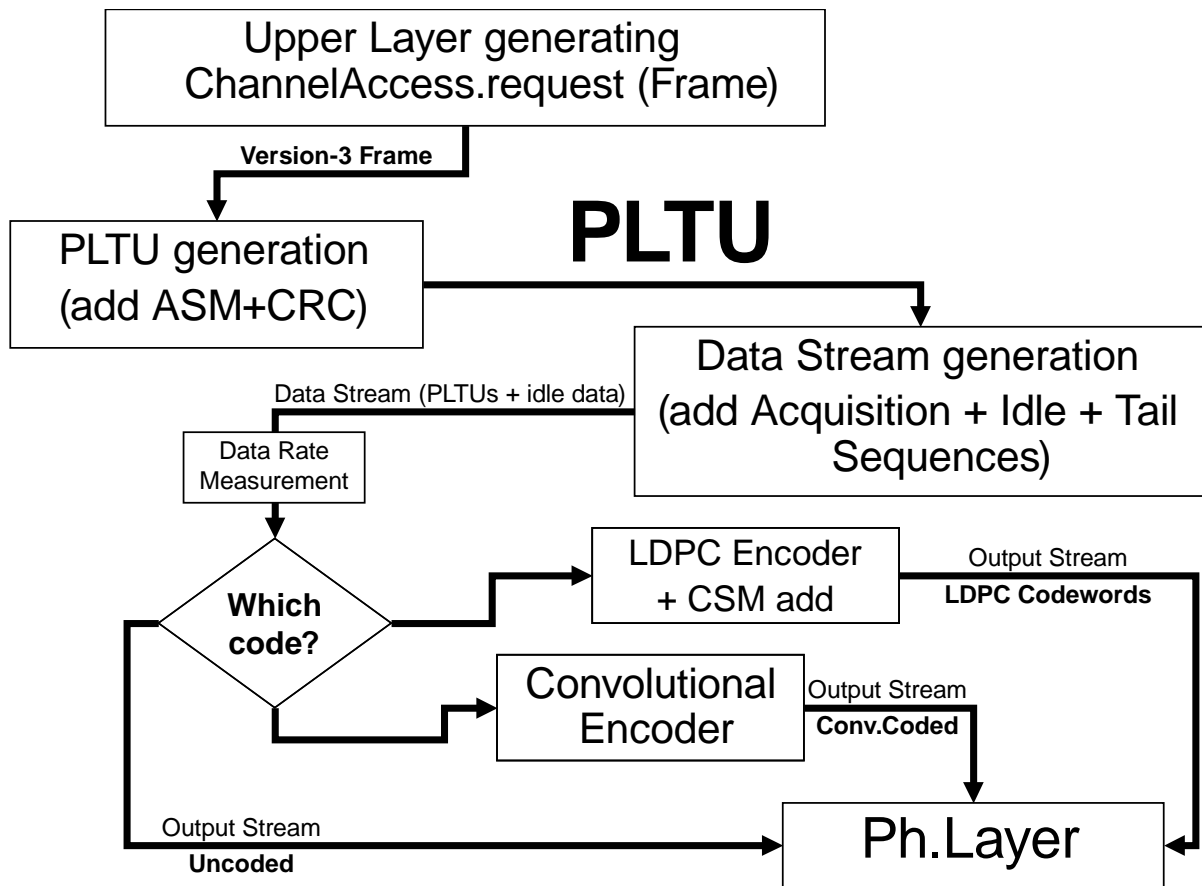


Figure 3-2: Behavior of the C&S Sublayer

3.4.3 CONVOLUTIONAL CODE

3.4.3.1 The convolutional code shall be the rate 1/2, constraint-length 7 convolutional code defined in reference [2].

NOTES

- 1 The convolutional encoding process does contain symbol inversion on the output path of connection vector G2.
- 2 Only the non-punctured convolutional code from reference [2] is specified for use on Proximity-1 links.

3.4.3.2 When the convolutional code is applied, all data to be transmitted, i.e., PLTUs and Idle data, shall be convolutionally encoded.

NOTES

- 1 The format of Idle data is specified in 3.3.

2 All transmitted bits are convolutionally encoded; therefore the ASM and CRC in the PLTU are also encoded.

3.4.3.3 Soft bit decisions with at least three bits quantization are recommended whenever constraints (such as complexity of decoder) permit.

3.4.4 LDPC CODE

3.4.4.1 When the LDPC code is used, fixed-length LDPC message blocks of length $k=1024$ bits shall be constructed as follows.

- a) PLTUs shall be generated as described in 3.2.
- b) Idle data shall then be inserted between PLTUs, as necessary (i.e. before the first PLTU, between PLTUs, and after the last PLTU), according to 3.3.
- c) The resulting bitstream shall then be partitioned into LDPC message blocks 1024 bits long.

NOTE – Idle Data include Acquisition, Idle, and Tail Sequences.

3.4.4.2 The first LDPC message block shall start with the first bit of the Acquisition sequence, and this shall be the first bit of the PN sequence defined in 3.3.2.2.

3.4.4.3 Each LDPC message block shall be encoded using the LDPC code ($n=2048$, $k=1024$) rate 1/2 code defined in reference [2].

3.4.4.4 The LDPC codewords shall be randomized according to 3.4.5.

3.4.4.5 LDPC Codewords shall be synchronized by using a stream of fixed-length LDPC Codewords with a Codeword Sync Marker (CSM) between them.

NOTE – Synchronization is acquired on the receiving end by recognizing the specific pattern of the CSM in the physical channel data stream; synchronization shall then customarily be verified by making further checks.

3.4.4.6 The CSM shall consist of a 64-bit (8-octet) marker with the following bit pattern (in hexadecimal): 0347 76C7 2728 95B0.

3.4.4.7 The CSM shall immediately precede the LDPC codeword.

3.4.4.8 The CSM shall immediately follow the end of the preceding LDPC codeword; i.e., there shall be no intervening bits (data or fill) preceding the CSM.

NOTE – The LDPC coding procedure is shown in figure 3-3.

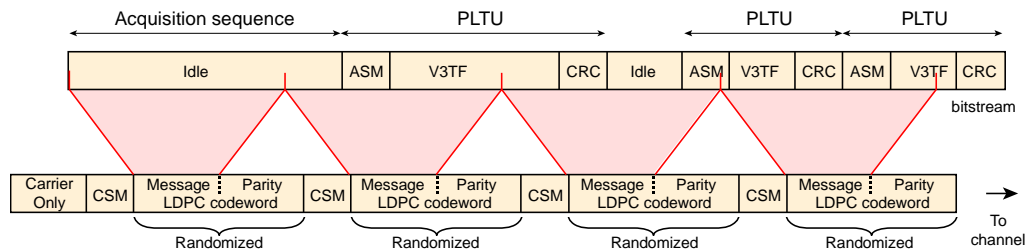


Figure 3-3: LDPC Coding Procedure

3.4.5 RANDOMIZATION OF LDPC CODEWORDS

3.4.5.1 Discussion

Since the LDPC code is quasi-cyclic, the LDPC codewords require randomization in order to minimize the probability of false synchronization due to potential symbol slips. When LDPC coding is used, this is achieved using the pseudo-randomizer defined in this section. When LDPC coding is used, a random sequence is exclusively ORed with the LDPC codewords to increase the frequency of bit transitions. On the receiving end, the same random sequence is exclusively ORed with the decoded LDPC codewords, restoring the original data form. The random sequence is generated by the pseudo-randomizer defined in this section.

3.4.5.2 Requirements

3.4.5.2.1 On the sending end, the pseudo-randomizer shall be applied to the LDPC Codeword.

3.4.5.2.2 On the receiving end the pseudo-randomizer shall be applied to de-randomize the randomized LDPC codewords before decoding.

3.4.5.2.3 The CSM shall be used for synchronizing the pseudo-randomizer.

3.4.5.2.4 The pseudo-random sequence shall be applied starting with the first bit of the LDPC Codeword.

3.4.5.2.5 On the sending end, the LDPC Codeword shall be randomized by exclusive-ORing the first bit of the Codeword with the first bit of the pseudo-random sequence, followed by the second bit of the Codeword with the second bit of the pseudo-random sequence, and so on.

3.4.5.2.6 On the receiving end, the original Codeword shall be reconstructed (i.e., de-randomized) using the same pseudo-random sequence.

3.4.5.2.7 After locating the CSM in the received data stream, the data immediately following the CSM shall be de-randomized.

NOTES

- 1 The CSM was not randomized and is not de-randomized.
- 2 Derandomization can be accomplished by performing exclusive-OR with hard bits or inversion with soft bits.

3.4.5.2.8 The random sequence shall be generated using the following polynomial:

$$h(x) = x^8 + x^6 + x^4 + x^3 + x^2 + x + 1$$

NOTE – This is the same polynomial used in reference [E3].

3.4.5.2.9 The random sequence shall begin at the first bit of the LDPC Codeword and shall repeat after 255 bits, continuing repeatedly until the end of the Codeword.

3.4.5.2.10 The sequence generator shall be initialized to the all-ones state at the start of each Codeword.

NOTES

- 1 The first 40 bits of the pseudo-random sequence from the generator are shown below. The leftmost bit is the first bit of the sequence to be exclusive-ORed with the first bit of the Codeword; the second bit of the sequence is exclusive-ORed with the second bit of the Codeword; and so on.

1111 1111 0011 1001 1001 1110 0101 1010 0110 1000

- 2 Figure 3-4 represents a possible generator for the specified sequence.

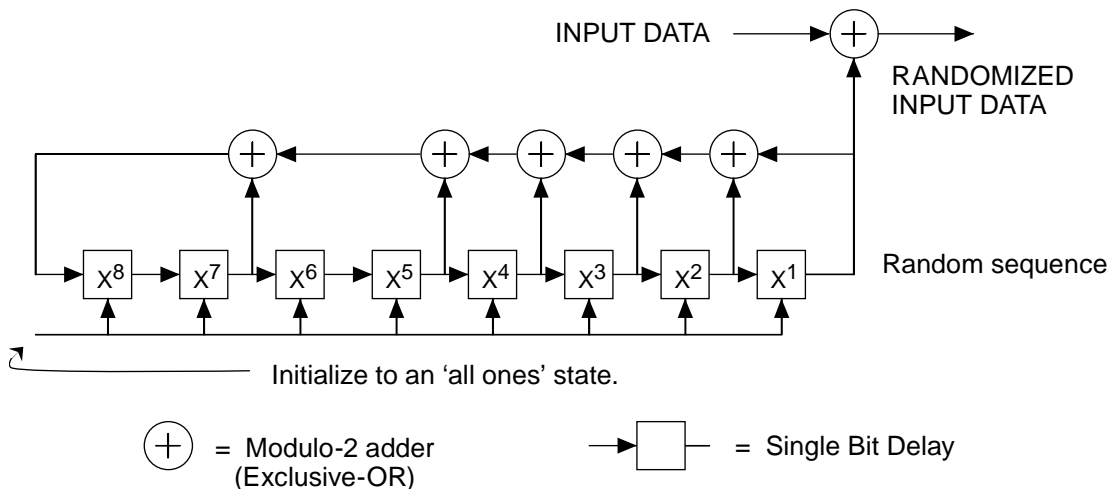


Figure 3-4: Pseudo-Randomizer Logic Diagram

3.5 SEND SIDE PROCEDURES IN THE C&S SUBLAYER

3.5.1 The C&S Sublayer shall accept Version-3 Transfer Frames from the Frame Sublayer.

3.5.2 For each frame, the C&S Sublayer shall construct a PLTU containing the frame.

3.5.3 The C&S Sublayer shall generate the bitstream for encoding by inserting Idle data as required.

3.5.4 The C&S Sublayer shall apply the selected encoding (see 3.4.2.2) and generate the output coded symbol stream.

3.5.5 The C&S Sublayer shall deliver the generated output coded symbol stream to the Physical Layer at a constant rate (R_{cs}).

3.5.6 When time tag collection is active,

- a) before computing CRC, the C&S Sublayer shall store the values of the clock, frame sequence number, QOS Indicator, and direction (egress) of each outgoing Version-3 Transfer Frame.
- b) The captured clock value shall correspond to when the trailing edge of the last bit of the ASM of the outgoing PLTU crosses the clock capture point (defined by the implementation) within the transceiver.

NOTE – The captured clock value is eventually processed to provide a value corresponding to a common reference point as described in reference [3] section 5, Proximity-1 Timing Services.

3.6 RECEIVE SIDE PROCEDURES IN THE C&S SUBLAYER

3.6.1 The C&S Sublayer shall accept the received coded symbols stream from the Physical Layer.

NOTE – The Physical Layer delivers the coded symbols stream at a given rate. Such a rate is configured using the SET RECEIVER PARAMETERS and SET PL EXTENSIONS directives defined in annex A of reference [3].

3.6.2 The C&S Sublayer shall apply the decoding of the selected channel coding option defined in 3.4.2.2.

3.6.3 The C&S Sublayer shall use the ASM to locate the beginning of a PLTU, for frame synchronization with the Version-3 Transfer Frame it contains.

NOTE – For the purpose of frame synchronization, an implementation can choose to recognize an ASM with bit errors.

3.6.4 The C&S Sublayer shall use the Frame Length field in the Transfer Frame Header of the Version-3 Transfer Frame to locate the position of the CRC-32 field of the PLTU.

NOTE – The CRC-32 marks the end of the PLTU, which can be followed by Idle data. The C&S Sublayer searches the received coded symbol stream following the end of the PLTU, looking for the ASM of the next PLTU, so any intervening idle bits are discarded.

3.6.5 The C&S Sublayer shall apply the CRC-32 decoding procedure to the received CRC-32 codeword in a PLTU, to check for errors in the received frame.

3.6.6 If the CRC-32 decoding detects any error in the CRC-32 codeword, the C&S Sublayer shall mark the received frame as invalid.

NOTE – As defined in annex B, which provides service definition in the form of primitives, the received frame indication is passed from the service provider to the service user at the receiving end, and frame handling depends on the specific implementation approaches (e.g., the invalid frames may be discarded or not).

3.6.7 The C&S Sublayer shall deliver the received frames to the Frame Sublayer.

3.6.8 When time tag collection is active,

- a) after decoding, the C&S Sublayer shall store the values of the clock, frame sequence number, QOS Indicator, and direction (ingress) of each received Version-3 Transfer Frame.
- b) The captured clock value shall correspond to when the trailing edge of the last bit of the ASM of the received PLTU crosses the clock capture point (defined by the implementation) within the transceiver.

NOTE – The captured clock value is eventually processed to provide a value corresponding to a common reference point as described in reference [3] section 5, Proximity-1 Timing Services.

ANNEX A

PROTOCOL IMPLEMENTATION CONFORMANCE STATEMENT PROFORMA

(NORMATIVE)

A1 INTRODUCTION

A1.1 OVERVIEW

This annex provides the Protocol Implementation Conformance Statement (PICS) Requirements List (RL) for an implementation of *Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer* (CCSDS 211.2-B-2). The PICS for an implementation is generated by completing the RL in accordance with the instructions below. An implementation claiming conformance must satisfy the mandatory requirements referenced in the RL.

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

- the implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;
- a supplier or potential acquirer of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;
- a user or potential user of the implementation, as a basis for initially checking the possibility of interworking with another implementation (it should be noted that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICSes);
- a tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A1.2 ABBREVIATIONS AND CONVENTIONS

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

Item Column

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

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.
- N/A Not applicable.

Support Column Symbols

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

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

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

A1.3 INSTRUCTIONS FOR COMPLETING THE RL

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

**A2 PICS PROFORMA FOR PROXIMITY-1 SPACE LINK PROTOCOL—CODING
AND SYNCHRONIZATION SUBLAYER (CCSDS 211.2-B-2)**

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 Versions	
Other information necessary for full identification, e.g., name(s) and version(s) for machines and/or operating systems;	
System Name(s)	

A2.1.4 Identification of Specification

CCSDS 211.2-B-2	
Have any exceptions been required?	Yes [] No []
<p>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.</p>	

A2.2 REQUIREMENTS LIST

Item	Description	Reference	Status	Support
1	PLTU structure: ASM, V3 Transfer Frame, CRC	3.2	M	
2	Idle data	3.3	M	
3	Coding option: uncoded data	3.4	O.1	
4	Coding option: convolutional	3.4.3	O.1	
5	Coding option: LDPC	3.4.4, 3.4.5	O.1	
6	Time tag support	3.5.6, 3.6.8	O	
7	Handling of invalid received frames	3.6.6	M	

O.1 It is mandatory to support at least one of these items.

ANNEX B

SERVICE

(NORMATIVE)

B1 BACKGROUND

This annex provides service definition in the form of primitives, which present an abstract model of the logical exchange of data and control information between the service provider and the service user. The definitions of primitives are independent of specific implementation approaches.

The parameters of the primitives are specified in an abstract sense and specify the information to be made available to the user of the primitives. The way in which a specific implementation makes this information available is not constrained by this specification. In addition to the parameters specified in this annex, an implementation can provide other parameters to the service user (e.g., parameters for controlling the service, monitoring performance, facilitating diagnosis, and so on).

B2 OVERVIEW OF THE SERVICE

B2.1 The Proximity-1 Synchronization and Channel Coding provides unidirectional (one way) transfer of a sequence of variable-length Version-3 Transfer Frames at a variable frame rate over a physical channel across a space link, with optional error detection/correction.

B2.2 Only one user can use this service on a physical channel, and Version-3 Transfer Frames from different users are not multiplexed together within one physical channel.

B3 SERVICE PARAMETERS

B3.1 FRAME

The Frame parameter is the service data unit of this service and shall be a Version-3 Transfer Frame defined in reference [3].

NOTE – The length of Version-3 Transfer Frames transferred on a physical channel is variable, and the maximum length is established by management.

B3.2 QUALITY INDICATOR

The Quality Indicator parameter shall be used to notify the user at the receiving end of the service that there is an uncorrectable error in the received Version-3 Transfer Frame.

B4 SERVICE PRIMITIVES

B4.1 GENERAL

B4.1.1 The service primitives associated with this service are:

- a) ChannelAccess.request;
- b) ChannelAccess.indication.

B4.1.2 The ChannelAccess.request primitive shall be passed from the service user at the sending end to the service provider to request that a Frame be transferred through the physical channel to the user at the receiving end.

B4.1.3 The ChannelAccess.indication shall be passed from the service provider to the service user at the receiving end to deliver a Frame.

B4.2 CHANNELACCESS.REQUEST

B4.2.1 Function

The ChannelAccess.request primitive is the service request primitive for this service.

B4.2.2 Semantics

The ChannelAccess.request primitive shall provide a parameter as follows:

ChannelAccess.request (Frame)

B4.2.3 When Generated

The ChannelAccess.request primitive shall be passed to the service provider to request it to process and send the Frame.

B4.2.4 Effect On Receipt

Receipt of the ChannelAccess.request primitive shall cause the service provider to transfer the Frame through the physical channel to the user at the receiving end.

B4.2.5 Additional Comments

None.

B4.3 CHANNELACCESS.INDICATION

B4.3.1 Function

The ChannelAccess.indication primitive is the service indication primitive for this service.

B4.3.2 Semantics

The ChannelAccess.indication primitive shall provide parameters as follows:

ChannelAccess.indication (Frame,
Quality Indicator)

B4.3.3 When Generated

The ChannelAccess.indication primitive shall be passed from the service provider to the service user at the receiving end to deliver a Frame.

B4.3.4 Effect On Receipt

The effect of receipt of the ChannelAccess.indication primitive by the service user is undefined.

B4.3.5 Additional Comments

None.

ANNEX C

CRC-32 CODING PROCEDURES

(NORMATIVE)

C1 CRC-32 ENCODING PROCEDURE

C1.1 For the encoding procedure, the $(n-32)$ -bit transfer frame shall be the information message.

C1.2 The encoding procedure shall accept an $(n-32)$ -bit Version-3 Transfer Frame and generate a systematic binary $(n, n-32)$ block code by appending a 32-bit Cyclic Redundancy Check (CRC-32) as the final 32 bits of the PLTU, as shown in figure 3-1.

NOTES

- 1 The Bit Numbering Convention as specified in 1.6.2 is applicable below.
- 2 The ASM is NOT used for computing the CRC-32.

C1.3 If $M(X)$ is the $(n-32)$ -bit information message to be encoded expressed as a polynomial with binary coefficients, with the first bit transferred being the most significant bit M_0 taken as the coefficient of the highest power of X , then the equation for the 32-bit Cyclic Redundancy Check, expressed as a polynomial $R(X)$ with binary coefficients, shall be:

$$R(X) = [X^{32} \cdot M(X)] \text{ modulo } G(X)$$

where $G(X)$ is the generating polynomial given by:

$$G(X) = X^{32} + X^{23} + X^{21} + X^{11} + X^2 + 1$$

and where the first transferred bit of the Cyclic Redundancy Check is the most significant bit R_0 taken as the coefficient of the highest power of X .

C1.4 The n -bit CRC-32-encoded block, expressed as a polynomial $C(X)$ with binary coefficients, shall be:

$$C(X) = X^{32} \cdot M(X) + R(X)$$

The $(n-32)$ bits of the message are input in the order M_0, \dots, M_{n-33} , and the n bits of the codeword are output in the order $C_0, \dots, C_{n-1} = M_0, \dots, M_{n-33}, R_0, \dots, R_{31}$.

NOTE – A possible implementation of an encoder is described in figure C-1. For each frame, the shift register is preset to the ‘all zero’ state prior to encoding. This initialization differs from that performed for the 16-bit CRC described in other CCSDS books, for which the cells are initialized to all ‘ones’. The ganged switch is in position 1 while the information bits are being transferred and in position 2 for the 32 Cyclic Redundancy Check bits.

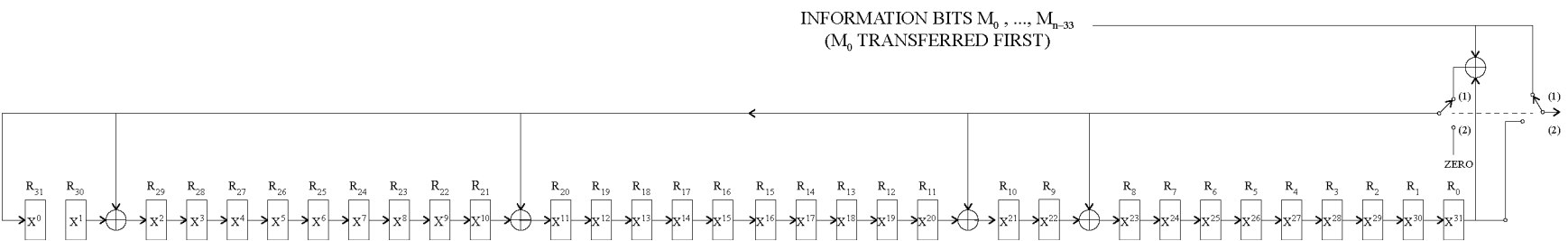


Figure C-1: A Possible Implementation of the Encoder

C2 CRC-32 DECODING PROCEDURE

C2.1 The decoding procedure shall accept an n -bit received codeword, including the 32-bit Cyclic Redundancy Check, and generates a 32-bit syndrome. An error is detected if and only if at least one of the syndrome bits is non-‘zero’.

C2.2 The received block $C^*(X)$ shall equal the transmitted codeword $C(X)$ plus (modulo two) the n -bit error block $E(X)$, $C^*(X) = C(X) + E(X)$, where both are expressed as polynomials of the same form, i.e., with the most significant bit C_0 or E_0 taken as the binary coefficient of the highest power of X .

C2.3 With $C^*(X)$ being the n -bit received codeword with the first transferred bit being the most significant bit C_0 taken as the coefficient of the highest power of X , then the equation for the 32-bit syndrome, expressed as a polynomial $S(X)$ with binary coefficients, shall be:

$$S(X) = [X^{32} \cdot C^*(X)] \text{ modulo } G(X)$$

The syndrome polynomial will be ‘zero’ if no error is detected, and non-‘zero’ if an error is detected, with the most significant bit S_0 taken as the coefficient of the highest power of X .

NOTE – A possible implementation of the syndrome polynomial generator is described in figure C-2. For each frame, the shift register cells are initialized to ‘zero’. This initialization differs from that performed for the 16-bit CRC described in other CCSDS books, for which the cells are initialized to all ‘ones’. The codeword includes n bits, i.e., $(n-32)$ information message bits plus the 32 bits of the Cyclic Redundancy Check. All the n bits of the codeword are clocked into the input and then the storage stages are examined. For an error-free block, the contents of the shift register cells will be zero. A non-zero content indicates an erroneous block.

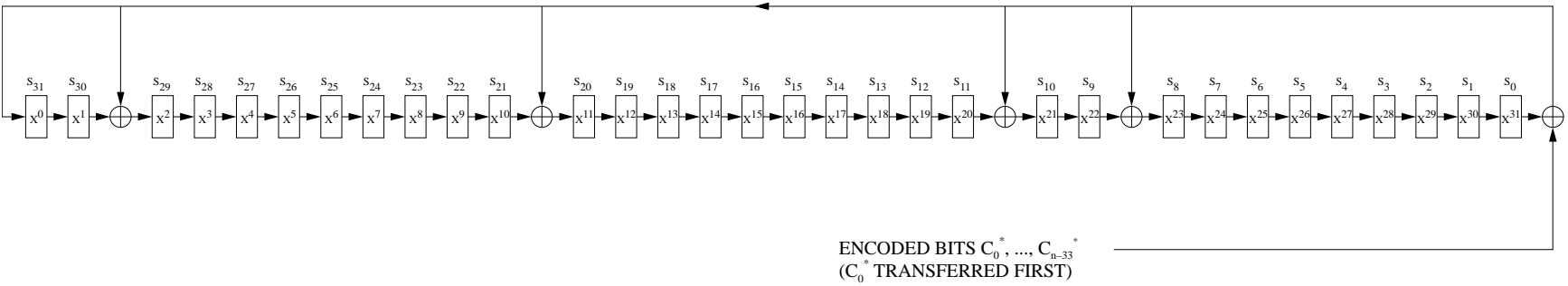


Figure C-2: A Possible Implementation of the Decoder

ANNEX D

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

D1 SECURITY CONSIDERATIONS

D1.1 BACKGROUND

It is assumed that security is provided by encryption, authentication methods, and access control to be performed at higher layers (Application and/or Transport Layers). Mission and service providers are expected to select from recommended security methods, suitable to the specific application profile. Specification of these security methods and other security provisions is outside the scope of this Recommended Standard. The C&S Sublayer has the objective of delivering data with the minimum possible amount of residual errors. The Proximity-1 codes ensure a very low error probability and the Frame Error Control Field is used to insure that residual errors are detected and the frame flagged. There is an extremely low probability of additional undetected errors that may escape this scrutiny. These errors may affect the encryption process in unpredictable ways, possibly affecting the decryption stage and producing data loss, but will not compromise the security of the data.

D1.2 SECURITY CONCERNS

Security concerns in the areas of data privacy, authentication, access control, availability of resources, and auditing are to be addressed in higher layers and are not related to this Recommended Standard. The C&S Sublayer does not affect the proper functioning of methods used to achieve such protection at higher layers, except for undetected errors, as explained above.

The physical integrity of data bits is protected from channel errors by the coding systems specified in this Recommended Standard. In case of congestion or disruption of the link, the C&S Sublayer provides methods for frame re-synchronization.

D1.3 POTENTIAL THREATS AND ATTACK SCENARIOS

An eavesdropper can receive and decode the codewords, but will not be able to get to the user data if proper encryption is performed at a higher layer. An interferer could affect the performance of the decoder by congesting it with unwanted data, but such data would be rejected by the authentication process. Such interference or jamming must be dealt with at the Physical Layer and through proper spectrum regulatory entities.

D1.4 CONSEQUENCES OF NOT APPLYING SECURITY

There are no specific security measures prescribed for the C&S Sublayer. Therefore consequences of not applying security are only imputable to the lack of proper security measures in other layers. Residual undetected errors may produce additional data loss when the link carries encrypted data.

D2 SANA CONSIDERATION

The current issue of this Recommended Standard does not require any action from SANA.

D3 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 E

INFORMATIVE REFERENCES

(INFORMATIVE)

- [E1] *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.
- [E2] *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft*. Issue 22. Recommendation for Space Data System Standards (Blue Book), CCSDS 401.0-B-22. Washington, D.C.: CCSDS, January 2013.
- [E3] *TC Synchronization and Channel Coding*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 231.0-B-2. Washington, D.C.: CCSDS, September 2010.

ANNEX F

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

ASM	Attached Synchronization Marker
C&S	Coding and Synchronization
CRC	Cyclic Redundancy Check
CSM	Codeword Sync Marker
FIFO	First In, First Out
ITU	International Telecommunication Union
LDPC	Low-Density Parity-Check
MAC	Medium Access Control
MIB	Management Information Base
OSI	Open Systems Interconnection
PLTU	Proximity Link Transmission Unit
PN	Pseudo-Noise
QOS	Quality of Service
R_{chs}	channel symbol rate
R_{cs}	coded symbol rate
R_d	data rate
RHCP	Right Hand Circular Polarization
SANA	Space Assigned Numbers Authority
SFCG	Space Frequency Coordination Group