The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

TC SPACE DATA LINK PROTOCOL

ECSS MODIFIED VERSION

RECOMMENDED STANDARD

CCSDS 232.0-B-3

BLUE BOOK
September 2015

4 PROTOCOL SPECIFICATION WITHOUT SDLS OPTION

NOTE – This section specifies the protocol data unit and the procedures of the TC Space Data Link Protocol without support for the SDLS protocol. Section 6 specifies the protocol with the SDLS option.

4.1 PROTOCOL DATA UNIT (TC TRANSFER FRAME)

4.1.1 TC TRANSFER FRAME

A TC Transfer Frame shall encompass the major fields, positioned contiguously, in the following sequence:

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

b) Transfer Frame Data Field (up to ~~1019 or~~ 1017 octets, mandatory);

c) Frame Error Control Field (2 octets, ~~optional~~mandatory).

NOTES

1 The TC Transfer Frame is the protocol data unit transmitted from the sending end to the receiving end by the TC Space Data Link Protocol. In this Recommended Standard, the TC Transfer Frame is also called the Transfer Frame or Frame for simplicity.

2 The maximum Transfer Frame length allowed by a particular spacecraft or ground implementation on a particular Virtual Channel may be less than the maximum specified here.

3 The structural components of the TC Transfer Frame are shown in figure 4-1.

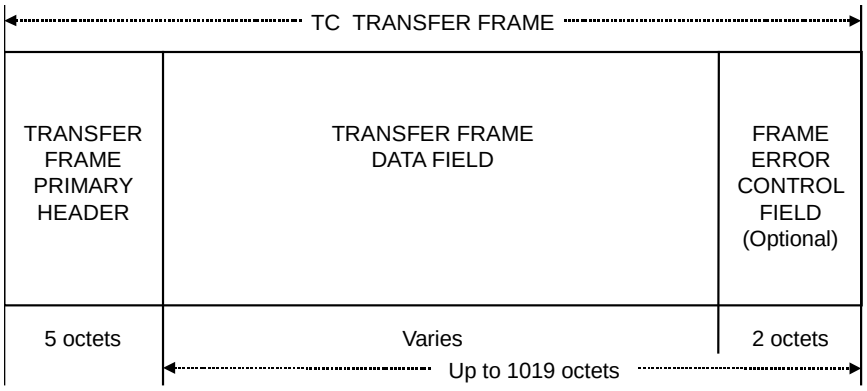

Figure 4-1: TC Transfer Frame Structural Components

a) a complete Packet;

b) multiple Packets;

c) a complete VCA_SDU.

4.1.3.2.1.4 The Segment Header is required for any Virtual Channel which has more than one MAP or which transfers service data units larger than permitted in a single Transfer Frame. Its use is optional otherwise, except that if it is used in any Transfer Frame carried on a Virtual Channel, it must be used for all Transfer Frames carrying Frame Data Units (not Control Commands) on that Virtual Channel.

NOTE 1 – A Frame Data Unit that has a Segment Header is called a Segment.

NOTE 2 – If the Packet Assembly Controller Function specified in 4.4.9 is used, there can be Frame Data Units that carry a MAP Reset command. In this case, the Frame Data Unit consists of a Segment Header only and the User Data field is absent. See 4.4.9.4.

4.1.3.2.2 Segment Header

4.1.3.2.2.1 General

4.1.3.2.2.1.1 If present, the Segment Header shall follow, without gap, the Transfer Frame Primary Header.

4.1.3.2.2.1.2 The Segment Header is optional; its presence or absence shall be established by management for each Virtual Channel.

4.1.3.2.2.1.3 The Segment Header must not be present in Transfer Frames carrying Control Commands.

4.1.3.2.2.1.4 The Segment Header shall contain the following fields:

a) Sequence Flags (2 bits, mandatory);

b) Multiplexer Access Point (MAP) Identifier (6 bits, mandatory).

NOTE – The format of the Segment Header is shown in figure 4-3.

4.1.3.2.2.3.2 If multiple MAPs are not used on a particular Virtual Channel, but the Segment Header is otherwise required to be present, the MAP Identifier shall be set to a constant value for all Frame Data Units which are placed on that Virtual Channel.

NOTE – There are no restrictions on the selection of MAP Identifiers. In particular, MAPs are not required to be numbered consecutively.

4.1.3.3 Control Commands

4.1.3.3.1 General

Two Control Commands are defined: Unlock and Set V(R); the action to be taken when the FARM receives one of these Control Commands is defined in reference [4].

4.1.3.3.2 Unlock

The Unlock Control Command shall consist of a single octet containing 'all zeroes'.

4.1.3.3.3 Set V(R)

The Set V(R) Control Command shall consist of three octets with the following values:

10000010 00000000 XXXXXXXX

where XXXXXXXX is the value to which the FARM should set the Receiver_Frame_Sequence_Number, V(R). This octet should therefore be set to the Sequence Number that will be put into the Header of the next Type-A Transfer Frame to be transmitted on that Virtual Channel.

4.1.3.3.4 Other Bit Combinations

All other bit combinations for Control Commands are reserved by the CCSDS for future application.

4.1.4 FRAME ERROR CONTROL FIELD

4.1.4.1 General

4.1.4.1.1 ~~The Frame Error Control Field is optional; its presence or absence shall be established by management~~Delete requirement.

4.1.4.1.2 ~~If present, t~~The Frame Error Control Field shall occupy the two octets following, without gap, the Transfer Frame Data Field.

4.1.4.1.3 ~~If present, the Frame Error Control Field shall occur within every Transfer Frame transmitted within the same Physical Channel throughout a Mission Phase~~Deleted requirement.

NOTES

1 The purpose of this field is to provide a capability for detecting errors which may have been introduced into the Transfer Frame during the transmission and data handling process.

2 Whether this field should be used on a particular Physical Channel will be determined based on the mission requirements for data quality and the selected options for the underlying Channel Coding Sublayer.

4.1.4.2 Frame Error Control Field Encoding Procedure

4.1.4.2.1 The Frame Error Control Field is computed by applying Cyclic Redundancy Check (CRC) techniques. The Frame Error Control Field Encoding Procedure shall accept an (n–16)-bit Transfer Frame, excluding the Frame Error Control Field, and generate a systematic binary (n,n–16) block code by appending a 16-bit Frame Error Control Field as the final 16 bits of the codeblock, where n is the length of the Transfer Frame.

NOTE – The Bit Numbering Convention as specified in 1.6.2 is applicable below.

4.1.4.2.2 The equation for the contents of the Frame Error Control Field is:

$$\text{FECF} = [(X^{16} \cdot \text{M}(X)) + (X^{(n-16)} \cdot \text{L}(X))] \text{ modulo } \text{G}(X)$$

$$= \text{P}_0 \cdot X^{15} + \text{P}_1 \cdot X^{14} + \text{P}_2 \cdot X^{13} + \ldots + \text{P}_{14} \cdot X^1 + \text{P}_{15} \cdot X^0$$

where

all arithmetic is modulo 2;

FECF is the 16-bit Frame Error Control Field with the first bit transferred being the most significant bit P_0 taken as the coefficient of the highest power of X;

n is the number of bits in the encoded message;

M(X) is the (n-16)-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;

L(X) is the presetting polynomial given by

$$\text{L}(X) = \sum_{i=0}^{15} X^i ;$$

G(X) is the generating polynomial given by

4.2.1.7 Reserved Spare

4.2.1.7.1 Bits 14-15 of the CLCW shall contain the Reserved Spare.

4.2.1.7.2 These two bits are reserved by CCSDS for future application and shall be set to '00'.

4.2.1.8 Flags

4.2.1.8.1 General

Bits 16-20 of the CLCW shall contain the Flags specified in the following subsections.

4.2.1.8.2 No RF Available Flag

4.2.1.8.2.1 Bit 16 of the CLCW shall contain the No RF Available Flag.

4.2.1.8.2.2 The No RF Available Flag shall provide a logical indication of the 'ready' status of the radio frequency (RF) elements within the space link provided by the Physical Layer.

NOTE – Precise definition of the set of physical states which must each be in the 'ready' condition before communication is possible is mission-specified. For example, the flag can represent a logical sum of the overall ready status of components such as the RF transponder and the demodulator.

4.2.1.8.2.3 A setting of '0' in the No RF Available Flag shall indicate that the Physical Layer is Available (i.e., any Transfer Frame will be received and processed by the Physical Layer and passed on to this protocol if correct).

4.2.1.8.2.4 A setting of '1' in the No RF Available Flag shall indicate that the Physical Layer is **not** available and that Transfer Frames cannot be transferred without corrective action within the Physical Layer.

4.2.1.8.2.5 The single No RF Available Flag shall apply to all Virtual Channels and shall be updated whenever a change is signaled by the Physical Layer.

NOTE – This field may be used by Agencies for local enhancements to operations of this protocol and is not part of the COP.

4.2.1.8.3 No Bit Lock Flag

4.2.1.8.3.1 Bit 17 of the CLCW shall contain the No Bit Lock Flag.

NOTES

1 The No Bit Lock Flag ~~is an optional, mission specific engineering measurement that~~ provides a performance quality indicator that indicates specifically whether the Physical Layer is working normally by having enough signal energy to achieve bit synchronization with the received data stream.

2 Failure to achieve bit lock may indicate that the Physical Layer is operating at a non-nominal performance level and that the Transfer Frame rejection rate may be correspondingly abnormally high.

4.2.1.8.3.2 The No Bit Lock Flag shall be set as follows:~~Use of the No Bit Lock Flag is optional; if used,~~

a) '0' when at least one of the spacecraft demodulation units for the physical channel has achieved bit lock~~'0' shall indicate bit lock has been achieved~~;

b) '1' when none of the spacecraft demodulation units for the physical channel has achieved bit lock~~'1' shall indicate bit lock has not been achieved~~.

4.2.1.8.3.3 The No Bit Lock Flag shall always carry an actual report of the status of the physical channel, even when other fields in the CLCW report the status of an inactive virtual channel~~The single No Bit Lock Flag shall apply to all Virtual Channels and shall be updated whenever a change is signaled by the Physical Layer~~.

4.2.1.8.3.4 Deleted requirement ~~If the No Bit Lock Flag is not used, it shall be set permanently to '0'~~.

NOTE – This field may be used by Agencies for local enhancements to operations of this protocol and is not part of the COP.

4.2.1.8.4 Lockout Flag

4.2.1.8.4.1 Bit 18 of the CLCW shall contain the Lockout Flag.

4.2.1.8.4.2 The Lockout Flag shall be used to indicate the Lockout status of the FARM of a particular Virtual Channel.

4.2.1.8.4.3 A setting of '1' in the Lockout Flag shall indicate Lockout.

NOTE – Lockout occurs whenever a Type-A Transfer Frame that violates certain Frame Acceptance Checks is received on a particular Virtual Channel. Once the FARM is in Lockout, all subsequent Type-A Transfer Frames will be rejected by the FARM until the condition is cleared.

4.2.1.8.4.4 A setting of '0' in the Lockout Flag shall indicate that the FARM is not in Lockout.

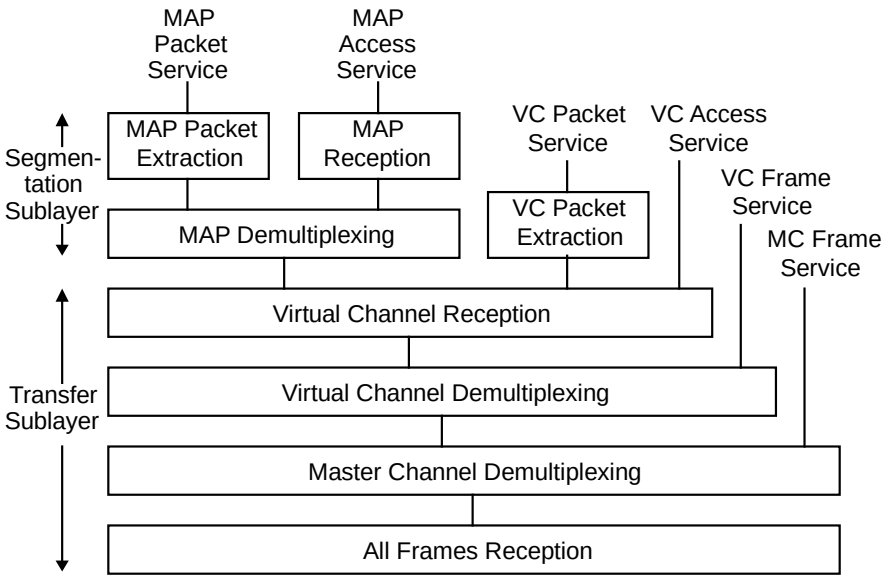

Figure 4-19: Internal Organization of Protocol Entity (Receiving End)

4.4.1 MAP PACKET EXTRACTION FUNCTION

4.4.1.1 The MAP Packet Extraction Function shall be used to extract variable-length Packets from Frame Data Units on a MAP Channel.

NOTE – There is an instance of the MAP Packet Extraction Function for each MAP Channel that carries Packets.

4.4.1.2 The MAP Packet Extraction Function shall extract Packets from Frame Data Units received from the MAP Demultiplexing Function.

4.4.1.3 Original Packets shall be extracted and reconstructed from Frame Data Units using the Sequence Flag of the Segment Header of each Frame Data Unit and, if blocking of Packets is permitted, the length field of each Packet.

4.4.1.4 Extracted Packets shall be delivered to the users on the basis of the PVN in their header.

4.4.1.5 Incomplete Packets are not required to be delivered in cross support situations.

NOTE – An abstract model of the MAP Packet Extraction Function is illustrated in figure 4-20.

4.4.1.6 When extracting and reconstructing Packets from Frame Data Units, the Packet Assembly Controller Function specified in 4.4.9 may be used.

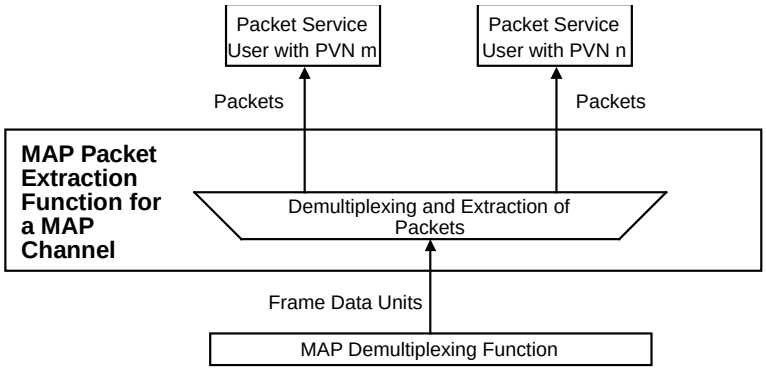

Figure 4-20: Abstract Model of MAP Packet Extraction Function

4.4.2 MAP RECEPTION FUNCTION

4.4.2.1 The MAP Reception Function shall be used to extract variable-length service data units (MAP_SDUs) from Frame Data Units on a MAP Channel.

NOTE – There is an instance of the MAP Reception Function for each MAP Channel that carries MAP_SDUs.

4.4.2.2 The MAP Reception Function shall extract MAP_SDUs from Frame Data Units received from the MAP Demultiplexing Function.

4.4.2.3 Original MAP_SDUs shall be extracted and reconstructed from Frame Data Units using the Sequence Flag of the Segment Header of each Frame Data Unit.

4.4.2.4 Extracted MAP_SDUs shall be delivered to the user.

NOTE – An abstract model of the MAP Reception Function is illustrated in figure 4-21.

4.4.2.5 When extracting and reconstructing MAP_SDUs from Frame Data Units, the Packet Assembly Controller Function specified in 4.4.9 may be used.

4.4.8.3 Frame Validation Check Procedure

4.4.8.3.1 The Frame Validation Checks shall be applied to all incoming Transfer Frames, regardless of whether they are Type-A or Type-B.

4.4.8.3.2 Failure to pass any test within the Frame Validation Checks shall cause the Transfer Frame to be rejected (discarded).

4.4.8.3.3 The Frame Validation Checks shall consist of the following tests:

a) The Transfer Frame must have an expected Transfer Frame Version Number.

b) The Transfer Frame must have one of the expected MCIDs (Transfer Frame Version Number and Spacecraft IDs).

c) The Transfer Frame Header must not contain any values which are not consistent with the implemented features for that spacecraft.

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

e) If the Frame Error Control Field is present, the recomputed CRC value for the Transfer Frame must match the content of the Frame Error Control Field.

4.4.9 PACKET ASSEMBLY CONTROLLER FUNCTION

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4.4.9.1 Overview

The Packet Assembly Controller Function can be used by the MAP Packet Extraction Function to reassemble Packets and by the MAP Reception Function to reassemble MAP_SDUs.

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The Packet Assembly Controller Function includes the handling of exceptions. When the function detects an exception it enters a lockout state. In the lockout state, it does not reassemble or deliver Packets or MAP_SDUs. When it receives a valid MAP Reset command, the Packet Assembly Controller Function exits lockout state.

Despite the word “packet” in its name, the function can be used for Packets and for MAP_SDUs: the name is inherited from earlier standards.

4.4.9.2 MAP Identifiers for the Packet Assembly Controller Function

4.4.9.2.1 Each instance of the Packet Assembly Controller Function shall use a pair of MAP Identifiers with the following properties:

a) The pair of MAP Identifiers identifies one MAP for data and one MAP for control.

b) The MAP Identifier for the data MAP has the most significant bit set to ‘0’.

c) The MAP Identifier for the control MAP has the same value as the data MAP except that the most significant bit is set to '1'.

NOTE - The MAP Identifier is a 6-bit value. Therefore, the data MAP has an identifier in the range 0 to 31 and the control MAP has an identifier in the range 32 to 63. So, control MAP Identifier = data MAP Identifier + 32, and the least significant 5 bits of the two MAP Identifiers are the same.

4.4.9.2.2 The MAP Identifier in the Segment Header of a frame carrying Packet or MAP_SDU data shall be set to the MAP Identifier of the data MAP.

4.4.9.2.3 The MAP Identifier in the Segment Header of a frame carrying a control segment shall be set to the MAP Identifier of the control MAP.

NOTE - A control segment can contain a MAP Reset command: see 4.4.9.4.

4.4.9.3 Behaviour of the Packet Assembly Controller Function

4.4.9.3.1 For frames with the MAP Identifier of the data MAP, the Packet Assembly Controller Function shall reconstruct the Packets or MAP_SDUs from the Frame Data Units, using the Sequence Flags of the Segment Header of each Frame Data Unit.

4.4.9.3.2 The Packet Assembly Controller Function shall have a reassembly status flag set as follows:

a) '0' when the Packet Assembly Controller Function has completed reconstruction of a Packet or MAP_SDU;

b) '1' when reconstruction of a Packet or MAP_SDU is in progress in the Packet Assembly Controller Function.

4.4.9.3.3 The Packet Assembly Controller Function shall enter a lockout state when it detects one of the following errors:

a) an incorrect sequence of Frame Data Units, as indicated by the Sequence Flags;

b) a control segment with an invalid format.

NOTE - The following is a list of the incorrect sequences of Sequence Flags that cause the Packet Assembly Controller Function to enter lockout state. The values for the Sequence Flags are shown in parentheses:

- a first segment ('01') followed by a first segment ('01');
- a first segment ('01') followed by a no segmentation ('11');
- a continuing segment ('00') followed by a first segment ('01');
- a continuing segment ('00') followed by a no segmentation ('11');

- a last segment (‘10’) followed by a continuing segment (‘00’);
- a last segment (‘10’) followed by a last segment (‘10’);
- a no segmentation (‘11’) followed by a continuing segment (‘00’;
- a no segmentation (‘11’) followed by a last segment (‘10’).

4.4.9.3.4 The Packet Assembly Controller Function shall have a lockout status flag set as follows:

a) ‘1’ when the Packet Assembly Controller Function is in a lockout state;

b) ‘0’ when the Packet Assembly Controller Function is not in a lockout state.

4.4.9.3.5 When the Packet Assembly Controller Function is in a lockout state, it shall not reconstruct Packets or MAP_SDUs.

4.4.9.3.6 When the Packet Assembly Controller Function is in a lockout state, it shall remain in that state until it receives a MAP Reset command as specified in 4.4.9.4.

4.4.9.3.7 The Packet Assembly Controller Function shall report its status to the sending end, including the following:

a) the MAP Identifier of the data MAP, and

b) the reassembly status flag, and

c) the lockout status flag.

NOTE - The correct operation of the Packet Assembly Controller Function relies on its status being known by the sending end. This Standard does not specify the format of the status information nor the mechanism to be used to transport it from the Packet Assembly Controller Function to the appropriate entity at the sending end. It also does not specify any resulting behaviour at the sending end, such as the decision to send a control segment containing a MAP Reset command.

4.4.9.3.8 When the Packet Assembly Controller Function receives a MAP Reset command and the reassembly status flag is ‘1’, the function shall:

a) discard the partially reconstructed Packet or MAP_SDU, and

b) set the reassembly status flag to ‘0’.

4.4.9.3.9 When the Packet Assembly Controller Function receives a MAP reset command and the function is in lockout state, the function shall exit lockout state.

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NOTE - The MAP Reset command is used, for example, to recover from breaks in the sequence of received frames due to link difficulties or unplanned termination of transfer services.

4.4.9.4 Control segment and MAP Reset command

4.4.9.4.1 A control segment shall have a length of one octet.

4.4.9.4.2 The Sequence Flags in the Segment Header of a control segment shall be set to '11'.

4.4.9.4.3 The MAP Identifier in the Segment Header of a control segment shall contain the MAP Identifier of a control MAP.

4.4.9.4.4 A valid control segment shall be considered to be a MAP Reset command.

NOTE 1: A control segment is a special case of a Frame Data Unit. It has no User Data field and therefore consists of a Segment Header only.

NOTE 2: If a Frame Data Unit has the MAP Identifier of a control MAP but it does not conform to these rules then it is considered to be an invalid control segment.

5 MANAGED PARAMETERS WITHOUT SDLS OPTION

NOTES

1 In order to conserve bandwidth on the space link, some parameters associated with the TC Space Data Link Protocol are handled by management rather than by inline communications protocol. The managed parameters are those which tend to be static for long periods of time, and whose change generally signifies a major reconfiguration of the protocol entities associated with a particular mission. Through the use of a management system, management conveys the required information to the protocol entities.

2 In this section, the managed parameters used by the TC Space Data Link Protocol are listed for each of the Channels and for Packet transfer. These parameters are defined in an abstract sense and are not intended to imply any particular implementation of a management system.

3 This section specifies managed parameters for the TC Space Data Link Protocol without support for the SDLS protocol. Additional managed parameters for the TC Space Data Link Protocol with the SDLS option are specified in 6.6.

5.1 MANAGED PARAMETERS FOR A PHYSICAL CHANNEL

The managed parameters associated with a Physical Channel shall conform to the definitions in table 5-1.

Table 5-1: Managed Parameters for a Physical Channel

Managed Parameter	Allowed Values
Physical Channel Name	Character String
Maximum Transfer Frame Length (octets)	Integer
Transfer Frame Version Number	1
Valid Spacecraft IDs	Set of Integers
MC Multiplexing Scheme	Mission Specific
Presence of Frame Error Control	Present~~, Absent~~
Maximum Number of Transfer Frames Given to the Coding Sublayer as a Single Data Unit	Integer
Maximum Length of Data Unit Given to the Coding Sublayer	Integer
Maximum Bit Rate Accepted by the Coding Sublayer	Real number/second
Maximum value for the Repetitions parameter to the Coding Sublayer	Integer

5.4 MANAGED PARAMETERS FOR A MAP CHANNEL

The managed parameters associated with a MAP Channel shall conform to the definitions in table 5-4.

Table 5-4: Managed Parameters for a MAP Channel

Managed Parameter	Allowed Values
Maximum Frame Data Unit Length (octets)	Integer (up to ~~1019~~1017)
Spacecraft ID	Integer
VCID	0, 1, …, 63
MAP ID	0, 1, …, 63
Data Field Content	Packets, MAP_SDU
Blocking (if Data Field Content is Packets)	Permitted, Prohibited
Segmentation	Permitted, Prohibited
Maximum MAP_SDU Length (octet) (if the MAP permits Segmentation)	Integer
NOTE – The value of the Transfer Frame Version Number is the same for all Transfer Frames on a Physical Channel.	

5.5 MANAGED PARAMETERS FOR PACKET TRANSFER

The managed parameters associated with a Virtual or MAP Channel used for the VC or MAP Packet Service shall conform to the definitions in table 5-5.

Table 5-5: Managed Parameters for Packet Transfer

Managed Parameter	Allowed Values
Valid PVNs	Set of Integers (see reference [5])
Maximum Packet Length (octets)	Integer
Whether incomplete Packets are required to be delivered to the user at the receiving end	Required, Not required

the presence of the Security Header in Type-D frames is a managed parameter of the Virtual Channel.

3 The length of the Security Trailer is an integral number of octets and is a managed parameter of the MAP or Virtual Channel.

6.3.7 FRAME ERROR CONTROL FIELD IN A FRAME WITH SDLS

In a Transfer Frame with SDLS, the Frame Error Control Field, ~~if present,~~ shall occupy the two octets following, without gap, the Security Trailer if the Security Trailer is present, or the Transfer Frame Data Field if a Security Trailer is not present.

The Frame Error Control Field of a frame with SDLS shall conform to the specifications of ~~4.1.4.1.1, 4.1.4.1.3,~~ 4.1.4.2, and 4.1.4.3.

6.4 SENDING-END PROTOCOL PROCEDURES WITH SDLS

6.4.1 OVERVIEW

When a secure TC link is required, the TC Space Data Link Protocol supports the use of the SDLS protocol. In this case, the TC Space Data Link Protocol contains differences in the sending-end procedures compared to the procedures described in 4.3. This subsection defines those differences.

6.4.2 ORDER OF PROCESSING BETWEEN TC, COP-1, AND SDLS PROTOCOLS

6.4.2.1 Virtual Channel Generation Function

In the Virtual Channel Generation Function at the sending end the order of processing between the functions of the TC, COP-1, and SDLS protocols shall occur as follows:

a) the Frame Generation Procedure (first step of processing by the function);

b) the SDLS ApplySecurity Function;

c) the Frame Operation Procedure (FOP-1), which is a sub-procedure of the Communications Operation Procedure (COP-1) and an integral part of the Virtual Channel Generation Function (final step of processing by the function).

6.4.2.2 Discussion

For completeness, figure 6-3 shows the order of processing between TC, COP-1, and SDLS functions at both the sending and receiving ends. The order of processing of the Frame Generation Function under the SDLS option differs from that of 4.3.5.1.