Consultative Committee for Space Data Systems

RECOMMENDATION FOR SPACE DATA SYSTEM STANDARDS

PROXIMITY-1 SPACE LINK PROTOCOL—

CODING AND SYNCHRONIZATION SUBLAYER

CCSDS 211.2-B-1

BLUE BOOK

April 2003

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DOCUMENT CONTROL

Document	Title and Issue	Date	Status
CCSDS 211.0-B-1	Proximity-1 Space Link Protocol	October 2002	Superseded
CCSDS 211.2-B-1	Proximity-1 Space Link Protocol—Coding and Synchronization Sublayer	April 2003	Current issue (see note)

Note

This document contains the Coding and Synchronization Sublayer specification originally published as part of CCSDS 211.0-B-1, *Proximity-1 Space Link Protocol*.

CONTENTS

1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide a Recommendation for Space Data System Standards in the area of Proximity space links. 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 Recommendation defines the coding and synchronization sublayer of the Proximity-1 Space Link Protocol. It defines the data unit of this sublayer, i.e., the PLTU. It defines the coding and synchronization mechanisms required for cross support. It also specifies the send and receive side functionality of this sublayer. This Recommendation 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. The Data Link layer is defined in the separate CCSDS recommendation entitled, *Proximity-1 Space Link Protocol—Data Link Layer*; see reference [3]. The Physical layer is defined in the separate CCSDS recommendation entitled, Proximity-1 Space Link Protocol—Physical Layer; see reference [4].

1.3 APPLICABILITY

This Recommendation 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 Recommendation 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 Recommendation is anticipated. Where mandatory capabilities are clearly indicated in sections of the Recommendation, 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 will be documented in the CCSDS Proximity-1 Space Link Green Book, which is under development.

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 DEFINITIONS

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

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

a) connection;

b) Data Link layer;

c) entity;

d) physical layer;

e) protocol control information;

f) Protocol Data Unit (PDU);

g) real system;

h) segmenting;

i) service;

j) Service Access Point (SAP);

k) SAP address;

l) Service Data Unit (SDU).

1.5.1.2 Terms Defined in This Recommendation

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

asynchronous channel: a data channel where the symbol data are modulated onto the channel only for the period of the message. The message must be preceded by an acquisition sequence to achieve symbol synchronization. Bit synchronization must be reacquired on every message. A hailing channel is an example of an asynchronous channel.

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

1) Asynchronous Data Link over an Asynchronous Channel

   Hailing provides an example of an asynchronous data link over an asynchronous channel. An important issue is resynchronization between successive hails. Idle is provided for the reacquisition process.

2) Asynchronous Data Link over a Synchronous Channel

   Data service provides an example of an asynchronous data link over a synchronous channel. Once the link is established via hailing, communication transitions to a synchronous channel and maintains the link in this configuration until the session is interrupted or ends. If the physical layer does not receive data from the data link layer, it provides idle to maintain a synchronous channel.

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 bits is transferred over a space link in a single direction.

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

Proximity link: 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.

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.

synchronous channel: a continuous stream of bits at a fixed data rate. If the data link fails to provide frames (data or fill), it is the responsibility of the physical layer to provide the continuous bit stream.

1.5.2 NOMENCLATURE

The following conventions apply throughout this Recommendation:

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.

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

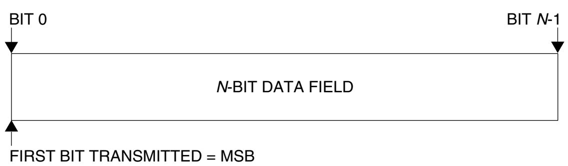

Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into 8-bit 'words' that conform to the above convention. Throughout this Recommendation, 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 shall be permanently set to value 'zero'.

Throughout this Recommendation, 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.

1.6 REFERENCES

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

[1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. International Standard, ISO/IEC 7498-1. 2nd ed. Geneva: ISO, 1994.

[2] *Telemetry Channel Coding*. Recommendation for Space Data System Standards, CCSDS 101.0-B-6. Blue Book. Issue 6. Washington, D.C.: CCSDS, October 2002.

[3] *Proximity-1 Space Link Protocol—Data Link Layer*. Recommendation for Space Data System Standards, CCSDS 211.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, April 2003.

[4] *Proximity-1 Space Link Protocol—Physical Layer*. Recommendation for Space Data System Standards, CCSDS 211.1-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, April 2003.

2 OVERVIEW

Proximity-1 is a bi-directional Space Link layer protocol to be used by space missions. It consists of a Physical Layer (reference [4]) a Coding and Synchronization (C&S) sublayer (of the data link layer) and a Data Link Layer (reference [3]). This protocol 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. On the send side, the Data Link layer is responsible for providing data to be transmitted by the Coding and Synchronization sublayer and Physical layer. The operation of the transmitter is state-driven. On the receive side, the Data Link layer accepts the serial data output from the receiver and processes the protocol data units received. It accepts directives both from the local vehicle controller and across the Proximity link to control its operations. Once the receiver is turned on, its operation is modeless. It accepts and processes all valid local and remote directives and received service data units.

The layered model consists of two layers (Physical and Data Link) and has five component sublayers within the Data Link layer:

a) Physical Layer

    1) On the send side:

        i) provides an Output Bit Clock to the Coding & Synchronization sublayer in order to receive the Output Bitstream.

        ii) provides status i.e., Carrier_Acquired and Bit_In_Lock_Status signals to the Media Access Control sublayer.

    2) On the receive side: Provides the Received Bit Clock/Data to the Coding & Synchronization sublayer.

b) Coding and Synchronization Sublayer. The C&S sublayer includes PLTU delimiting and verification procedures. In addition this sublayer performs as follows:

    1) On the send side:

        i) includes pre-pending Version-3 frames with the required Attached Synchronization Marker (ASM);

        ii) includes addition of CRC-32 to PLTUs.

    2) On both the send and receive sides: Captures the value of the clock used for time correlation process.

c) Frame Sublayer. The Frame sublayer includes frame validation procedures, such as transfer frame header checks, and supervisory data processing for supervisory frames. In addition, this sublayer performs as follows:

    1) On the send side:

i) encapsulates the Input/Output (I/O) sublayer–provided User Data (SDUs) into Version-3 frames;

ii) prioritizes and multiplexes the frames for output via the C&S sublayer to the Physical layer for transmission across the link.

2) On the receive side:

i) accepts delimited and verified frames from the C&S sublayer;

ii) delivers supervisory protocol data units (reports, directives) to the MAC sublayer;

iii) passes the user data to the Data Services sublayer;

iv) performs a subset of validation checks to ensure that the received data should be further processed.

d) Medium Access Control Sublayer. The Medium Access Control (MAC) sublayer defines how a session is established, maintained (and how characteristics are modified, e.g., data rate changes), and terminated for point-to-point communications between Proximity entities. This sublayer builds upon the Physical and Data Link layer functionality. The MAC controls the operational state of the Data Link and Physical layers. It accepts and processes Supervisory Protocol Data Units (SPDUs) and provides the various control signals that dictate the operational state. In addition this sublayer:

1) decodes the directives from the local vehicle's controller (e.g., spacecraft control computer);

2) decodes the directives received via the remote transceiver (extracting and processing SPDUs from the Frame Data Field);

3) stores and distributes the Management Information Base (MIB) parameters (implementation-specific) and status variables;

4) maintains and distributes the state control variables (MODE, TRANSMIT, DUPLEX, see figure 2-1);

5) provides status information to the local vehicle controller.

e) Data Services Sublayer. The Data Services sublayer defines the Frame Acceptance and Reporting Mechanism for Proximity links (FARM-P) (receive side) and the Frame Operations Procedures for Proximity links (FOP-P) (send side) associated with the Expedited and Sequence Controlled data services including how the FOP-P and FARM-P (COP-P) operate in the Sequence Controlled service.

f) Input/Output Sublayer. The Input/Output (I/O) interface sublayer provides the interface between the transceiver and the on-board data system and their applications. In addition, this sublayer performs as follows:

1) On the receive side:

   i) accepts received U-frames;

   ii) extracts the SDUs from U-frames;

   iii) provides required packet aggregation services;

   iv) routes SDUs to data service users via the specified Port ID.

2) On the send side: accepts local user-provided SDUs and associated routing and control information (SCID, PCID, Source-or-Destination ID, QOS, Port ID):

   i) aggregates these SDUs as required to form U-frame data fields;

   ii) provides required packet segmentation services;

   iii) delivers these U-frame data fields to the Data Services sublayer;

   iv) delivers acknowledgements to spacecraft vehicle controller for SDUs delivered via Sequence Controlled service.

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

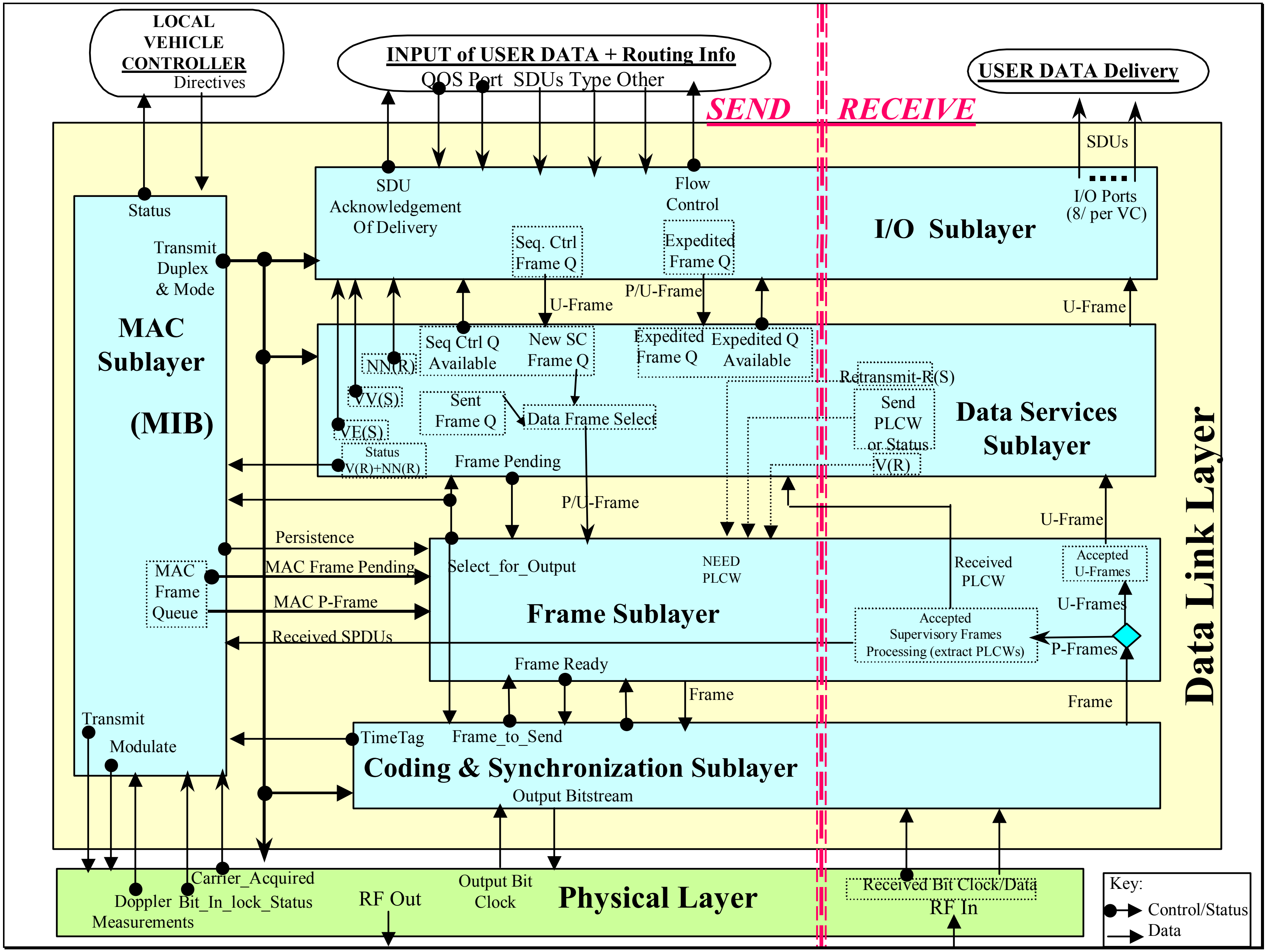

Figure 2-1: Proximity-1 Layered Protocol Model

3 CODING AND SYNCHRONIZATION (C&S) SUBLAYER

3.1 FUNCTIONS

3.1.1 At the sending end, the C&S sublayer shall perform the following functions:

a) pre-pend an Attached Synchronization Marker (ASM) for each frame provided;

b) calculate and append the CRC-32 to the end of the transfer frame forming the Proximity Link Transmission Unit (PLTU);

c) pass the PLTUs to the Physical layer for transfer across the communications channel;

d) capture the time and frame sequence number associated with the egress of the trailing edge of the last bit of the ASM;

e) provide the MAC sublayer access to the captured time and frame sequence number.

3.1.2 At the receiving end, the C&S sublayer shall perform the following functions:

a) delimit the PLTU from the bitstream received from the Physical layer;

b) perform the error detection (CRC-32) procedure;

c) verify that the decoded PLTU is error free;

d) pass the error free transfer frame contained within the PLTU to the Frame sublayer;

e) capture the time and frame sequence number associated with the ingress of the trailing edge of the last symbol of the ASM;

f) provide the MAC sublayer access to the captured time and frame sequence number.

3.2 PROXIMITY LINK TRANSMISSION UNIT (PLTU)

3.2.1 PLTU OVERVIEW

3.2.1.1 The PLTU shall be composed of the following three fields:

a) the 24-bit ASM (mandatory—see 3.4);

b) the variable-length Version-3 Transfer Frame (mandatory—see reference [3]);

c) the Cyclic Redundancy Code (mandatory—see 3.3.2).

NOTE – The size of the asynchronous PLTU shall be no greater than 2,055 octets (3 octets ASM + 2048 octets maximum transfer frame + 4 octets CRC), and shall be constrained by the size of the SDU contained within it. See figure 3-1.

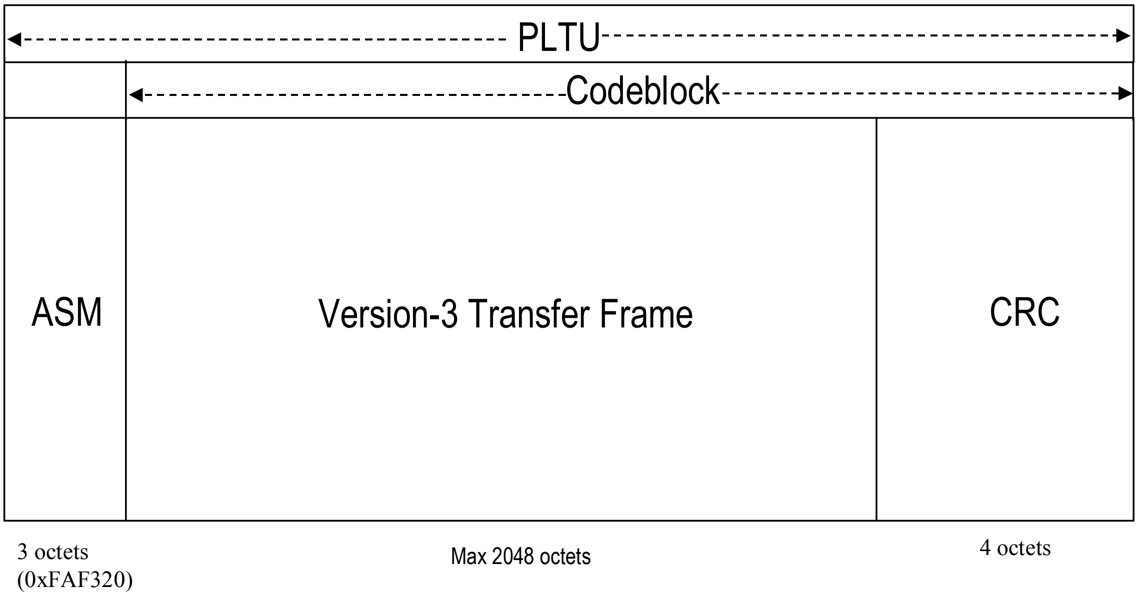

Figure 3-1: Proximity-1 Link Transmission Unit (PLTU)

3.2.1.2 Session establishment for half- and full-duplex links shall be accomplished using an asynchronous channel and an asynchronous data link. The data services phase shall be conducted on a synchronous channel using an asynchronous data link.

3.3 CODING

3.3.1 GENERAL

The same coding technique described below shall be applied to all frames for a given phase (session establishment, data services, session termination) and physical channel.

3.3.2 ATTACHED CYCLIC REDUNDANCY CODE

For an asynchronous data link (variable-length PLTUs), an attached 32-bit Cyclic Redundancy Check (CRC-32) shall be added without gap to the end of the Version-3 Transfer Frame.

3.3.3 CONVOLUTIONAL CODING

3.3.3.1 Convolutional coding is typically a managed parameter and shall be applied conditionally to Proximity-1 links.

NOTES

1 The capability to include or exclude Convolutional coding in the sending side is configured using the SET TRANSMITTER PARAMETERS directive, and in the receiving side by the SET RECEIVER PARAMETERS directive.

2 Data rate (not information rate) is the rate at which bits are output from the Convolutional decoder. Symbol rate is the rate entering the Convolutional decoder.

3 When the convolutional code is applied, all transmitted bits including the Idle data shall be convolutionally encoded; see reference [4].

3.3.3.2 The convolutional code used shall be a rate 1/2, constraint-length 7 convolutional code.

NOTE – The convolutional encoding process does contain symbol inversion on the output path of connection vector G2.

3.3.3.3 The decoding processor shall be capable of accepting soft symbols quantized to at least three bits.

NOTE – See annex A for CRC-32 encoding and decoding procedures.

3.4 ATTACHED SYNCHRONIZATION MARKER

3.4.1 An ASM shall signal the beginning of each PLTU.

3.4.2 The size of the ASM shall be 24 bits in length and shall consist of the following bit pattern (in hexadecimal): FAF320.

3.5 C&S SUBLAYER SEND SIDE SIGNAL

The C&S sublayer shall set PLTU_READY to *true* to indicate that it has a PLTU ready to send to the Physical layer. PLTU_READY shall be set to *false* when there is no PLTU to send.

3.6 IDLE PATTERN GENERATOR

The Idle Pattern Generator shall create an idle bit pattern (it consists of the repeating Pseudo Noise sequence, 352EF853 in hexadecimal) for insertion by the C&S sublayer into the radiation stream provided to the Physical layer. See reference [4] for further details on the idle pattern.

3.7 C&S SUBLAYER RECEIVE SIDE SIGNAL

None.

3.8 C&S SUBLAYER BUFFERS

3.8.1 EGRESS_TIME_CAPTURE_BUFFER shall store the values of the clock and the associated frame sequence number for all Proximity frames leaving the C&S sublayer when timing services occur.

3.8.2 INGRESS_TIME_CAPTURE_BUFFER shall store the values of the clock and the frame sequence number for all Proximity frames received by the C&S sublayer when timing services occur.

NOTE – This buffer space is required by the Proximity-1 Timing Service specified in section 5 of reference [3].

ANNEX A

CRC-32 CODING PROCEDURES

(This annex **is** part of the Recommendation.)

A1 CRC-32 ENCODING PROCEDURE

A1.1 The encoding procedure accepts an n-bit transfer frame, excluding the cyclic redundancy check, and generates a systematic binary $(n+32,n)$ block code by appending a 32-bit Cyclic Redundancy Check (CRC-32) as the final 32 bits of the codeblock.

A1.2 If $M(X) = m_{n-1}X^{n-1} + \cdots + m_0X^0$ is the n-bit message (transfer frame) expressed as a polynomial with binary coefficients, then the equation for the 32-bit cyclic redundancy check, expressed as a polynomial $R(X) = r_{31}X^{31} + \cdots + r_0X^0$ with binary coefficients, is:

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

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

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

A1.3 The $(n+32)$-bit CRC-32–encoded block, expressed as a polynomial $C(X) = c_{n+31}X^{n+31} + \cdots + c_0X^0$ with binary coefficients, is:

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

The shift register is preset to the ‘all zero’ state prior to encoding.

The n bits of the message are input in the order $m_{n-1},\ldots, m_0$, and the $(n+32)$ bits of the codeblock are output in the order $c_{n+31},\ldots, c_0 = m_{n-1},\ldots, m_0, r_{31},\ldots, r_0$.

NOTE – A possible implementation of an encoder is described in figure A-1.

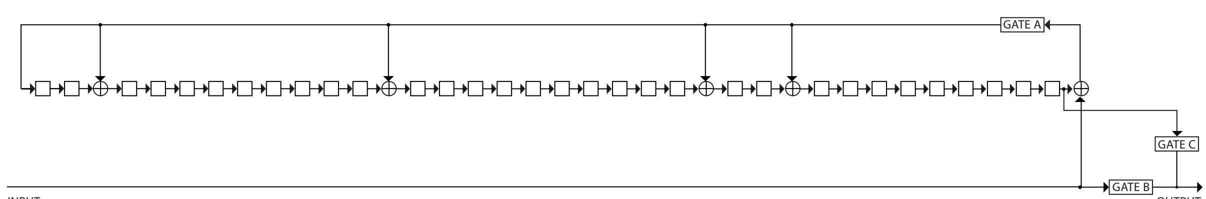

Figure A-1: A Possible Implementation of the Encoder

NOTE – Figure A-1 shows an arrangement for encoding using the shift register. To encode, the storage stages are set to 'zero', gates A and B are enabled (closed), gate C is inhibited (open), and *n* message bits are clocked into the input. They will appear simultaneously at the output. After the bits have been entered, the output of gate A is clamped to 'zero', gate B is inhibited, gate C is enabled, and the register is clocked a further 32 counts. During these counts the required check bits will appear in succession at the output.

A2 CRC-32 DECODING PROCEDURE

A2.1 The decoding procedure accepts an (*n*+32)-bit received codeblock, 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'.

A2.2 If $C^*(X) = c^*_{n+31} X^{n+31} + \cdots + c^*_0 X^0$ is the (*n*+32)-bit received codeblock, expressed as a polynomial with binary coefficients, then the equation for the 32-bit syndrome, expressed as a polynomial $S(X) = s_{31}X^{31} + \cdots + s_0X^0$ with binary coefficients, is:

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

The syndrome polynomial will be 'zero' if no error is detected, and non-'zero' if an error is detected.

A2.3 The received block $C^*(X)$ equals the codeblock $C(X)$ plus (modulo two) the (*n*+32)-bit error block $E(X)$, $C^*(X) = C(X) + E(X)$, where both are expressed as polynomials of the same form, i.e., $C(X) = c^*_{n+31} X^{n+31} + \cdots + c^*_0 X^0$ with binary coefficients.

NOTE – A possible implementation of a decoder is described in figure A-2.

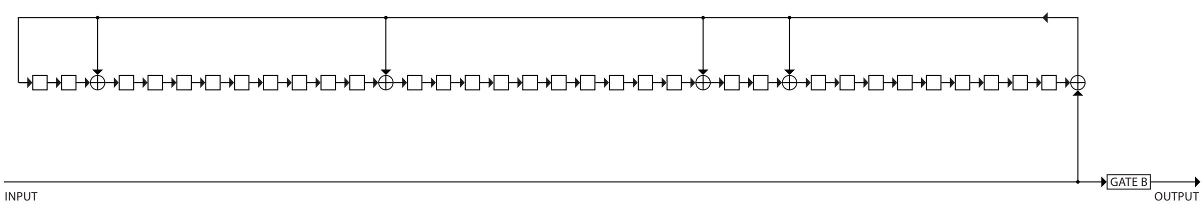

Figure A-2: A Possible Implementation of the Decoder

NOTE – Figure A-2 shows an arrangement for decoding using the shift register. To decode, the storage stages are set to 'zero' and gate B is enabled. The first *n* bits (message bits) of the (*n*+32) received bits are then clocked into the input. After *n* counts, gate B is inhibited, the 32 remaining received bits (check bits) are then clocked into the input, and the contents of the storage stages are then examined. For an error-free codeblock, the contents will be 'zero'. A non-'zero' content indicates an erroneous codeblock.

ANNEX B

PROXIMITY-1 DIRECTIVES AFFECTING THE C&S SUBLAYER

(This annex **is** part of the Recommendation.)

This annex simply lists for completeness the Proximity-1 Space Link Protocol directives which affect the C&S sublayer. These directives are defined in annex A of reference [3].

SET TRANSMITTER PARAMETERS

SET RECEIVER PARAMETERS

SET PL EXTENSIONS