CCSDS SLE Service Management: Real-World Use Cases

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I. Introduction

The Consultative Committee for Space Data Systems (CCSDS) has produced Recommended Standards for several Space Link Extension (SLE) data transfer services for the interoperable exchange of spacecraft telemetry and command data between spaceflight missions' ground facilities and the tracking, telemetry, and command (TT&C) networks that are used to communicate with those missions' spacecraft. As a companion activity to the specification of the SLE data transfer services, CCSDS has developed a framework for SLE *Service Management* (SLE-SM), for the creation of service management services to be used to negotiate, configure, execute, control, and monitor the provision of TT&C and SLE data transfer services[1]. In 2006, CCSDS issued the Draft Recommended Standard (Red Book) *SLE-SM Service Specification*[2], which specifies a set of SLE-SM services through which spaceflight missions:

- Submit, modify, and query the status of requests for contact periods (a.k.a. passes).
- Submit and query TT&C link and SLE transfer service configuration information used to fulfill requests for contact periods.
- Submit and query trajectory prediction information used by the TT&C provider to perform necessary antenna-pointing and Doppler compensation.

The SLE-SM services constitute a standard interface for the exchange of information associated with the above management interactions between spaceflight mission ground facilities and TT&C service providers.

The purpose of this paper is to illustrate how the standard SLE-SM services can be applied to the operations of current TT&C providers. It begins with a brief overview of the scope and operating environment of the SLE-SM services, then describes several use cases in which SLE-SM services can be applied to existing operational situations. The paper also addresses how SLE-SM services can be adopted in an evolutionary fashion. The paper concludes with a brief identification of additions to SLE-SM that are under consideration to make SLE-SM applicable to an even broader range of network operations concepts, policies, and procedures.

II. SLE-SM Overview

A. SLE Service Management Services

The SLE-SM environment is illustrated in figure 1, which is derived from the *Cross Support Reference Model*[1]. In this model, *SLE services,* comprising both *SLE transfer services* and *SLE service management,* provide the interfaces between an *SLE Complex* that provides SLE transfer services and space link TT&C services, and a spaceflight mission that uses the services that the SLE Complex provides.

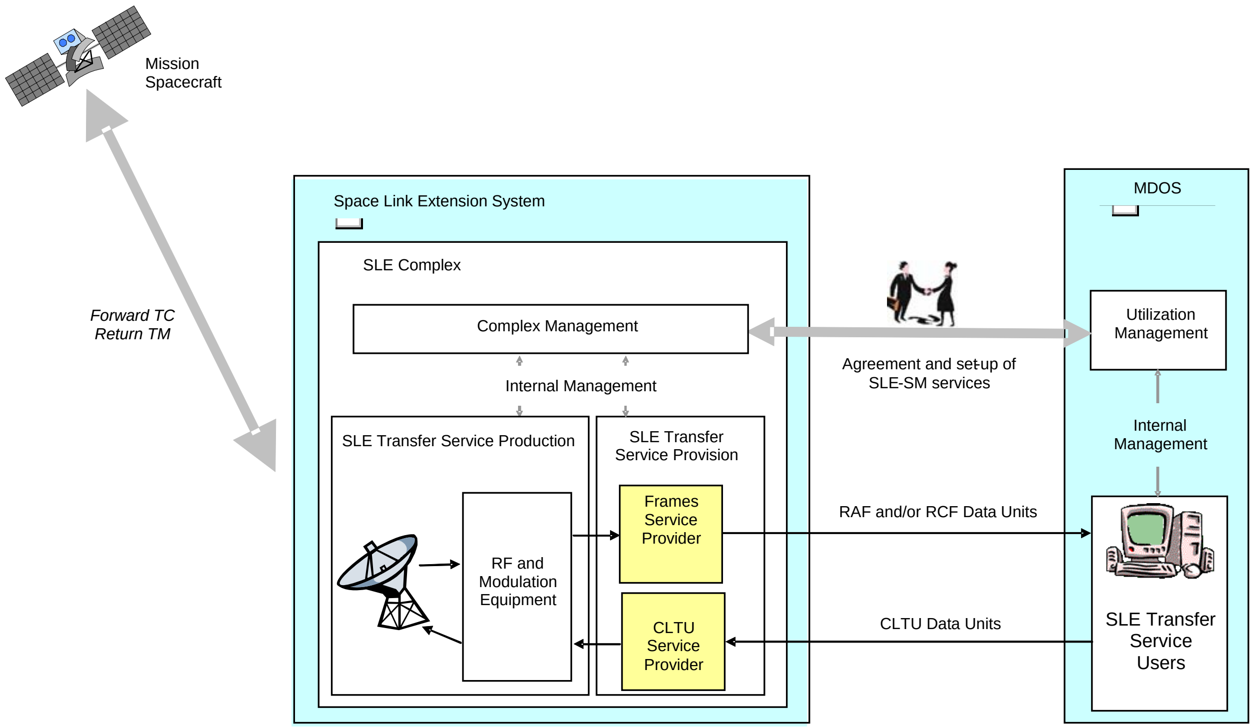

Figure 1

The spaceflight mission is composed of a single *mission spacecraft* and the *Mission Data Operations System* (MDOS), which represents all of the mission's ground-based functions. A spaceflight mission uses the SLE Complex's services so that the MDOS can communicate with and track the mission spacecraft.

SLE Utilization Management (UM) is the function within the MDOS that coordinates the requests by users for space link and SLE services from the Complex. UM:

1) Coordinates RF, modulation, space link service, and space link extension transfer service configuration information that is used by by an SLE Complex (see below) to support subsequent requests for service;
2) Requests periods of provision of space link services and space link extension transfer services;
3) Provides Trajectory Prediction information that allows the Complex to determine where the mission spacecraft will be at the requested periods of service provision; and
4) Coordinates with Mission User Entities within the MDOS to enable the execution of SLE transfer services and to collect status information.

An SLE Complex is a collection of ground station resources under a single management authority. It may be a single ground station or a network of ground stations. *SLE Complex Management* (CM) controls the extent to which UM can affect actual SLE Complex resources. Because CM acts as the intermediary for UM, only those aspects of the resources of an SLE Complex that CM chooses to expose are visible to UM for management operations. CM:

1) Negotiates types of services, numbers of service instances, and the length of the Service Agreements with UM;
2) Responds to requests from the UM for individual space link sessions;
3) Provides configuration information to the resources of the Complex to enable the production and provision of SLE services, and monitors their correct operation.

The interactions between UM and CM are the domain of SLE-SM. The other interactions illustrated in figure 1 are governed by other interface standards or in some cases are bilaterally determined, but in any case they are outside the purview of SLE-SM.

B. SLE Service Management Services

SLE-SM comprises a set of services for the standardized exchange of management information associated with the space link TT&C services and SLE transfer services defined in the SLE transfer service Recommended Standards. The management services are:

- Service Package service;

- Configuration Profile service;
- Trajectory Prediction service; and
- Service Agreement service.

1. *Service Package Service*

The SLE-SM Service Package service is the core service of SLE-SM. The *Service Package* defines all of the space link and SLE transfer services that are to be provided by a Complex to a spaceflight mission for a specific duration of time. A Service Package holds information about the types of SLE transfer services to be executed (e.g., CLTU, RAF, and RCF), the periods the services that are to be provided, the end users that access the services, the agreed configuration(s) for the space link and SLE production processes for specific space link sessions, and the trajectory to be referenced in provision of these services.

The Service Package service provides operations by which a UM can request that CM create, replace, delete, or change Service Packages (and operations by which CM can inform UM when Service Packages have been unilaterally modified or cancelled due to uncontrollable events).

Although the Service Package defines the space link and data transfer services to be provided during a given space link session, it does not explicitly contain all of the information within itself. Rather, it explicitly specifies when the space link session is requested to be executed, but references *Configuration Profiles* and *Trajectory Predictions* to supply the detailed space link and transfer service configuration and orbital dynamics information (respectively) necessary to fully specify the services required.

A Configuration Profile specifies a reusable set of space link and SLE services parameters that are established between UM and CM for supporting a mission spacecraft during the lifetime of the Service Agreement. Once established, a Configuration Profile can be referenced by any number of Service Packages. Configuration Profiles allow the full set of configuration parameters to be defined independently of the Service Packages. The use of Configuration Profiles is well-suited to the majority of spacecraft that have one or more well-defined modes of TT&C operation, e.g., housekeeping, high rate instrument operation, tracking, and various combinations thereof. It allows the clear separation between the reusable configuration data of the Configuration Profile from the dynamic schedule information contained in Service Packages.

There are two categories of Configuration Profiles: *Carrier Profiles* and *Event Sequence Profiles*. The Carrier Profile captures RF, modulation, and coding parameters for a single carrier across the space link, and the configuration profiles for one or more SLE transfer services associated with that carrier. The Event Sequence Profile specifies a time-ordered sequence of changes to selected RF parameters to be executed by the Complex.

2. *Configuration Profile Service*

The SLE-SM Configuration Profile service is used to add, delete and query configuration information to be referenced by Service Packages. The Configuration Profile service provides separate operations for handling Carrier Profiles and *Event Profiles.* The Configration Profile service is an optional SLE-SM service.

3. *Trajectory Prediction Service*

The SLE-SM Trajectory Prediction service is used to manage the spacecraft trajectory data that are employed by CM to derive the pointing angles and Doppler compensation settings needed to acquire the spacecraft. Using this service, UM can add, delete, and query trajectory data that resides at CM. The Trajectory Prediction service is an optional SLE-SM service.

4. *Service Agreement Service*

The *Service Agreement* is negotiated between the SLE Complex and the spaceflight mission to establish the service and performance envelope within which all Service Packages, Configuration Profiles, and Trajectory Predictions will be established during the lifetime of the relationship between the mission and the Complex. The Service Agreement contains information about the services to be provided, including spacecraft communication characteristics, static and default Configuration Profile parameters, nominal frequency and duration of contacts, nominal trajectory and so on. It also specifies the range in which the exact values of parameters in Service Packages, and Configuration Profiles are allowed to fall, and the allowed Trajectory Predictions formats, . The information contained in the Service Agreement assists the Complex in determining the resources needed to support the mission (e.g., RF equipment, data storage, terrestrial network bandwidth).

The negotiation and generation of the Service Agreement are beyond the scope of the current SLE-SM Service Specification Recommended Standard. The SLE-SM Service Agreement service has only one operation, which allows UM to query the contents of a Service Agreement. The Service Agreement service is an optional SLE-SM service.

III. SLE-SM Use Cases

A. Service Package Scenarios
This use case involves a service package with two scenarios -- one in reference to trajectory that has a spacecraft engine "burn" modeled into it for a trajectory correction maneuver, and the other in reference to trajectory that does not have the spacecraft engine burn modeled into it. This illustrates how preplanned contingencies can be accommodated via the SLE service management draft recommendation. This is a simple use case demonstrating operation via the same carrier profile and transfer service instances across the multiple contingencies; the description will conclude with a few words about how other aspects could also vary by scenario for accommodating preplanned contingencies such as changing between RF carriers on different frequency bands.

<Figure and breif steps description to be supplied>

B. Event Sequences
This use case involves a service package constructed to allow for changes in the space link configuration as a function of time during a space link session. This type of activity occurs often in real-world operations; for example, in relation to a spacecraft's apparent elevation over a particular tracking station (i.e. better signal to noise ratio due to less atmospheric interference) or as a result of a spacecraft being occulted by planetary body. This use case has particular applicability to the deep space domain where spacecraft are often preprogrammed for space link configuration changes as a function of time and implement the changes in an autonomous fashion as the spacecraft are too distant from Earth for effective closed loop "real-time" control.

<Figure and breif steps description to be supplied>

C. Evolutionary Adoption of Configuration Profile Service

This use case involves a service package referencing a configuration profile that is not part of the draft CCSDS recommendation for SLE service management. The CCSDS recognizes that there is a substantial base of installed equipment around the world for providing spacecraft tracking operations. The draft recommendation for SLE service management allows for gradual adoption so that the benefits of utilizing standardized service packages can be achieved without having to implement the complete recommendation. This use case illustrates how a bilaterally defined configuration profile (i.e. legacy configuration parameters specific to particular service provider's equipment and mutually agreed to between the service provider and service user) may be accommodated while still operating via standardized service packages. It is anticipated that this will likely occur in the early adoption of the CCSDS draft recommendation for day-to-day spacecraft operations.

<Figure and breif steps description to be supplied>

IV. Additional Capabilities Under Consideration
The draft recommendation defines a service packages in relation to what is called *specific scheduling.* In other words, specific acquisition start and stop times are identified in the service package. Although ultimately this is what is required for proper coordination between service provider and service user, there is interest from multiple space agencies to allow for the expression of "standing orders" or "bulk scheduling requirements". As of the writing of this paper the Service Management working group within CCSDS has coined the term "algorithmic scheduling" to represent these types of activities. The intention is to allow for *constraints* to be stated as an input to a *contact planning* service that would algorithmically produce the specifically scheduled service packages. Examples of constraints under consideration include the notion of providing tracking services at least four times per week with no two service instances more than 72 hours apart. This type of constraint information would be supplied in conjunction with a trajectory to the contact planning service which would in turn identify opportunities for providing services consistent with the constraints and other service provider obligations. These opportunities could in turn be transformed into the individually (ie specifically) scheduled service packages.

V. Conclusion

The CCSDS has produced a draft recommendation for SLE service management. Via the use cases presented, the ability of this draft recommendation to accommodate day-to-day real-world spacecraft operations coordination with respect to TT+C service providers has been indicated. Future developments within CCSDS are aimed at providing a standard contact planning service. Completion of this activity will yield a robust and capable international standard for the necessary planning and day-to-day coordination between space missions and TT+C network service providers.

References

[1]CCSDS, *Cross Support Reference Model — Part 1: Space Link Extension Services.* Recommended Standard for Space Data System Standards, CCSDS 910.4-B-2. Blue Book. Issue 1. Washington, D.C.: CCSDS, October 2005.

[2]CCSDS, *Space Link Extension — Space Link Extension Service Managment Service Specification*. Draft Recommended Standard for Space Data System Standards, CCSDS 910.1-R-1. Red Book. Issue 1. Washington, D.C.: CCSDS, March 2006.