**Draft Next Generation Space Link Protocol (NGSLP) Concept Paper**

SLS-SLP WG

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**1) Purpose and Timeliness**

The primary concept describes a new generic CCSDS Data Link layer protocol, the Next Generation Space Link layer Protocol (NGSLP) to provide the required format, services, and primitives for all CCSDS space links i.e., Direct to Earth (DTE), Direct from Earth (DFE), and Proximity Environments. The Protocol is targeted for agencies’ emerging missions, both human and robotic, which we anticipate will require higher performance (higher data rates and throughput) and operate with enhanced security. We define a new space data link layer protocol that is largely based upon the proven features of the existing CCSDS link protocols and which adds options to tailor future mission link layer needs. In addition, the paper references emerging channel coding options currently under study by the C&S WG and describes their fundamental relationship to the NGSLP common transfer frame format. These options include removing the constraint to align the transfer frame with the code block, allowing frame sizes to be explicitly tailored to mission requirements and enable future mission operational link layer modes.

The purpose of this concept paper is to assert the importance of developing a new convergent space link protocol by forming a new project, i.e. the Next Generation Space Link Protocol (NGSLP) project. We believe this project is timely for several reasons: 1) We anticipate that a long lead time will be required to develop this standard; 2) We have identified emerging link layer requirements for the newly formed optical communications Working Group (WG); 3) By forming this project, it will be possible to provide a coherent protocol that can address current shortcomings in the existing CCSDS link layer protocols and provide a framework for the inclusion of new features as other CCSDS protocols mature e.g., SDLS.

**2) Key Technical Features and Benefits**

* 1. One CCSDS Link protocol for all Space Data Links

Currently each link type (DFE, DTE, and Proximity Environments) has its own unique protocols, largely due to the incremental development of emerging mission needs. For example, when it was apparent that a new type of space vehicle was to be developed (e.g., the ISS), CCSDS developed a new protocol (AOS) to handle higher data rates and more Virtual Channels. However, we are now at the point where the C&S WG is paving the way to handle even higher data rates, increased space vehicle populations, and the removal of the key constraint of alignment of the transfer frame to the code block. We already have removed this constraint for the Proximity environments. Once this constraint is removed for DFE and DTE links, it is no longer necessary to maintain distinct formats for forward and return links. Furthermore, we anticipate future agency savings in terms of end-to-end link testing as well as implementation and operations costs due to the consolidation of 4 link layer formats into one.

2-2) Increased Frame length/Frame Sequence Counter for higher rate links

There are numerous missions in the planning phase that require significantly higher rates, including Earth Science missions planning to use Ku band, SCCC, DVB and optical downlinks. These missions include optical communications development missions scheduled to fly on the ISS. Part of the problem with today’s ground systems is that they are incapable of processing the data received at rates that are above 1 Gbps. Thus operational equipment needs to be developed to handle those very high rates, and their development needs to start sooner rather than later to ensure mission success. NASA’s Constellation Program identified performance problems with the ground services utilizing the current maximum transfer frame size of 2048 bytes (per current standards) even when uplink rates were lower than 10 Mbps.

Agency data accountability services depend upon a reasonably stable frame sequence counter, one whose frame sequence count does not return to zero over short periods of time. CCSDS agencies currently utilize this type of counter as the primary means of uniquely identifying telemetry frames. At 10 Gbs with the current maximum transfer frame size of 2048 bytes, the extended frame sequence counter rolls over in ~ 7 minutes. We have heard from several NASA mission operations personal that this amount of time is unacceptable for data accountability. However, in our proposal, if this counter were extended to a larger size, it could take years to overflow the counter.

Thus it is imperative to increase the frame size and frame sequence counter to reduce the impact on future link communications service implementations both on the ground and on-board.

* 1. Increased Spacecraft ID (SCID) named Space

The number of available Spacecraft IDs available to future missions is limited and current use presently consumes 75% of the available Version 1 SCIDs and 63% of the Version 2 SCIDs, according to the CCSDS Secretariat. Currently there are two sets of SCIDs, one for the TC and TM recommendations (Version 1) up to 1024 SCIDs, and one for AOS that supports 256 SCIDs. For example, if a spacecraft uses the TC-SDLP on the forward link and the AOS-SDLP on the return link, it must be assigned two SCIDs, one for the TC-SDLP (V=1) and the other for the AOS-SDLP (V=2). Another factor that leads to the rapid consumption of SCIDs is multiple assignments per spacecraft. Currently most missions require multiple SCID assignments in order to differentiate the data based upon mission phase (i.e., System Test vs. Mission Operations). Thus a larger SCID field along with the addition of an associated field signaling how the SCID will be used provides a single concatenated ID for all mission phases and on all links. Moreover, we anticipate the need for more SCID assignments due to the increased activities of agencies developing cubesat/microsats together with the future expectation of internetworking in space.

* 1. Accommodation of Space Data Link Security protocol and New Implementations to incorporate Security

The addition of the CCSDS Space Link Layer Security (SDLS) Recommendation will cause changes in both ground and spacecraft implementations in the near future. SDLS is another important driver for the timeliness of this activity. The redesign of the uplink processing required for SDLS could also accommodate the changes in the NGSLP link formats and thereby extend the life of the new equipment and the compatibility with future mission needs.

The NGSLP upgrades are associated with link performance, becoming more ISO layer compatible and simplifying COP-1 operations for missions implementing security.

1. Addition of short Forward Error correcting codes for DFE and Proximity Environment links
   * The C&S WG is currently studying the use of short LDPC codes on the uplink. The transition to a short LDPC code from the current BCH code will improve uplink and cross link performance by 5 to 9 dB with a substantial reduction in undetectable error rates.
2. Multiple addressable sub channels within a single Virtual Channel (replaces TC MAPs, Proximity-1 Ports)
   * A key capability in NGSLP is the creation of VC sub-channels within a given VC. VC sub-channels replace the MAPS and Ports approaches used in TC and Prox-1 with a common method that provides the sub addressing of frame data associated with a single Virtual Channel (VC).
   * This technique is perfectly suited to the COP-1 and especially useful when trying to provide security for multiple Virtual Channels utilizing a single Security Association (SA). The use of sub-channels allows the COP-1 to be executed on a single VC instead of requiring that these services be provided across multiple VCs. This technique also enables a single SA to use the existing VC sequence counter to provide the required uniqueness to block command replay for many years using a single key, which simplifies key management security design. Since this technique also allows the sequence counter to be used for anti-reply it eliminates the need to include a separate counter in the security header reducing overhead.
3. Enables SDLS protocol to work in Proximity-1 Environments
   * Currently Prox-1 cannot use SDLS because there is no VCID in the protocol and SDLS is based upon VCs. The NASA Mars Program is concerned that SDLS security services does not pertain to Prox-1. Since the NGSLP contains VCs, SDLS protocol will work for proximate environments wherever they are deployed.
   1. Allows for Data-Driven Master Channel Services

The trend in data processing is to make ground processes data driven so there is less or no management involved, so more compute power is used and less people operations are required. The NGSLP signals the presence/absence of several Master Channel fields so that computers can make decisions on how to process this data. We believe such a data driven approach will save money in mission operations because processing power is conserved for throughput, and efficiency gains will be realized from reduced staffing requirements.

**3) Requirements of Prospective Missions**

We cannot reference any specific missions that are requesting a next generation space link protocol. However our collective experience in CCSDS has been that effective CCSDS standards are the ones that have correctly anticipated and emerged ahead of mission needs. We believe this is the case with NGSLP. We anticipate that the optical communications WG will have emerging link layer protocol needs. We believe these needs will be better met by a well engineered and well thought through project in CCSDS as opposed to throwing the problem of operating in the optical comm environment over to operations, if the existing link layer format and services are not modified.

**4) Relationships to Existing Standards**

4-1) Under the Purview of SLS (C&S and SDLS)

Documents related to this work done in C&S are: a) TM Sync and Channel Coding, b) TC Sync and Channel Coding, c) Proximity-1 Coding and Synchronization Sub-layer, d) Emerging Short LDPC codes, e) Emerging pink sheets to TM Sync and Channel coding regarding removing the constraint to align the transfer frame size to the code block size.

The key interface between C&S and this proposed NGSLP Project is the emergence of new operational modes if the transfer frame size is no longer constrained to the size of the channel code block. Defining and exploiting those new operational link layer modes will be developed within the NGSLP project.

Documentation related to this work done in SDLS is: a) the emerging SDLS protocol.

The key interface between SDLS and the proposed NGSLP project is a single common link layer format so that SDLS has but one interface to space link protocols. Also the creation of a new VC sub-channel as explained in section 2-4.

4-2) Under the Purview of the CSS (SM and CSTS)

Documents related to this work done in CSS are: SLE RAF, SLE RCF, SLE CLTU Service, and the SLE Enhanced Forward CLTU Service Orange Book

In dialog with the CSS area, we have learned that the SLE services can handle frame sizes up to the proposed 65 KB and that the service management (SM) definitions are not significantly affected by the NGSLP proposed changes. However a new generation of equipment and software may be required to provide these services to missions to service the anticipated very high data rates.

* 1. Under the Purview of System Engineering (SANA)

SANA registries for several link layer fields would need to be changed and some new fields (e.g., VC sub-channel) would need to be added. In general we feel that by making these fields larger we are reducing the overall impact on SANA by avoiding small incremental changes that would have to be executed across all 4 link layer protocols as technology and mission needs advance.

**5) Identified deficiencies, flaws, and limitations in existing standards**

* 1. Reuse of a given CCSDS link layer protocol in a different link environment

Currently each of the 4 CCSDS link layer protocols (TM, TC, AOS, and Proximity-1) has unique formats and services which prohibit their reuse across all space link applications of CCSDS member space agencies. For example, the current Mars missions are required to implement TC, either TM or AOS and Proximity-1. The proposed NGSLP would require only a single link protocol. The use of a single link protocol and the separation of frame and code block will enable development of a frame relay methodology for orbiters that provide trunk line services for supporting enterprises consisting of multiple data acquisition missions.

* 1. Currently there is limited spacecraft name space in the current SCID field. See 2-3.
  2. The current transfer frame length is inefficient and the frame sequence counter is unacceptable for transfer frame accountability at higher data rates. See 2-2.

**6) Anticipated agency adoption of any proposed standards and their dependencies**

NASA, UK Space Agency, and DLR have formally acknowledged their participation in the proposed project. Both NASA (GSFC, MSFC and JPL) and UK Space Agency will work on the development of a white book, with NASA being the book captain. DLR has officially stated that they will support the development of a software prototype of NGSLP providing 3 to 6 MM of resources starting in 2015.

**7) Novel Operational scenarios related to any proposed standards**

7-1) Supports Frame Relay for LEO to GEO to Earth links.

The same transfer frame format can be relayed from multiple spacecraft, because the same frame structure is transferred across all operational links.

7-2) Supports Frame Relay for Proximity Mars to/from Earth links.

Currently, and envisioned through 2020 on the telemetry link, landed assets format their telemetry in DTE transfer frames tunneled across via Proximity-1 frames reliably to an orbiter. These DTE frames are stored in an orbiter’s data system as orbiter packets and then downlinked to Earth in Orbiter transfer frames. NGSLP enables both landed asset generated transfer frames and orbiter self-generated frames to be prioritized and downlinked over the physical channel without any intermediary processing (packetizing the lander’s frame for inclusion in Orbiters frame) of the landed assets telemetry. Note that frame relay could also apply to the command (forward) link, since the bulk of commands are transferred via files.

7-3) The Human Exploration program has very ambitious goals that include clusters of vehicles, very high data rates, link security and relay services.

The NGSLP is designed to facilitate this environment. The NGSLP needs to be perfected and codified in time for this program to utilize it.