06. The Consultative Committee for Space Data Systems

Report Concerning Space Data System Standards

NEXT GENERATION SPACE LINK PROTOCOL (NGSLP)

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FOREWORD

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The prime purpose of this Green Book is to describe the new general purpose CCSDS Data Link layer protocol, here in called the Next Generation Space Link layer Protocol (NGSLP). The NGSLP provides the required services for all the CCSDS space links (ground to/from space and space to space links). The Protocol is be targeted for the emerging missions, both human and robotic, that will need to support the escalating data rates, identifying the ever growing number of new space vehicles, support for Variable Code Modulation (VCM) and include link layer security. This new space data link layer protocol utilizes the proven features of existing CCSDS protocols, providing backward compatibility, and adds options to that allow missions to tailor their link layer constructs. In addition this paper references new coding options that offer significant performance gains for communications links that terminate in space vehicles, and describes the advantages of disassociating the transfer frame from the forward error correcting code block.

Future missions are projected to require the following:

a) a higher rate links

- Sustained uplink data rates of megabits per second and occasional data rates of tens of megabits per second) than the current limit of 2 mbps under the current set of CCSDS recommendations, The utilization of high performance codes for uplinks to enable the higher rates and to enable smaller antennas to provide service that today requires larger antennas.

- Telemetry data rates exceeding 1 gigabit per second with optical links providing up to 10 gigabits per second.

b) Increased spacecraft populations will require increase spacecraft identification capabilities.

c) the ability to utilize the same link layer protocol to support all its required links. Currently Mars Landers need to support three CCSDS Link layer protocols: Telecommand (TC), Proximity-1 and either Advanced Orbiting Systems (AOS) or Telemetry (TM).

d) inclusion of link layer security to block any unauthorized entities form commanding of receiving restricted information from their mission.

e) utilization of variable coding and modulation techniques to improve throughput due to trajectory or climatic issues

f) ability to insert low latency messages into the link without changes to the basic frame contents. This feature can support launch and decent and landing operation.

1.2 APPLICABILITY

This document is a CCSDS Informational Report and contains descriptive materials and supporting rationale for future missions that require telecommunications and will require support from CCSDS member agencies. The Next Generation Space Link Protocol structures can be utilized for all space links [Direct from Earth (DFE), Direct to Earth (DTE) and Space to Space (Proximity)].

1.3 Background and Rationale

The CCSDS space link protocols [i.e., Telemetry (TM), Telecommand (TC), Advanced Operating Systems (AOS)) were developed in the early growth period of the space program. They were designed to meet the needs of the early missions, be compatible with the available technology and focused on the specific link environments. Digital technology was in its infancy and spacecraft power and mass issues enforced severe constraints on flight implementations. Therefore the Telecommand protocol was designed around a simple Bose, Hocquenghem, Chaudhuri (BCH) code that provided little coding gain and limited error detection but was relatively simple to decode on board. The infusion of the concatenated Convolutional and Reed-Solomon codes for telemetry was a major milestone and transformed telemetry applications by providing them the ability to better utilize the telemetry link and its ability to deliver user data. The ability to significantly lower the error rates on the telemetry links enabled the use of packet telemetry and data compression. The infusion of the high performance codes for telemetry was enabled by the advent of digital processing, but it was limited to earth based systems supporting telemetry.

There was also no need to provide uplink security when the original protocols were codified. There were very few nations with the required uplink capabilities to command spacecraft especially deep space vehicles. But with the advance of technology that is no longer the case and thus NASA has dictated that we must provide security for national (space) assets. This requires us to redesign our uplink equipment and gives us the opportunity to change the protocol and uplink coding.

The latest CCSDS space link protocol, Proximity-1 was developed in early 2000 to meet the needs of short-range, bi-directional, fixed or mobile radio links characterized by short time delays, moderate but not weak signals, and short independent sessions. Proximity-1 has been successfully deployed on both NASA and ESA mission at Mars and is to be utilized by all Mars missions in development.

The current relationship that requires synchronization of the frame with the error correcting code blocks was codified for four reasons all of which have reduced in significance over the intervening years. The reasons for the synchronization were: 1) reduce the data link overhead, 2) to reduce the processing by limiting the synchronization process to a single instance instead of one for the code and one for the frame, 3) to maximize the forward error performance because single erred Code Block only affected a single frame, and lastly 4) to perform the encoding and decoding processing in the digital components because the transponders focused exclusively on modulation and signal processing. Today link data rates are substantially greater and the added overhead that is caused by adding a separate code block synchronization code word (CSM) is small especially since new codes provide improved error correction performance and higher rates can use larger frame sizes to improve the operational processing for high rate links. Additionally, transponders are now being designed using digital technology and incorporating the coding and randomization into the transponder and thus removing the constraint of frame and code block synchronizations improves the protocol layer process and testability and provides layer independence..

A new age has arisen, one that now provides the means to perform advanced digital processing in spacecraft systems enabling the use of improved transponders, digital correlators, and high performance forward error correcting codes for all communications links. Flight transponders utilizing digital technology have emerged and can efficiently provide the means to make the next leap in performance for space link communications. Field Programmable Gate Arrays (FPGAs) provide the capability to incorporate high performance forward error correcting codes implemented within software transponders providing improved performance in data transfer, ranging, link security, and time correlation. Given these synergistic technological breakthroughs, the time has come to take advantage of them in applying them to both on going (e.g., command, telemetry) and emerging (e.g., space link security, optical communication) space link applications. However the largest prohibiting factor within the Data Link Layer in realizing these performance gains is the lack of a generic transfer frame format and common supporting services amongst the existing CCSDS link layer protocols. Currently each of the 4 CCSDS link layer protocols (TM, TC, AOS, and Proximity-1) have unique formats and services which prohibits their reuse across the totality of all space link applications of CCSDS member space agencies. For example, a Mars mission that implements their fundamental data link layer applications using the Proximity-1 frame format and services cannot be readily reused by a deep space mission without first re-implementing them using multiple deep space transfer frame services and formats i.e., TM or AOS, and TC.

The rationale for the development of a Next Generation Uplink by CCSDS member agencies includes the following:

1. A long lead time is required to develop and interoperability test new recommendations. At least three years are required to budget, design, build, and test a new telecommunication capability and hardware to perform them at the projected rates.

2. The deficiencies of the current link layer protocols: frame size is too limited and inadequate spacecraft naming capability is corrected.

3. Telemetry rates ate rapidly increasing and the current Earth station implementation receiving and processing telemetry will soon be exceeded. Thus its time to move forward with a next generation link layer protocol that will provide the capabilities required in the future, and enable the next generation of ground station equipment to utilize incorporate the features provided by the NGSLP.

4. The next generation of Human Space Missions is in development. Currently it is trying to utilize the current CCSDS Link Layer Protocols. These missions are in thee future required to have communications links of all types and data rates that far exceed the current communications rates for these missions. The ability of eliminating the inclusion of an idle frame in response to an Internet delivery delay by only inserting a few Idle bits, necessary to maintain the continuous bitstream, can provide the means to minimize latency and jitter for voice communications.

5. Link Layer security for critical missions has been mandated by NASA and will perturb the current endpoints of the communications links. Again, change is in the air based on current needs and change that will support missions for the next 20 years needs is what needs to be implemented.

6. The short LDPC codes that provide improved performance for links that terminate in space borne receivers are being codified by the CCSDS and are starting to be incorporated into missions. The communications system's receivers have or will need to be upgraded to provide the full benefits of these codes. Current development transponders,like the advanced JPL Electra units can achieve symbol lock at symbol to noise levels as low as -2 db. At these SNR levels the longer LDPC codes that have been codified fot telemetry are overkill and the reduced complexity of the shorter codes are optimized to operate at the achievable SNR levels.

7. Current receivers that are being purchased for the NASA to support high rate telemetry for use by the NASA Near Earth Tracking Stations are designed to provide the forward error correction decoding independently of the link layer data formatting. This separation of coding from the formatting provides for a clean boundary between symbol processing in the receivers with the information bitsteam that is input to the link layer service process. This separation is enabled by the growth of technology and commercially to support a variety of links for cost benefits. The separation of codeblock from frame enables operational features that were previously unobtainable. This will be discussed in section 2.3

1.4 DOCUMENT STRUCTURE

This document is divided into six numbered sections: **To Be Updated Later**

a) section 1 (this section) contains administrative information, definitions, and references;

b) section 2 presents an overview the proposed Next Generation Space Link Protocol.

c) section3 presents an overview of Telecommand issues:

d) Section 4 presents an overview of the Telemetry Issues

e) Section 5 presents an overview of the space to space and Relay issues.

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 DEFINITIONS

1.5.2.1 General

Within the context of this document the following definitions apply.

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

This document is defined using the style established by the Open Systems Interconnection (OSI) Basic Reference Model. This model provides a common framework for the development of standards in the field of systems interconnection.
The following terms, used in this Report, are adapted from definitions given in reference [5].

Layer: A subdivision of the architecture, constituted by subsystems of the same rank.

Protocol Data Unit (PDU): A unit of data specified in a protocol and consisting of protocol control information and possibly user data.

Service: A capability of a layer (service provider), together with the layers beneath it, which is provided to the service-users.

Service Data Unit (SDU): An amount of information whose identity is preserved when transferred between peer entities in a given layer and which is not interpreted by the supporting entities in that layer.

1.5.2 TERMS DEFINED IN THIS REPORT

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

Cross support: An agreement between two or more organizations to exploit the technical capability of interoperability for mutual advantage, such as one organization’s offering support services to another in order to enhance or enable some aspect of a space mission.

1.3 REFERENCES

The following documents are referenced in this Report. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Report 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 documents.

[A list of documents referenced in the report goes here. See CCSDS A20.0-Y-3, *CCSDS Publications Manual* (Yellow Book, Issue 3, December 2011) for reference list format.]

[1] *Telecommand Part 1 – Channel Service (Historical)*. Recommendation for Space Data System Standards, CCSDS 201.0-B-3-S, Silver Book. Issue 3. Washington, D.C.: CCSDS, June 2000.

[2] *Telecommand Part 2 – Data Routing Service (Historical)*. Recommendation for Space Data System Standards, CCSDS 202.0-B-3-S, Silver Book. Issue 3. Washington, D.C.: CCSDS, June 2001.

[3] Telecommand Part 3 – Data Management Service (Historical). Recommendation for Space Data System Standards, CCSDS 203.0-B-2-S, Silver Book. Issue 2. Washington, D.C.: CCSDS, June 2001.

[4] *TC Synchronization and Channel Coding*. Recommendation for Space Data System Standards, CCSDS 231.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, September 2010.

[5] *TC Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 232.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, September 2010.

[6] *Communications Operation Procedure-1*. Recommendation for Space Data System Standards, CCSDS 232.1-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, September 2010.

[7] *CCSDS Space Data Link Security Protocol.* Recommendation for Space Data System Standards, CCSDS 355.0-R-2. Red Book. Issue 2. Washington, D.C.: CCSDS, Feb. 2012

[8] *AOS Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 732.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, July 2006.

[X] CCSDS Space Data Link Security Protocol

2 OVERVIEW OF THE NGSLP LINK LAYER PROTOCOL

The model for the space data link layer can be depicted as composed of three protocol sub-layers as shown in Figure 1. The Link Layer sub-layer that connects to the physical layer is the Coding and Synchronization Sub-Layer. This Sub-layer is used to provide the means to delimit and decode the code block to provide the desired very low error rate data channel and optionally to delimit the Transfer Frame. The Link Layer Services Sub-layer provides the data structures to transport the data across the link and provides accountability and security. The Link Layer Session Management and Reliable Delivery Protocols sub-layer connects to the network providing session control and reliable delivery services. The prime purpose of this green book, , is to describe a new general purpose Data Link Services Sub-Layer that will provide the required services for all the CCSDS space links (ground to/from space and space to space links) and to describe the optional application of forward error correction encoding within the Link Layer's Coding and Synchronization Sub-layer

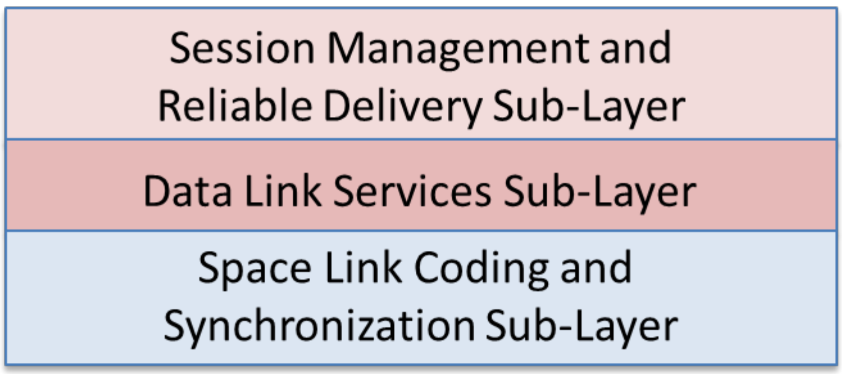


Figure 1 Space Link Layer Protocol stack

A) <u>Overview of the proposed new Transfer Frame</u>

The proposed Data Link Services Sub-Layer incorporates a flexible transfer frame structure that can be optimized for the specific needs of each space link type and its constraints, all using the flexible Next Generation Space Link Protocol (NGSLP) frame format. The NGSLP transfer frame format provides sufficient data visibility within the frame header to enable the receive side link layer frame processing to delimit the frame, separate and route Master and/or Virtual Channel (VC) frames without management details nor the security encoding incorporated within them. The tailoring of the frames functionality is accommodated within the Transfer frame header and the Transfer Frame's VC Data Contents Group . The details of the tailoring capabilities of the data structure will be explained in a subsequent section of this Green Book. An attached synchronization marker (ASM) is required and is pre-pended to the frame. The exact size and bit pattern chosen for the ASM is dependent upon the applicable channel error characteristics. When the ASM is attached to the transfer frame, the combination is called the Protocol Link Transmission Unit (PLTU). The ASM and the application of the Frame Error Control (FEC) field is discussed later in this Green Book.

In order to provide increased mission operability, the inclusion of Virtual Channel Sub-Channels (VCS) has been added. The Virtual Channel Sub-channel (VCS) is a multiplexing feature that allows a VC to deliver up to 64 independent sub channels one at a time over the same VC. The capability to include multiple different VCS Service Data Units (SDUs) within a Virtual Channel provides the capability to utilize a single Security Association (SA) to deliver those independent VCS SDUs that share the same VC. This capability enables a single VC to provide reliable delivery of the various VCS-SDUs sharing that VC using the “Go-Back-N” protocols for that VC as currently used in Telecommand and Proximity Links. The VCS sub-channel field provides the capability for an operational control facility to provide its unique security coding on those data streams that it controls with a single SA, while the data traffic to/from equipment in other agency control facilities can use their own VC and SA.

The current Telecommand Protocol relies on a segmentation process to allow large packets to be carried within small frames, while the TM and AOS protocols provide this capability by a process named in this document as “streaming”. In the “streaming” process, packets are allowed to flow across frame boundaries. The streaming process has been incorporated within this proposed protocol for use on all links to provide this functionality. The streaming process in combination with the VC-Sub-Channels replaces the segmentation process uniquely utilized in Telecommand (TC).

2.1 The NGSLP Transfer Frame Fields

The NGSLP transfer frame divides up into three major functional groups: the Transfer Frame/Master Channel Group, the Virtual Channel Data Contents Group and the Transfer Frame Security Group The fields in each group are shown in the same color.

Transfer Frame Header	Master Channel Insert Zone	Virtual Channel Insert Zone	Frame Security Header	Virtual Channel Data Field **(VCDF)**	Frame Security Trailer	Virtual Channel Operational Control Field	Transfer Frame Error Control Field
6-13 Octets Mandatory	Optional	Optional	Variable Optional	Variable Optional	Variable Optional	4 Octets Optional	Variable Optional

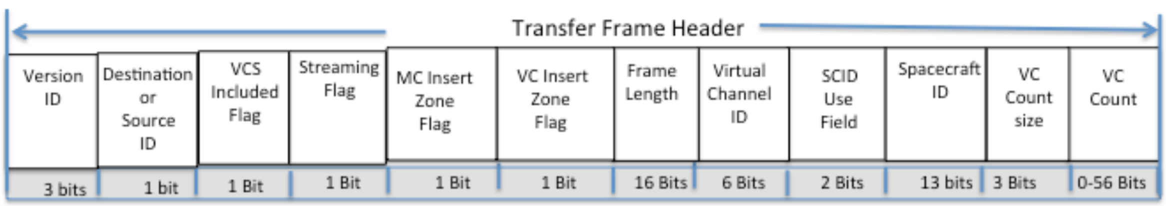
The Transfer Frame Header is the only mandatory field in the frame and it contains a frame length field providing the capability for the Transfer Frame to be of variable length making it compatible for all data links. The frame structure is backward compatible for each link type supporting all currently provided services (as described in Sections 3,4 and5). The Frame Error Check field (FECF), frequency and modulation are management controlled items for setting up a link connection. The FECF is only required for links where coding does not provide a very low undetected and that is only for uncoded and BCH coded links and thus is either included or not based on the Master Channel.

2.1.1 THE TRANSFER FRAME / MASTER CHANNEL GROUP FIELDS

The Transfer Frame / Master Channel group contains three fields: Transfer Frame Header ,Master Channel Insert Zone and the Transfer Frame Error Check Field. The first field, the Transfer frame Header is the only mandatory field in the entire transfer frame. It contains the frame length field providing each link the option of transmitting and receiving variable length frames. The Master Channel Insert Zone is also optional and is signaled in the TF header. The Transfer Frame Error Check Field is optional and only required when the Transfer Frame is to be transmitted via an uncoded link. Note that the transfer frame structure is backward compatible for each CCSDS Space Data Link Protocol supporting all currently provided services.

2.1.1.1 THE TRANSFER FRAME HEADER

The transfer frame header contains eleven fields and the order that they appear in the header are shown in Figure 2-2 below.



Transfer Frame Header											
Version ID	Destination or Source ID	VCS Included Flag	Streaming Flag	MC Insert Zone Flag	VC Insert Zone Flag	Frame Length	Virtual Channel ID	SCID Use Field	Spacecraft ID	VC Count size	VC Count
3 bits	1 bit	1 Bit	1 Bit	1 Bit	1 Bit	16 Bits	6 Bits	2 Bits	13 bits	3 Bits	0-56 Bits

Figure 2-2: Transfer Frame Header

2.1.1.1.1 TRANSFER FRAME VERSION NUMBER (TFVN)

The Transfer Frame Version Number identifies the format of the transfer frame. By examining the TFVN SANA registry, one can determine the space data link protocol associated with a given TFVN. This field is 3 bits long. The original field specified in references [TBD] has been extended by one bit to allow for one future version number. The version one NGSLP Frame uses the last remaining value available in the 2 bit Transfer Frame Version Number field i.e., ‘11’ and appends “0” to it to complete the 3 bit version number (‘110’).

2.1.1.1.2 SOURCE or DESTINATION ID (S/D ID)

The Source-or-Destination Identifier is used to interpret the value of the SCID field. A S/D ID of “0” (source) identifies the spacecraft that created this frame. A S/D ID of ‘1’ (destination) identifies the intended recipient of this frame.

The behavior of the recipient of this frame with respect to the values of the SCID field and Source-or-Destination Identifier is described below:

1) When the value contained within the Source-or-Destination Identifier field is “0” then the recipient may accept this frame if allowed by mission management. This methodology allows the sender to broadcast the data to one or more recipient entities.
2) When the value contained within the Source-or-Destination Identifier field is “1” then the recipient only accepts this frame if its assigned SCID equals the value of the SCID contained within the frame. The methodology is used to transfer data exclusively to the designated recipient spacecraft.

2.1.1.1.3 TRANSFER FRAME HEADER SIGNALING FLAGS

The transfer frame header contains all the information required to signal the presence or absence of the all the CCSDS Master/Virtual Channel Services. In order to make Master/Virtual Channel services data driven as opposed to managed, four new signaling fields have been inserted in the TF header. They signal the following conditions: 1) whether or not a MC Insert Zone, and/or 2) a VC Insert Zone are included later within the frame and 3) signals whether the VC contains VC Sub-channels and 4) the data transfer method used within the VC Data Field.

2.1.1.1.3.1 VIRTUAL CHANNEL SUB-CHANNELS (VCS) INCLUDED FLAG

When the VCS Included Flag equals “1”, the VC Data Field for this frame contains: 1) Data Type field used for identifying the type of data (packets or user provided octets) contained within the VC Data Field, 2) the VC Sub-channel Identifier, and 3) the VCS counter, required for continuity checks on the packets or octet stream.

2.1.1.1.3.2 STREAMING FLAG FIELD

The Streaming Flag identifies the data transfer method used for transferring the data contained within the VC Data Field. An integral number of complete packets or user octets are transferred when this flag is set to “0”, which is the non-streaming mode. When this Flag field contains a “1”, it signals that the First Header Pointer method as defined in the current CCSDS AOS and TM recommendations [references TBD] is used to provide the ability for packet data to span across transfer frame boundaries.

2.1.1.1.3.3 MASTER CHANNEL INSERT ZONE INCLUDED FLAG

If the value in the field is “0”, then no MC Insert Zone Field is contained. When the value contained within this field is a “1”, it signals that a MC Insert Zone Field is contained within the transfer frame. The MC Insert Zone may be included to provide a data transfer zone in the frame in addition to the Frame Data Field . The contents of the MC Insert Zone would be provided to the frame generation process by the MC Insert Service. Previous to the NGSLP, the MC Insert Zone was only included in the AOS protocol [reference TBD] and it was required to occur in every frame of that Master Channel. The service in AOS was defined to provide for the transfer of isochronous data only and required the MC Insert Zone to be of fixed (but managed) length. The NGSLP does not impose the constraint of the current AOS or TM All Frames Generation Function i.e., that the MC Insert Zone must be contained in every transfer frame in a particular Physical Channel. However the mission may impose such a constraint if isochronous data transfer is required.. ****

2.1.1.1.3.4 VIRTUAL CHANNEL INSERT ZONE INCLUDED FLAG

If the value in the field is “0” then no VC Insert Zone field is contained. When the value contained within this field is a “1”, it signals that a VC Insert Zone field is contained within the transfer frame. The VC Insert Zone may be included to provide a data transfer zone in the frame in addition to the Frame Data Field. This flag is set by the VC generation process. Previous to the NGSLP, a service similar to the VC Insert Zone was exclusive to the TM protocol and it required that the Virtual Channel be present in every frame on the Virtual Channel. The NGSLP does not impose this constraint because inclusion of the MC Inset Zone field in the frame is signaled. It must be noted that the frame generation process becomes much more complicated when MC Insert Zone inclusion is spasmodic while frames are required to be fixed length.

2.1.1.1.4 TRANSFER FRAME LENGTH

The Transfer Frame Length Field is 16 bits in length providing the capability to create a maximum frame of 65,536 octets long. Thus a range of frame lengths from very small to very large can be accommodated i.e., an emergency command containing 1 octet of payload data can be as small as 7 octets (6 octet TF Header, no MC Insert Zone, no VC Insert Zone, No Security Header/Trailer, no Sequence Count Field, no VCS and no FEC).

2.1.1.1.5 VIRTUAL CHANNEL ID

The Transfer Frame Primary Header shall contain the Virtual Channel Identifier (VCID). It is 6 bits in length and is the same field provided in the AOS specification.

NOTES

1 If only one Virtual Channel is used, these bits are set permanently to value ‘all zeros’. A Virtual Channel used for transmission of Idle Transfer Frames is indicated by setting these bits to the reserved value of ‘all ones’.

2 There are no restrictions on the selection of Virtual Channel Identifiers except the rules described above. In particular, Virtual Channels are not required to be numbered consecutively.

3 A Transfer Frame on the ‘Idle’ Virtual Channel may not contain any valid user data within its Transfer Frame Data Field, but it must contain the Insert Zone if the Insert Service is supported.

2.1,1,1,6 SPACECRAFT ID USE FIELD

This field describes the applicable mission phase in which the data contained in the transfer frame was generated. This field is 2 bits long.

Currently missions request multiple SCID assignments to uniquely identify the environment in which the data was generated. This practice reduces the number of SCIDs that are available to CCSDS member agencies. Moreover the SANA spacecraft ID registry is very limited: The number of possible SCIDs by Transfer Frame Version Number are: 1024 Version 1, 256 Version 2, 1024 Version 3 IDs. The Spacecraft ID Use Field provides a mission unique Spacecraft ID applicable for all pre and post launch phases while self-identifying the phase in which the data was generated. Three of the four values of this field (“00”, “01”, “10”) are mission defined. The fourth value, ‘11’ is reserved for post launch data.

2.1.1.1.7 SPACECRAFT ID (SCID)

The value contained in the SCID identifies the Master Channel for that transfer frame. The Spacecraft ID field has been extended from the current 8 (Version 2) or 10 bits (Version 1 and 3) to 13 bits (Version 4) to accommodate a larger population of spacecraft expected (up to 8192), especially due to the advent of Cube and Micro Satellites and landed data gathering sensor platforms. Coupled with the use of the SCID Use Field, the Version 4 SCID provides a mission with a single unique SCID for all mission phases simplifying the service management required to configure those services.

2.1.1.1.8 VIRTUAL CHANNEL SEQUENCE COUNT SIZE

The value contained within this field identifies the size of the Virtual Channel Sequence Count. This 3 bit field allows the size of the VC Sequence Count to vary from 0 to 7 octets in length. Once the value for this field is chosen, it is fixed for the mission phase.

2.1.1.1.9 VIRTUAL CHANNEL SEQUENCE COUNT FIELD

The Virtual Channel Sequence Count is the only field within the Transfer Frame Primary Header with a variable length. The size of this field is determined by the value contained within the VC Sequence Count Size Field. The Virtual Channel Sequence Count size can vary from 0 to 7 bytes in length. The maximum count would be approximately 7.2×10^{16}. This field would be larger than currently obtainable using the AOS Space Data Link Protocol or as small as desired for commanding, messaging or emergency telemetry modes.

2.1.1.2 MASTER CHANNEL INSERT ZONE

The MC Insert Zone, if used, must be signaled by the MC Insert Zone Flag within the Transfer Frame header for each frame of the Master Channel within which it appears. In order to comply with the requirement to make MC services data driven, it is necessary to include an Insert Zone Header within the Insert Zone itself that identifies its size. The first bit of the MC Insert Zone, called the MC Length Field Size, defines the size of this field that contains the length of the data contents of the MC Insert Zone. If the first bit of the MC Length Field Size is a “0” then the length is contained within the first byte of the MC Insert Zone and the MC Insert Zone contains between 0 to 127 bytes. A “1” in the MC Length Field Size signals that the size of the data in the MC Insert Zone is contained in the following 15 bits and thus the MC Insert Zone data contents can be between 0 and 32,768 bytes in length.

The ability to provide a synchronous data insert using the MC Insert Zone requires that MC transfer frames occur at a fixed interval and therefore the size of the MC Insert Zone is fixed. Currently the AOS recommendation require each transfer frame in the Master Channel to be of fixed length and the size of the MC Insert Zone is fixed and no additional idle bits between frames is accommodated. This exact optional implementation can be accomplished using the NGSLP assuming the same constraints.

The MC Insert zone could be used to carry real time data/data messages if the frame size is allowed to vary to accommodate the varying size of the contents of the MC Insert zone. This approach could be utilized for rapid signaling but again it would most probably require the frame length to vary to accommodate the variable contents to be included within the MC Insert Zone.

2.1.1.3 Master Channel Frame Error Control field

The presence of this field is conditional on the managed agreements for operation on a physical channel. The function of this field is to carry the data generated by the frame validity check algorithm designated for use on this specific Master Channel. This field is only required when the frame will be transferred over an uncoded physical links.

2.1.2 Virtual Channel (VC) Data Contents Group Fields

The VC Data Contents Group contains that portion of the Transfer Frame that is associated with the VC. It contains three major Fields shown in Figure 2-3: the VC Insert Zone, , the VC Frame Data Field, and the VC Operational Control Field (OCF). Note that Transfer Frame Security is inserted between the fields in the VC data Contents Group as shown in Figure 2-3.

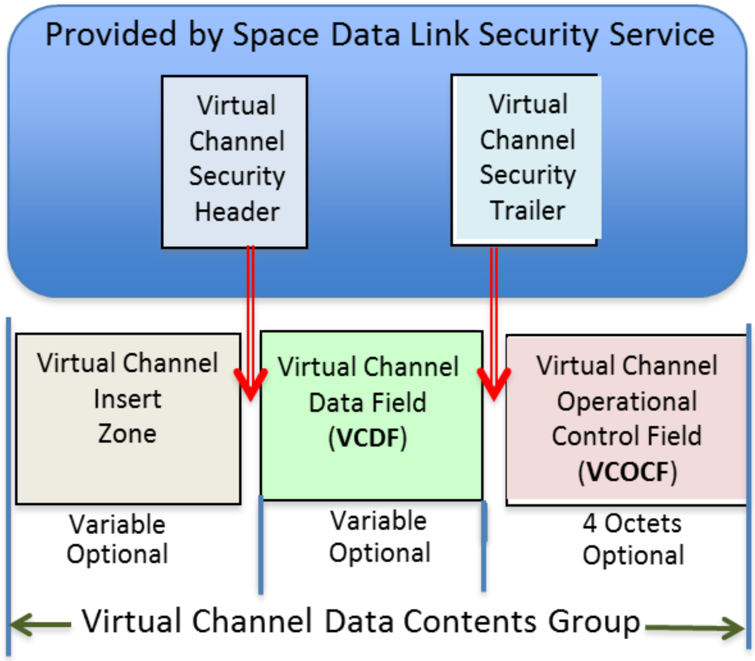


Figure 2-3 The Virtual Channel Data Contents Group

2.1.2.1 VIRTUAL CHANNEL INSERT ZONE

This optional field is present when the VC Insert Zone Included Flag field in the Transfer Frame header contains a "1".

This field can may be designated to carry real-time inserted data or messages. The use of this field could reduce latency for delivery of control information. A formal header for the VC Insert Zone has not been defined because its use is confined to a VC and thus it would preferably be specified by the user. No VC Insert Service is defined. The contents of the VC Insert Zone can may be managed, but it is suggested recommended that the following header information be inserted at the start of the VC Insert Zone in order to identify the size of thise field: The first bit of the VC Insert Zone, called the VC Insert Zone Size field, defines the length of the field that contains the size of the VC Insert Zone. If the first bit of the VC Insert Zone Size field is a "0" then the length is contained within the first byte octet and provides for a VC Insert Zone between 0 and up to 127 bytes octets in length. Awhile a "1" in the first bit signals that the size is contained in the following 15 bits and thus the VC Insert Zone can be between 0 and 32,767 octets in length.

2.1.2.2 Virtual Channel Data Field (VCDF)

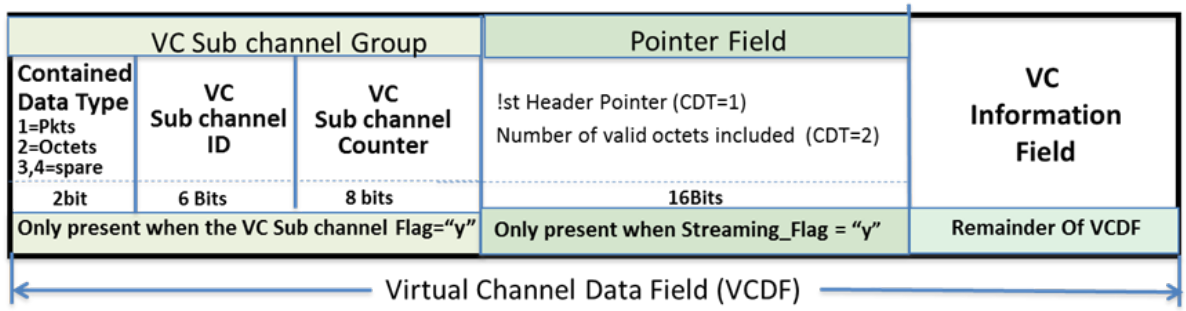


Figure 2-4 Virtual Channel Data Field Contents

The VC Data Field is divided into 3 optional field group: VCS Group, VC Pointer Field, VC Information Field described below:.

2.1.2.2.1 Virtual Channel Sub channel (VCS) Group

The fields in this group are only present when the value in the VCS Included Flag in the Transfer Frame Header is contains the value equal to "1. The VCS Group consists of three fields: Contained Data Type Field, VC Sub_channel ID, and the VC Sub_channel Counter.

2.1.2.2.1.1 Contained Data Type (CDT) Field

The first field in this group is the Contained Data Type field that identifies the type of data contained in the VC Information Field (VCIF). There are four possible values of which only 2 have been specified. When the value in this field equals "01", then the data contained in the VC Information field (VCIF) are packets. See http://sanaregistry.org/r/packet_version_number/packet_version_number.html. When the value in this field is equal to "10" the data are user octets. Values "00" and "11" are spares defined for future use.

2.1.2.2.1.2 VC Sub channel ID

The second field is called the VCS_ID field which identifies the active VC Sub-channel for this frame. The VCS_ID can identify up to 64 VC Sub-channels.

2.1.2.2.1.3 VC Sub channel Counter

The third field is the VCS sub channel Counter field that increments by one every time a new frame with this specific VC Sub-channel ID for insertion in the this VC is generated. This counter is used by the VC Sub channel receiving process to verify that no loss of continuity has occured. The test for continuity is to check that the count in the previous received frame within the same VCID and VCSID is exactly one less than the current frame (modulo 256).

2.1.2.2.2 VC Pointer Field

The VC pointer field is only present when the Streaming Flag in the Transfer Frame Header equals ”1”. This field contains the pointer to the first octet of the first packet header contained in the VC Information Field when the Contained Data Type (CDT) field equals ”1”. If the Streaming Flag equals “0’, then this field will point to the last valid user octet in the VC Information Field. If the size of the Information Field, for the octet service, is larger than the value contained in the pointer field, then the remainder of the Information octets within the VC Information field will contain idle octets.

2.1.2.2.3 VC Information Field (VCIF)

The VC Information Field is an optional field that carries the payload data in transit for the VC. The type of data is identified by the Contained Data Type Field in the VCS Group.

2.1.2.2.4 Virtual Channel Operational Control Field

The presence of this optional field is managed at the VC level. When the COP is in use, this field contains the Command Link Control Word (CLCW)/Proximity Link Control Word (PLCW).

2.1.2.3 Transfer Frame Security Fields

There are two transfer frame security fields that are provided by the Space Link Security Service when mandated.

2.1.3.1 Virtual Channel Security Header

This field is optional and is only required if CCSDS SDLS security is employed on this VC. The contents of the field shall be consistent with the rules and recommendations documented in the CCSDS Space Data Link Security Protocol Recommendation, Reference [TBD].

2.1.2.3.2 Virtual Channel Security Trailer

This field is optional and only required if authentication or authenticated encryption service is required on this VC. The contents of the field shall be **consistent with the rules and recommendations documented in the CCSDS Space Data Link** Security Protocol Recommendation (Reference TBD).

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2..2 TRANSFER FRAME ASSEMBLY PROCESS

The total length of all the included fields plus the frame header will be identified in the length field in the Transfer Frame header. The size, content and presence of the remaining fields are as prescribed by the management rules for the specific VC. The order for inclusion of the data fields within the frames is provided by three assembly processes as follows: 1) the Virtual Channel Assemby process accepts the optional Virtual Channel Data Field (VCDF) and inserts it into the frame being assembled along with optional Virtual Channel Insert Zone, and the optional VC Operational Control Field as supplied by the Frame Acceptance and Reporting Mechanism (FARM), 2) the Master Channel Assembly process provides the mandatory Transfer Frame header (since the length of the frame can now be calculated) along with the optional Master Channel Insert data 3) the optional Space Link Security Service can then calculate and provide the Security Header and Trailer that use the assigned Security Association and optionally lastly 4) the inclusion of the Frame Error Control field (FECF) is managed (thus its inclusion in the frame is anticipated by the Master Channel Assembly Process for determining the length of the frame) calculated based on all the fields already placed in the frame using the predefined algorithm defined for the link. Figure 5 illustrates the composition of the frame and serializes the order in which the fields are included into the frame.

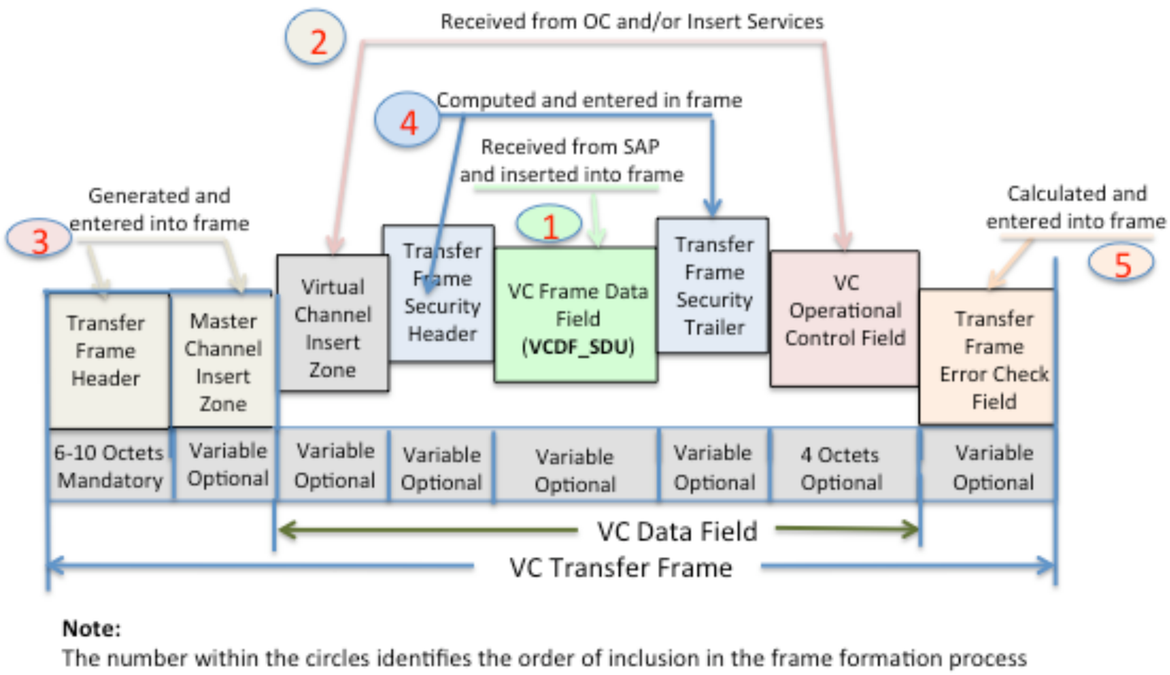


Figure 5: Order in which the Transfer Frame is composed.

2.3 Relationship Of The Frame To The Code Block

This section identifies the possible relationships that can be utilized for forward correction services for the Transfer Frame. Three relationships are defined;

1) Uncoded,

When the transfer frame is uncoded, the frame must contain the optional Frame Error Control Field. This requirement assures, with a high probability, that the contents of the frame have not been corrupted in transit. The FEC used may be dependent upon the link characteristics. For example the Proximity link uses a 32 bit CRC to check for erred bits because the symbol error rate may be substantially lower than required for reliable bit recognition due to slant range conditions and or multicast from nearby surfaces.

2) Transfer Frame Length dependent upon Code Block length

The block codes that are recommended for use by the CCSDS have substantially low undetected error rate, except for the BCH code which should be phased replaced by short Low Density Parity Codes (LDPC). The use of the LDPC codes eliminates the requirement for inclusion of a FEC for transit issues but the FEC could be used to test for errors caused by handling processes. In this mode, two independent synchronization markers are used. In the symbol domain, the Code Synchronization marker (CSM) delimits the codeblock and the derandomization process. A series of code words can also be used in this mode to create a code block of the desired size (i.e. a series of 4 1024 bit LDPC code words can be concatenated to form the code block for a 4096 bit frame). Anytime a code word error is detected the randomization and decoding processes are reinitialized and search is initiated for the CSM. In the bit domain, the Attached Synchronization Marker (ASM) is used to delimit the frame.

Note that there are numerous issues with this mode when using a variable length frame with fixed length codes:

When the code block and frame are not the same length, fill bits are appended to the frame to fill the code block.

When multiple code words are concatenated to form the code block it is required to determine how many code words are included in the code block. This can be automatically accomplished by concatenating a non-decodable code word to the last code word that encompasses the frame. Another way would be to read the frame length field obtained from the first code word and using that value to determine the number of code words in the code block.

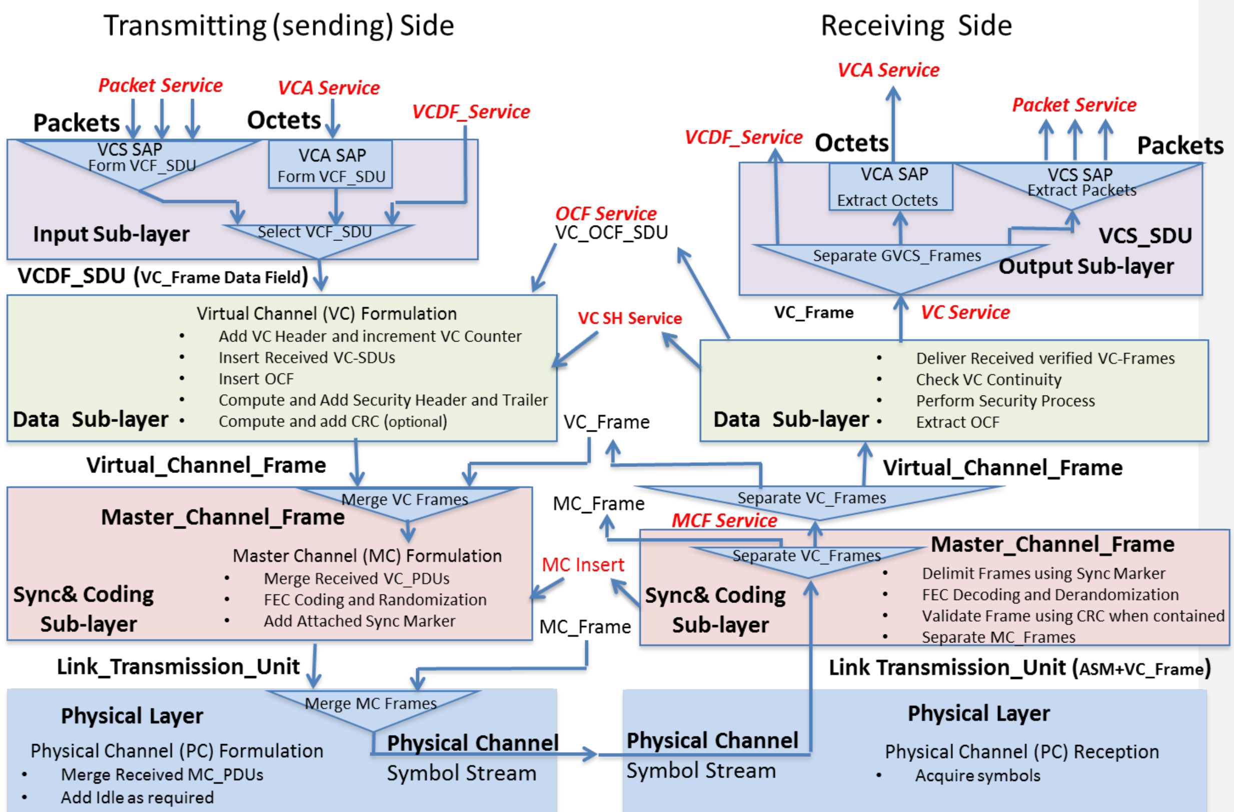
3) Transfer Frame length independent of the Block Code length

When the code block and frame lengths are independent on one another,then the code blocks are required to be continuous linked only by the CSM. In this mode the as in the one above the CSM delimits the beginning of the code block and the derandomization process while the fixed length of the code block delimits the end of the decoding and derandomization processes.. The start of the Frame is located using the ASM and the value in the length field in the frame header determines where the frame ends. Whenever a code word error is detected decoding and derandomization processes are terminated, CSM search is initiate and any partial frame data acquired is discarded. The search for the transfer frame is reinitiated by synchronizing to the ASM.

Note that since the Frame and Code block lengths are independent and the output from the coding sublayer is basically error free then the search for the ASM and the value of the acquired frame length field value has a high probability of being valid. The independence of the frame from the codeblock makes it possible to efficiently accommodate the transfer of variable length frames on a link that is maximizing its coding effectiveness by utilizing fixed length code blocks. Since the bit error rate of the bitstream output from the forward error decoders is virtually error free the synchronization process for the start of the frame is simplified. Therefore it is possible to insert idle bits between data frames as desired as long as synchronous insert zone is not required.

2.4 Data Link Services

Figure 2-6 is an end-to-end illustration of the services that can be provided by the data link layer.



Service Descriptions To Be Included see Annex A

2.5 Tailored Frame Descriptions

The NGSLP Frame format can be tailored to optimize its structure to support the needs required for the link. Note that four of the five flags included in the Frame header are used to signal the optional forms that are either included or not included in the frame. These structural options are controllable by setting flags within the Transfer Frame header that notify the receiving entity of the exact form of the frame. The inclusion of a Master Channel Insert Zone or VC Insert Zone are signaled and can be included in all frame forms. Note that the presence or absence of specific fields in the VC Data field (VCDF) are not signaled and there presence of absences is transparent to Master Channel services. The content of the VCDF is managed by the users of the VC. The FECF is a managed field that is only required if the frame is to transported across an uncoded link.

2.5.1 Non-Streaming Frame Types

These Frame formats are tailored for operations that desire or require variable length frames that contain the message to be transferred in its entirety. This form resembles the

Telecommand frame structure including the control commands. This format is also useful for the operational control commands for proximity operations such as Hailing and physical layer change commands. The inclusion of a Master Channel Insert Zone or Virtual Channel Insert Zone in these forms is optional.

2.5.1.1 Non-streaming frame form without VC Sub channels

This frame format without sub channels resembles that used to transmit either an integer set of packets or a complete set of user provided octets. This format type can be further tailored to support operational control commands especially emergency commands that require minimum size. In this form the VCDF reduces to include only the VC Information Field. When sequence control is not required the number of bytes for the sequence counter can be set to zero reducing the frame header size to 6 octets. This format is shown I figure 2-xx with the optional security fields and the optional VC OCF included.

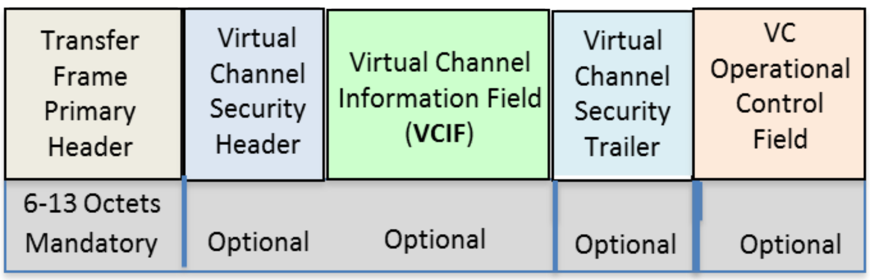


Figure 2-xx Non-VC Sub channel Frame Form

2.5.1.2 Non-streaming frame Form that includes a VC Sub channel

2.5.1.2.1 This Frame form of the transfer frame include a VC Sub channel and provide an additional data routing capability for the frame. The inclusion of the VC Sub channel enables a single VC to support multiple data streams. This enables the multiple VC Sub channels to be under the control of a single Command Operations Procedure (COP) that can provide reliable delivery of the entire set of VC Sub channels without duplication or omission of data. This frame format replaces the Multiplexer Access Point (MAP) function in TC and the Port function in Proximity

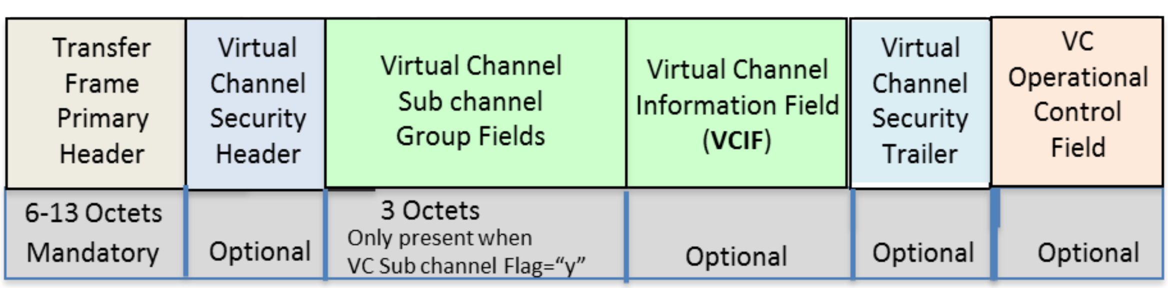


Figure 2-xy VC Sub channel Frame Form

2.5.2 Streaming Frame Types

These Frame formats are tailored after those specified for telemetry using the AOS specifications. The streaming rules eliminate the constraint that packets within the VCIF must be complete but rather allow the packets to span frame boundaries requiring only that they continue in the next VC with the same VCID (and same VCSID when VC Sub channel are signaled). This format may be used with or without VC sub channels. The inclusion of Insert zones when signaled adds the capability to insert low latency data into to the data stream without changing the structural aspects of the VCDF. This feature is dependent on the frame and code blocks being independent.

2.5.2.1 The Streaming Frame format when used without VC sub channels conforms to that in Figure 2-xz and whether the VCIF contains packets or octets is managed ,not signaled because the CDT field is not included in the frame. The use of management rules for determining the type of data contained in the frame is consistent with the current rules associated with the AOS specification.

Transfer Frame Primary Header	Virtual Channel Security Header	Virtual Channel Pointer Field	Virtual Channel Information Field (**VCIF**)	Virtual Channel Security Trailer	VC Operational Control Field
6-13 Octets Mandatory	Optional	2 Octets Only present when Streaming_Flag = "y"	Optional	Optional	Optional

Figure 2-xz

2.5.2 When streaming is combined with VC sub channels the form conforms to that described in figures 2-yz. In this case the CDT is included in the frame and thus the type of data contained within the VCIF is signaled. This form was originally designed for operation with fixed length frames but can be used even when fixed length frames are not a constraint.

Transfer Frame Primary Header	Virtual Channel Security Header	Virtual Channel Sub channel Group Fields	Virtual Channel Pointer Field	Virtual Channel Information Field (**VCIF**)	Virtual Channel Security Trailer	VC Operational Control Field
6-13 Octets Mandatory	Optional	3 Octets Only present when VC Sub channel Flag="y"	2 Octets Only present when Streaming_Flag = "y"	Optional	Optional	Optional

Figure 2-zz

3.0 Application of NGSLP to the DFE link (Telecommand/AOS)

There currently are two link protocols that are used for direct from Earth commanding. These are the Telecommand (TC) Recommendation that was codified in the early 1980s and the Advanced Orbiting System (AOS) recommendation that was designed to use block codes and the inclusion of packets as provided by the Telemetry Recommendation. The TC recommendation was for low rate uplinks while the AOS was designed for higher rates and larger block codes

3.1.1 The current Telecommand recommendation is designed for unmanned missions and has three distinct features:

1) The use of a short block code word that can be concatenated as required to create a Command Link Transmission Unit (CLTU) (the code block) to contain the command contents. Both the frame start and the code word are delimited by a single synchronization marker.
2) A variable length frame structure containing a frame length field that is used to eliminate any fill required to be added to the frame in order to fill the codeblock (constructed of one or more concatenated code words), and to validate that the delivered data had an adequate number of bits to delimit the command frame. An erred code word was used to terminate the decoding processing of the codeblock and initiates the search for the next CLTU containing the next command.
3) The use of MAPs allows for the routing individual commands to different entities within the spacecraft and segmentation provides the means to transfer packets larger than the maximum, allowed by management, transfer frame size.

3,1.2 The current DFE recommendation for manned missions utilizes the AOS specification. The basic features utilized are:

1) The use of fixed length frames to improve the frame synchronization process because the use of higher performance codes increases symbol error rate making the ASM more difficult to locate. The fixed size frame provides a means to assure synchronization by knowing where the following ASM should be located,
2) The use of streaming data rules that don’t limit the size of packets.

3.1.3 the use of the NGSLP format for DFE operations.

The NGSLP can be used in the exact same fashion as currently used if desired. The frame has a length field for delimiting the frame's terminus and uses a marker to delimit its start. The short LDPC code words can be concatenated in the same fashion to provide the forward error correction desired and the code block can be delimited with the same marker as the frame and can be terminated an erred code word. The same functions provided by MAPs and Segmentation can be accommodated by using VC Sub-channels and streaming..

Now let's get into the added ways that NGSLP provides for Telecommand.

1) The replacement of the BCH code with the small LDPC codes provides substantial coding gain enabling higher data rates with lower frame and undetected error rates. The gain obtained will allow 34 meter antennas to provide commanding that today is only obtainable using the 70 meter antennas.
2) The NGSLP provides for many VCs and the rules for VC processing are managed. Control commands and Emergency commands can use their own VC that respond to those rules (i.e. Sequence control, sequence counter size). The current Telecommand systems use the VC to differentiate address the physical receiver and command decoder that is to proves the frame. The increased number of provided VCs also provides this functionality but can be used to independently identify the receiver output and command decoder that should process the received transfer frame
3) The dissociating of the frame from the codeblock provide enables the use of continually repeating code words separated by a code word synchronization marker allowing for improved synchronization (as per the AOS example) and in essence providing a error free bitstream to the frame handling entity with only the very low probability of a sequence break in the data stream that results in data loss. This also eliminates the need for an erred code word to delimit the codeblock containing the frame. The frame length can now be used reliably to delimit the frame because undetected code word error rates are exceeding low for any suggested LDPC (hopefully soon to be recommended) codes.

4) The use of VC Sub-channels provides the means to use the COP and or security for an entire VC while delivering the frame data packages that are carried by the different Sub-channels to different spacecraft elements. This provides the functionality that MAPs provide in Telecommand.
5) The current segmentation process requires all frames to use the segmentation frame form even if just a single frame in the mission needs the segmentation feature. The NGSLP streaming feature provides the means to segment packets across frame boundaries as provided in the Telemetry and Advanced Orbiting System Recommendations. This feature is signaled in the frame header so that it need only be used when desired or necessary.
6) The addition of uplink security will force a reimplementation of current designs and it requires larger frames. It is conceivable that this could add 400% overhead for emergency command and 5% for all others. If a new design is required it would be beneficial to implement NGSLP because it adds features currently not available, provides improved performance in harmony with small LDPC codes and it is adaptable for all uplinks; both low rate and high rate.
7) The VC Operational Control Field may be utilized to support bi-directional data transfers that rely on the COP to provide reliable data transfer.

8) The use of the MC Insert Zone is limited in AOS to provide a fixed length insert zone in every frame, NGSLP provides a signaling feature that allows the MC Insert Zone to be of a signaled length and inserted only when desired. This can be used for delivering low latency messages while delivering a bulk data transfer.

3.2 The NGSLP for Downlink process

The AOS protocol recommendation is in use for the Manned Missions It was designed to support higher rates and a diversity of data suppliers. The current AOS recommendation is designed around three distinct features:

1) The use of a long block code [particularly the Reed-Solomon 223,255 code(R-S)]. The frame start and the code word start is delimited by a single marker. Achieving code block and simultaneously frame

synchronization is more difficult than with the BCH because the symbol search for ASM is complicated the increased symbol error rates attributable to the use of the R-S code. This is one of the reasons that fixed length frames were adopted.

2) The AOS protocol was designed to provide for isochronous data delivery using a MC Insert Zone. Thus the AOS specification requires that all frames be the same size and if an insert service is to be provided it would via the MC Insert Zone that would be required in each and every frame in the master channel. The MC insert zone is also required to be the same length in each frame.
3) The requirement to support a diversity of users is accomplished by enabling frames to identify themselves as being associated with a different user. Thus pseudo-independent data stream can occupy the same Master Channel. Each stream is called a Virtual Channel (VC). Each VC would have its own counter that would linearly increase. This feature provides a continuity check so that the contents of each specific VC could be systematically appended allowing the packet extraction process to be accomplished without error. A first packet header pointer was incorporated into each frame that would be used to find the first packet header within the frame if a preceding frame was lost.

The NGSLP can be used in the exact same manner as AOS if desired. The frame length can be fixed by management. The frame can be aligned with the codeblock utilizing a single marker to delimit the frame and the code block. The space borne transponders however have their limitations. The near term transponders will most likely be limited in there ability to acquirer symbol synchronization ant very low Symbol to Noise ratios that are driven down by the forward error correction code's performance gain. Because of this consequence it is expected that the most effective LDPC code that code be utilized is the CCSDS 1024 bit code word. A fixed series of these short LDPC code words can be concatenated to form the codeblock that would contain a frame that would, in this example , contain a multiple of the 1024 bits . The MC Insert Zone can be used in the same manner if required by setting the MC Insert Zone Included Flag and fixing the size of the MC Insert Zone. The same streaming data features are provided to allow packets to cross frame boundaries. The VC Sub-channel Counter is provided to test for continuity.

Now let's get into the added ways that NGSLP provides for AOS type Uplink:.

1) The increase versatility is obtained by disconnecting the frame from the codeblock. The frame has its own ASM that is search for in the low bit error domain that is output from the underlying coding process. The underlying code provides the increased performance of the channel thus supporting the required higher rates. Since the Frame and the codeblock are not tied together the frame can vary in size if desired. For example, either of both the MC Insert Zone or the VC Insert Zone could be periodically used to carry real time data that needs to be injected into the stream with a minimum of delay. This feature is enabled because the frame can rubber band to accept the added message and the frame length field would provide the necessary information to delimit the end of the frame.
2) Very high data rate links may be challenged by jitter within the ground network delivery the frames to the station where there are stitched together to form the uplink. An instance of excessive Internet delay could be tolerated by just adding a few idle bits between frames eliminating the need to add Idle frames if the frame and the code block were locked together. Very high rate links often desire long frames, NGSLP can accommodate frames up to 65k bytes.

   NOTE: *The requirement to add whole frames when Idle was required was because the AOS specification required that there be a continuum of frames to facilitate the codeblock delimiting process.*
3) The uplink to orbital platforms typically carry frames that are dedicated to a selected entity. The data directed to that entity could be contained with a VC Sub-channel. A specific collection of sub-channels could emanate from the same POCC and require the same Security Association. This would be accommodated by assigning all those VC Sub-cannels to the same VC and assigning a SA to that VC.

3.3 The NGSLP for Proximity Operations

The characteristics of Proximity communications are similar to DFE communications but bi-directionally. There are significant operational differences that require significantly more control commands and operational states. Here again the characteristics of the NGSLP can add improved performance. The individual control command and state diagrams will be incorporated into the NGSLP Blue Book.

Annex A

3 2 NGSLP OVERVIEW FOR MISSION SERVICES

3.1 2.1 USER APPLICATIONS

The NGSLP Recommendation supports single space vehicles, or constellations of space vehicles, which simultaneously execute a wide spectrum of applications in near-earth orbit, geostationary orbit, or deep space. The NGSLP can be tailored to support observational science, experimental science, manned and robotic platforms/vehicles, launch services and the transfer of engineering data for the operational control of the space vehicle ("core") systems.

3.1.1 2.1.1 OBSERVATIONAL SCIENCE

Observational science is primarily performed from unpressurized platforms in orbits around the Earth or other planetary bodies. Examples include astronomy, space physics, and Earth observation.

Typically, the lifetime of observational payload investigations is in the order of years. The user equipment is relatively stable in terms of location and functionality and usually requires minimal on-orbit human interaction during the life of a mission. There is therefore a relatively static association between a space instrument and its ground processing facility.

Since transmitted data rates are often high, the observational user requires streamlined techniques for acquiring, buffering and delivering large volumes of data from space to ground, with protocols optimized so as to reduce requirements for onboard processing resources and communications bandwidth. The data taking process usually is performed during much of the trajectory path but communications is often limited to preplanned periods. The process therefore typically requires the acquired data to be buffered until it can be down linked during a communications session. Because of the need to share limited onboard resources between multiple users (i.e. instruments), observational operations may require extensive preplanning and scheduling. Uplink data delivery requirements are significant lower than the downlink rate requirements. A large degree of protocol flexibility, such as the capability to change addresses dynamically, is therefore unnecessary.

The CCSDS "Path service" was developed to be of particular use in satisfying the data handling needs of the observational user. It is virtually identical to the services provided by current CCSDS Recommendations.

3.1.2 2.1.2 EXPERIMENTAL SCIENCE

Experimental science, such as materials processing and the effects of space on human physiology, is conducted primarily in pressurized space vehicles since a high degree of flight crew interaction may be required.

In contrast to observational science, experimental science investigations are often scheduled for only a limited time duration. General purpose "laboratory" equipment that has been used in one experiment may be almost immediately reconfigured for use in another. A crew member may control an experiment from workstations at different locations, possibly assisted by an investigator on earth. Hence, source-destination data communications pairs may be only temporarily associated with any particular experiment, and these associations will typically exist only for relatively short sessions. The level of human interaction is high in terms of monitor and control of the experiment and much of the information that is generated will be evaluated on board. Thus, the volume of data that is transmitted to and from the ground may be relatively low.

Experimental users have needs that are quite similar to those of users of a local area network facility located on the ground. In particular, they need data communications protocols which provide routing flexibility by supporting global source and destination addressing, and which support a rich repertoire of upper-layer data handling services.

The CCSDS Internet service was developed to meet the needs of experimental users. It is a new CCSDS service, which opens doors to a much wider level of potential upper-layer standardization than is currently available for conventional systems.

3.1.3 2.1.3 ROBOTIC PLATFORMS/VEHICLES

The links that support robotic platforms/vehicles typically operate in short windows of time based on the available geometry between the robotic platforms/vehicles and the other terminus of the link. These links can be end-to-end or rely on a relay system to forward the data between the robotic platform/vehicle and its Earth based control entity. The link characteristics can be significant different but the end to end services would likely be the same. The NGSLP is designed to accommodate the differences in link characteristics primarily by allowing the frame and the link layer coding to be independent. thus freeing the framing from the constraints of link's coding implementations.

3.1.4 DISASSOCIATING THE FRAME FROM THE CODE BLOCK ALSO PROVIDE THE OPPORTUNITY TO PROVIDE A FRAME RELAY SERVICE. IN THIS MODE THE COMMUNICATIONS HUB CAN RECEIVE FRAMES AND RELAY THEM TOWARD THEIR DESTINATION BASED ON A MANAGED PATH FOR FRAMES USING THEIR SPACECRAFT ID AND THE VALUE IN THE DESTINATION/SOURCE FLAG.

3.1.5

3.1.6 2.1.5 MANNED PLATFORMS/VEHICLES

Communications links to support manned mission are typically 24/7. The required links include emergency control and voice delivery, science data telemetry, instrument and vehicle remote control, human text type services, health and safety data and video. The data for these services, as currently being designed for the NASA manned program, utilizes Internet network packets and services. The NGSLP is designed to efficiently transfer these network packets, contained within CCSDS Encapsulation Service Packets, between Internet routers on the ground and in space. It is anticipated that during normal operations link data rates can be in the multi-megabit range for selected data. It is also anticipated that Operations Control Centers would provide some form of link layer security for the user data that is under its purview and it is desired to limit the number of Keys required. Security for other users may use the security algorithm but may control their own keys. In total the desire might be to limit the number of different security associations to limit the key management complexity.

3.1.7 2.1.5 LAUNCH VEHICLES

The data rates supporting launch vehicles are typically limited in both directions. Timeliness of data delivery is the critical factor in both the return and forward links. The NGLP has a few features that are designed to support these requirements. The capability to send variable length frames and capitalize on using a Master Channel Insert Zone for critical messaging keeps latency to a minimum. The separation of the frame from the code block allows the frame size to vary while the code word size is maintained. This functionality is also useful for decent and landing telemetry links for telemetering critical event information with minimum latency.

3.1.8 2.1.6 CORE OPERATIONS

The core infrastructure operates and maintains the space vehicle systems that support the payload users. Core user requirements share attributes that are common to all space vehicle applications. Since the safety of the space mission (as well as often the safety of human lives) is involved, reliability concerns may strongly influence the selection of services that are used for transmission of core data.

A high degree of interaction is required in order to perform adaptive command and control (similar to experimental users), yet fairly large quantities of systems monitoring data must be repetitively and continuously returned to static locations on Earth in order to support long-term analysis of engineering performance (similar to observational users). Core users are therefore likely to use both the Internet service and the Path service for message exchange. For piloted missions, synchronized digitized audio and video must also be integrated with message traffic between ground controllers and onboard crew; the Path service can often satisfy these needs, but for some applications special CCSDS point-to-point space link data-transfer mechanisms have been provided.

3.2 2.2 SPACE NETWORKING ENVIRONMENT

Space/ground data transmission requires use of high capital-investment tracking facilities that must be shared not only by multiple users, but also by multiple space missions. Onboard resources are almost invariably subject to constraints of power, weight, volume, and the high costs of flight-qualifying hardware and software.

All of these considerations point to the need for robust space data handling services which are optimized for efficiency and low utilization of onboard resources. Because of the intermittent nature of the space/ground link transmission contacts, onboard data storage and replay must be accommodated. Removing the artifacts of transmission across the space link often requires considerable value-added processing prior to delivery of data to end users.

3.3 2.3 NGSLP SERVICE CONCEPT

A project's data handling network that provides end-to-end data flow in support of a particular mission can utilize the NGSLP to support eight different types of data handling services:

— Path service;
— Frame Relay
— Virtual Channel Data Unit service;
— Virtual Channel Access service;
— MC and VC Data Insert services;
— Encapsulation service;
— Multiplexing service.
--- Security Service

The Path and Frame Relay Services conceptually operate end to end across the network. The Encapsulation service is a carrier for both Internet and Delay Tolerant Services that operated across a link but connects Internet and Delay Tolerant Service provides so that they conceptually operate end to end. The remaining services operate only point to point across the space link.

Note – *All of the NGSLP services are specified in terms of the stack of raw protocols that exist at the interface between a spacecraft and its supporting ground system, or between two communicating spacecraft. It is very important to note that most of these raw services require augmentation within the ground system before they are finally exposed to end users. The CCSDS has developed the overall service architecture which allows the underlying NGSLP services to be extended to the users in a real operational environment of mission cross support.*

All of the protocols conceptually operate bi-directionally (i.e., from space to ground, from ground to space, or from space to space). However, when data are transmitted from space to ground, some value-added "production data processing" services may be performed at the receiving end of the data flow prior to delivery of data to users. For instance, network-induced artifacts produced by the onboard storage and replay of data must be removed by appropriate preliminary ground processing before telemetry data are forwarded to the end user.

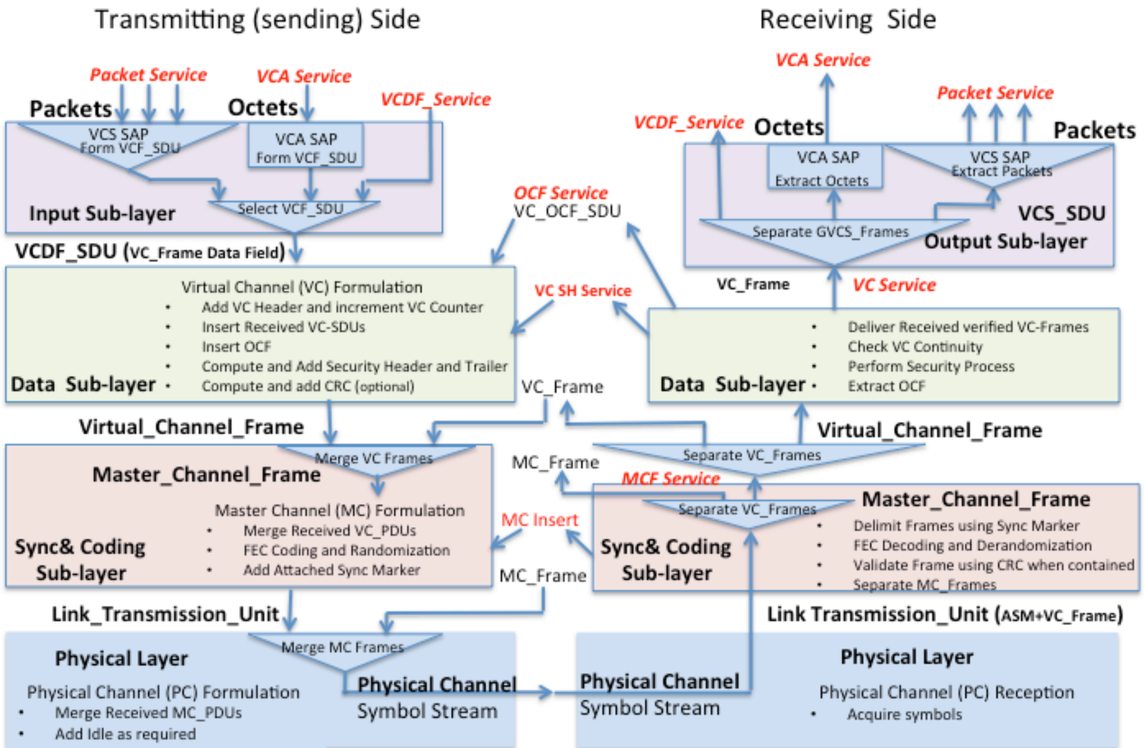
3 NGSLP SERVICES AND PROTOCOLS

3.4 3.1 END-TO-END SERVICES

The three “end-to-end” services (Path, Internet and Delay Tolerant Network) conceptually correspond to the Network layer of the OSI Reference Model of Open Systems Interconnection. They are fully complementary services that are designed for different applications.

The Path service supports a space-unique enhanced performance architecture that allows the user Application layer to directly access the space Data Link layer without providing formal Presentation, Session, or Transport services. The Path protocol is multi-layered, wrapping functions at Layer-2 (delimiting), Layer 3 (addressing), Layer 4 (sequence control), and Layer 7 (application data unit delimiting, naming and numbering) into one very lean and compact data structure.

The Internet and DTN services (as provided using the encapsulation service), on the other hand, maps directly into the Network layer of the OSI protocol stack in a strictly layered manner, interfacing to the Internet Transport layer above and the CCSDS Link Layer below via the CCSDS Data Encapsulation Services.



3.1.1 Path Service

The CCSDS Path service is implemented using a special-purpose protocol, originally developed by the CCSDS, which was optimized to handle the "telemetry" data type. The NGSLP extends its utilization to all link types. Path service supports high processing speed and efficiency, at the expense of some flexibility. The Path service uses a "CCSDS Packet" as its protocol data unit.

The CCSDS Packet structure is similar to that currently used for telemetry and telecommand applications in space missions. It was selected because of its lean structure and its ability to provide a consistent user interface as a bridge between conventional missions and Internet using missions.

To support the Path service, "Logical Data Paths" (LDPs), which identify fixed routing relationships between the source/destination pairs in the flow of data, are preconfigured by network management. Data are then relayed across the provided space network by tagging each CCSDS Packet with the thin “Path Identifier”, rather than extensive global source and destination addresses. Routing decisions are made by examining the Path ID and, using tables supplied by network management, deriving the next point in the data flow. In this way the Path service provides multiple arterial “trunks” for the efficient transmission of large volumes of telemetry-type data between relatively static endpoints.

In order to conserve communications overhead, the Path ID naming space is kept small. Within one onboard subnet, the Path IDs are locally unique since they are named by the identifier of the subnet through which they flow. When the Path service data units flow out of a particular onboard subnet, they must be “qualified” with some external identification to make them unique. Normally, the individual spacecraft subnetwork names are used in the onboard relaying nodes as the qualifier; the spacecraft identifier (SCID) is used after the data cross the space link. This all sounds more complex than it really is; these kinds of techniques have in fact been used by space missions for decades.

3.4.1 3.1.2 ENCAPSULATION SERVICES

The CCSDS Encapsulation service complements the Path service by providing a large degree of flexibility in support of interactive applications, utilizing other protocols to achieve end to end continuity. The CCSDS provides the connectionless network protocol for use within the Encapsulation service, thus allowing space missions to exploit the rich upper-layer-service infrastructure of other protocols. The Internet and/or DTN packet, delivered by the Encapsulation service, provides global end-point addressing and is compatible with standard OSI subnetwork routing techniques is encapsulated within a CCSDS Encapsulation Packet in order to utilize the CCSDS Link Layer Services.

3.1.2.1 Internet Service

If an application uses the full OSI stack, then the Internet packets will probably carry protocols associated with the ISO Transport, Session, Presentation and Application layers. In addition to concerns over the large integrated communications overhead and processing requirements associated with such a stack, there may be problems associated with operating through very large propagation delays. For this reason, this CCSDS Link Recommendation only provides connectionless network services.

3.1.2.2 Delay Tolerant Service

CCSDS is currently developing the Delay Tolerant Network services that can provide end to end reliable delivery services using the CCSDS Path Link Layer Service carrying the DTN packet within the CCSDS Encapsulation packet.

The CCSDS Delay Tolerant service complements the Path service in a manner that is functionally similar to that of the Internet service but is architecturally quite different. Delay Tolerant service packets, termed “bundles”, likewise provide global end-point addressing, but they typically do not encapsulate data units of protocols at the ISO Transport, Session, or Presentation layers. Instead, bundles typically encapsulate only Application protocol data units, and they are typically encapsulated in “blocks” for transmission using the Licklider Transmission Protocol (LTP) of the Delay Tolerant service; LTP blocks, in turn, are segmented for incremental reliable transmission over space links characterized by long signal propagation delays and/or frequent and sustained lapses in connectivity, It is those LTP segments that are encapsulated within CCSDS Encapsulation Packets in order to utilize the CCSDS Link Layer Services.

The Delay Tolerant service automates several aspects of mission communications, aiming to maximize utilization of space link transmission opportunities while reducing mission operations cost and risk. Application data may be presented for transmission at any time. The Delay Tolerant service queues outbound data while links are temporarily unavailable, selects link opportunities to utilize for transmission of queued data, begins transmission on the selected links as soon as they become active (and ceases transmission when the links are lost), meters transmission over the selected links, sequences the transmission of data according to application-selected quality of service, detects packet loss and automatically retransmits lost data as required, and manages the retention and release of data storage resources in the course of data transmission. Data received at a mission entity, either in space or on the ground, may be either delivered to local applications or automatically forwarded to another entity, depending on the destination endpoints declared for the received data.

3.5 3.2 POINT-TO-POINT SPACE LINK SERVICES

Transmission of data through the Layer 1/2 space-to-ground and space-to-space communications channels is a problem that is unique to the space mission environment. CCSDS has therefore expended considerable resources in designing customized protocols which can both efficiently use these channels and make their error characteristics invisible to higher layers. In the process, capabilities have been provided to support specialized users who do not need end-to-end CPN services, but who instead require only point-to-point data transmission through the space channel including reliable transfer across the link.

The CCSDS Data Link layer protocol uses frames as carriers of user data to transpot the data across a link. Boundaries between frames are delimited by pseudonoise-encoded synchronization markers. A “Virtual Channel” identifier, inserted into the frame header, allows a particular frame to be allocated to a particular flow of data, thus supporting multiple different types of traffic on a single digital channel. The basic protocol data unit of the space link is therefore known as a “Virtual Channel Data Unit”, or VCDU. The NGSLP has added a Sub channel capability to a Virtual channel allowing 1 VC to support the transfer of data from up to 32 individual sources.

The CCSDS has been using forward error correction codes to improve the performance achievable on the physical space links. The latest recommended codes are the Low Density Parity Codes (LDPC) that have code word sizes from 64 bits to 16, 384 bits.

3.5.1

3.5.2 3.2.1 VIRTUAL CHANNEL DATA UNIT (VCDU) SERVICE

The Virtual Channel Data Unit service allows independently created VCDUs from a single spacecraft to be transferred across the space link by a host spacecraft, which simply interleaves them frame by frame adding the spacecraft’s SCID to each of those VCDUs. This service is available only to “trusted” guest users who are certified during the design process to ensure that the independently created protocol data units do not violate the operational integrity of the data link created by the host spacecraft. The continuum of frames baring the same SCID is called the Master Channel.

3.2.2 Master Channel Service

In some configurations a spacecraft which is creating its own Master Channel Frames may accept a stream of Frames that has been created by another spacecraft which has a different

SCID. These two streams may then be merged for transmission through a common channel, and separated again at the receiving end utilizing the CCSDS Master Channel Service.

3.5.3 3.2.3 VIRTUAL CHANNEL ACCESS (VCA) SERVICE

The VCA service allows a user to format a block of octets for point-to-point transmission across the space link on a dedicated Virtual Channel. Since he contents of the data field is unknown to the CCSDS services the contents of the frame's data field are transferred to the pre-identified use,

The VCA service is likely to be used to transmit high rate video (Reference [11]), a stream of time-division multiplexed telemetry, or a privately encrypted data block.

3.5.4 3.2.4 INSERT SERVICES

The Insert services allow small, octet-aligned service data units/messages to be inserted into a frame. Both Master channel and Virtual channel services are possible on a space link. The Master Channel service enables these service data units to be injected into the frames of a Master Channel. Virtual Channel Insert service limits the insertion of service data units within a single Virtual Channel on the link.

These services can be used in various ways depending on the need and the link definitions.

a) Isochronous data can be supported if the frames are limited to a fixed length with on inter-frame Idle and the same sized service data unit is inserted in each of the Master Channel frame.
b) Critical low latency data can be inserted into frames that are not constrained to a fixed size. This data can be used to signal operational events and/or report on critical operations providing pertinent data in a quick

for independent services space link under conditions where the overall transmitted link data rate is low. A small data carrying space is reserved just after the header of *every* frame that is transmitted on the link, into which a few octets of data may be inserted. Since the frames are of fixed length, a regular sampling interval is provided.

The most likely use if the Insert service is to support digitized audio (see Reference [11]) over low rate space links. More information about isochronous services is presented in Appendix B.

3.5.5 3.2.5 ENCAPSULATION SERVICE

The Encapsulation service supports end-to-end services by allowing variable-length, octet-aligned service data units (SDUs), that are not formatted as CCSDS Packets, to be transferred transparently through the space link. The incoming SDU is simply encapsulated within a special CCSDS Packet, which is the protocol data unit (PDU) of the Encapsulation service. The CCSDS Internet service uses this service to enable SDUs formatted as ISO 8473 packets to be multiplexed onto the space link; other Network-layer SDUs could also be conceptually supported.

3.5.6 3.2.6 MULTIPLEXING SERVICE

The Multiplexing service allows variable-length, octet-aligned SDUs, that are preformatted as CCSDS Packets, to be multiplexed together for efficient transfer across the space link. The Multiplexing service is used to allow variable-length CCSDS Packets to be mapped in and out of the data fields of frames. This capability allows packets to be transferred efficiently independent of frame size.

The mechanism for implementing the Multiplexing service is the Multiplexing Protocol that takes incoming CCSDS Packets and concatenating them, back-to-back, until they fill frame data area. A header is prepended to the data contents of the frame that contains a pointer which delimits the boundary between the first Packet pair; the individual Packet length fields then delimit the other boundaries.

The Path service (which uses the CCSDS Packet as its PDU) provides an SDU which is directly compatible with the Multiplexing service. The Internet and DTN services must first have its packet wrapped within a CCSDS Packet by the Encapsulation service; the Multiplexing service can then mix Path and Internet SDUs together on a common Virtual Channel.

3.6 3.3 GRADES OF SERVICE

Since many different types of digital data are multiplexed together for transmission over a single space link, it is reasonable to recognize that they may not all have the same requirements for data quality. The growth of technology has provided for immersion of high performance forward error correction coding in spacelinks and the use of data compression for reducing the amount of bits that are required to get information transferred. These advances have eliminated (to a large extent) the grade of service that possibly delivers erred data. The CCSDS therefore provides two different “Grades of Service” during transmission through the space link.

The error control for the Grades of Service is provided using a combination of error detection, error correction and by using retransmission control processes. Each Virtual Channel supports a single Grade of Service at the link layer. Different types of error control and retransmission mechanisms are used to provide the different Grades of Service. Frame retransmission is used in the link layer to provide complete error free transfer, while Delay Tolerant Network (DTN) uses their Licklider Transport Protocol (LTP) and CCCSDS File Delivery Protocol (CFDP) to provide end to end reliable transfer at the transport layer.

3.6.1 3.3.1 GRADE-2 SERVICE

Data transmitted using Grade-2 service may be incomplete, but data sequencing is preserved and there is a very high probability that no data errors have been induced by the Space Link Subnet. Error control is provided either by error detection or forward error correction. Forward Error Correction coding has progressed to where every spacelink should be encoded providing a link where frame loss is less than 10^{-5} and undetected frame error rates are less than 10^{-9}.

3.6.2 3.3.3 GRADE-1 SERVICE

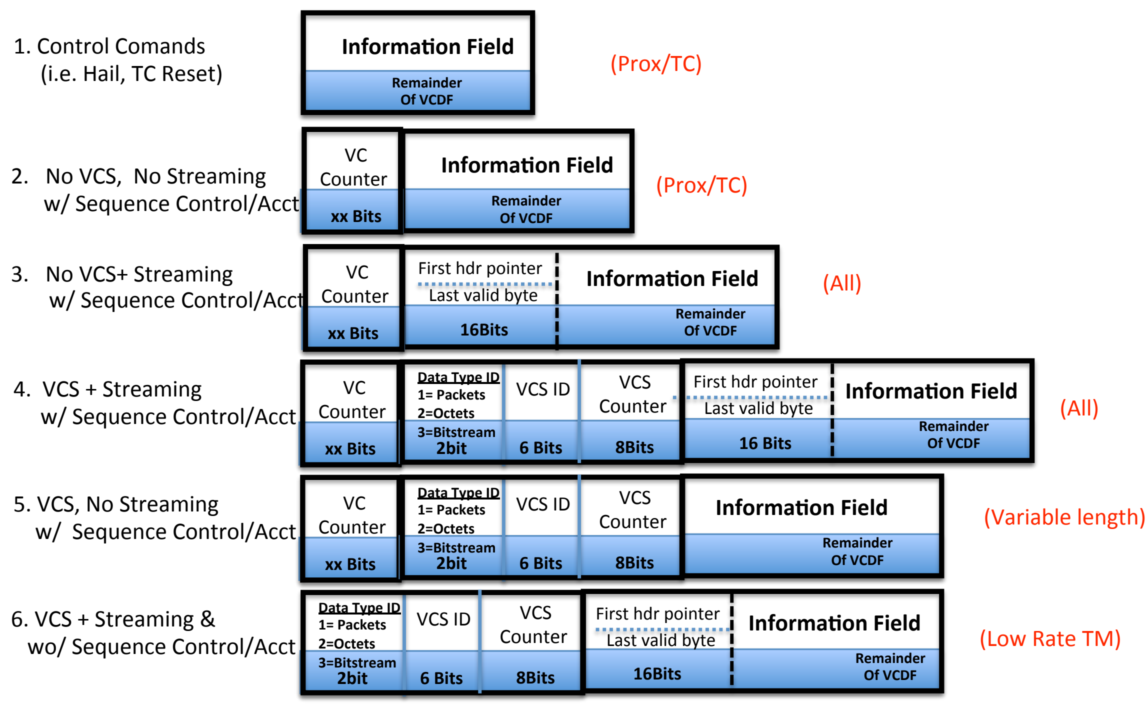
Data transmitted using Grade-1 service are delivered through the Space Link Subnet complete, in sequence, typically without duplication and with a very high probability of containing no errors induced by the Space Link Subnet. Grade-1 service is the highest quality of service available and relies on the implementation of an Automatic Repeat Queuing (ARQ) retransmission scheme in conjunction with the Reed-Solomon encoding.

CCSDS began the development of a Space Link ARQ Procedure using the Command Operation Proceedure-1 (COP-1) to provide Grade-1 service, using a reporting and accepting mechanism at the receiver to inform the sender of the progressof the transmission and when a frame loss was incurred so that the lost frame could be retransmitted.

The CCSDS has developed two transport layer protocols that provide Grade-1 service using the data delivered via the Grade -2 service. These Protocols (CFDP and LTP) are explained in references Y and X.

Annex B NGSLP VC Data Field & VC Counter Options

Other optional frame entities are not shown, i.e. Insert Zones, Security Fields, FEC, OCF



Note: When sequence control or accounting information is not employed/required the VCS counter is satisfactory for packet reconstruction purposes and thus the VC counter maybe unnecessary.