Cross Support Overview and Operations Concept for Future Space Missions

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Abstract

Ground networks must respond to the requirements of future missions, which include smaller sizes, tighter budgets, increased numbers, and shorter development schedules. The Consultative Committee for Space Data Systems (CCSDS) is meeting these challenges by developing a general cross support concept, reference model, and service specifications for Space Link Extension services for space missions involving cross support among Space Agencies. This paper identifies and bounds the problem, describes the need to extend Space Link services, gives an overview of the operations concept, and introduces complimentary CCSDS work on standardizing Space Link Extension services.

Introduction

Future space missions will require the support of ground networks operated by multiple Space Agencies as well as support by multiple Agency organizations. Current missions are supported on a case by case basis with custom interfaces being developed each time. This is a time consuming and expensive process. CCSDS is developing recommendations for standards for interfaces and services in missions involving multiple Space Agencies. The objectives are to reduce cost and development time while increasing flexibility and efficient utilization of resources.

Future ground systems must replace custom interfaces with standard interfaces and services to be cost effective. Prior CCSDS recommendations have focused on standardizing the communication services between spacecraft and ground stations (i.e., the Space Link Subnet). The CCSDS Recommendations for Advanced Orbiting Systems (CCSDS, 1992a), Packet Telemetry (CCSDS, 1992b), and Telecommand (CCSDS, 1987a; CCSDS, 1992c; CCSDS, 1991; CCSDS, 1987b) document these Space Link services and protocols.

The proposed concept, documented in a CCSDS Report (CCSDS, 1994a) describes *Space Link Extension* (SLE) services that extend the Space Link services on the ground. Extension is accomplished over distance, in time, and by adding information. SLE services may be distributed across multiple ground facilities, such as ground stations, mission-related control centers, and data processing facilities. These facilities may be grouped to provide the services required by each mission. These SLE Services are applicable between Agencies

as well as within Agencies with multiple ground networks.

Cross Support Operations Concept

Cross Support occurs when one Agency uses part of another Agency's data system resources to complement its own system in providing services.

Cross Support Environment

A space data system, for a particular mission, contains onboard spacecraft applications and ground applications. Ground applications interact with applications onboard the Spacecraft via application associations between them. The ground and onboard applications do not necessarily belong to the same Agency that is operating the spacecraft. The associations between ground and onboard applications are established and maintained using telecommunication and data transfer services built upon the Space Link communication services defined by CCSDS Recommendations.

CCSDS Recommendations are defined for Space Link services for the real-time transfer of data across the Space Link. However, space data systems generally require additional features in order to use the Space Link services to support mission application associations. These additional features, provided by SLE services, extend the application associations beyond the immediate endpoints of the space/ground link. The Space Link services are extended from onboard applications, attached to onboard local area networks, to ground applications, attached to terrestrial wide area networks. The SLE services provide the ability to hold data at one or more intermediate points between the peer applications. The Space Link and Space Link Extension domains are illustrated in Figure 1.

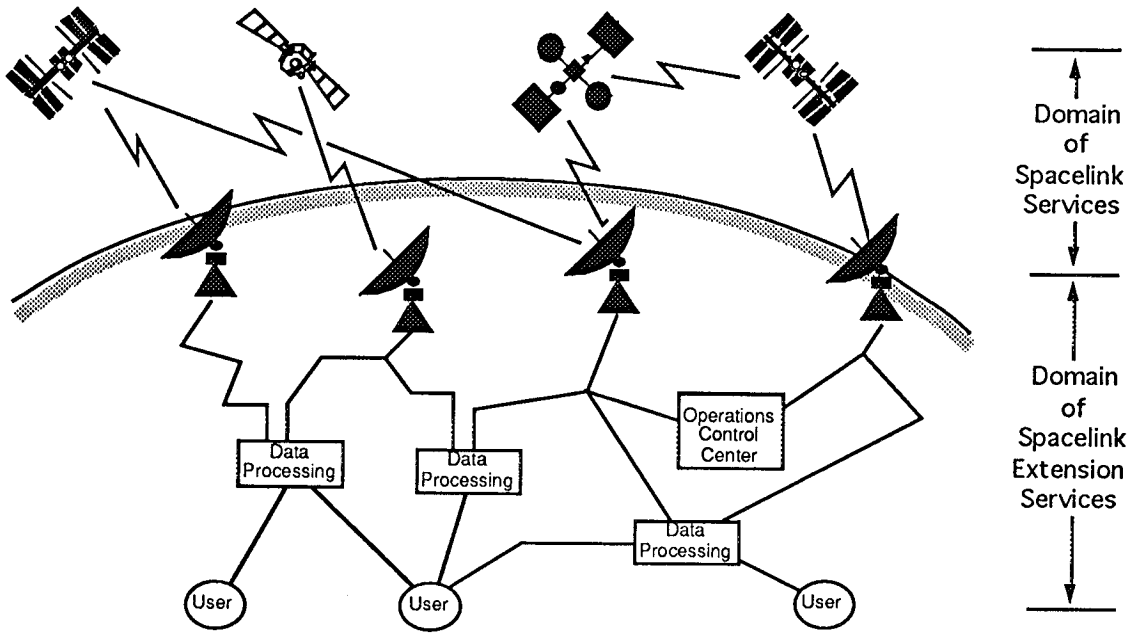

Figure 1 - Domains of Space Link and Space Link Extension Services

The ground-resident *Space Link Extension Component* (SLEC) and the onboard data system coordinate to provide SLE services. A particular mission may use all or a subset of the SLE services. In providing SLE Services, the SLEC performs: (1) RF modulation/demodulation at the ground termination of the space-ground link; (2) ground termination of the Space Link protocols used by the mission; (3) value-added annotation of the Space Link service data; (4) terrestrial networking among the ground elements that host the ground applications; and (5) interface to ground-side Space Link protocol processing and ground-side RF modulation/demodulation functions.

The SLEC has three types of interfaces with other components: interfaces over which mission data flow between the SLEC and the Spacecraft; interfaces over which space data flow between the SLEC and the ground applications; and the service management interface between the SLEC and Mission Management. Unlike the onboard data system service interfaces, the SLE service interfaces are intended to be standardized across all missions.

The SLE-Spacecraft interface operates over an RF medium and executes the Space Link protocols specified in the CCSDS Space Link Recommendations. The ground applications exchange SLE Protocol Data Units (SLE-PDUs) with the SLEC. The SLEC and Mission Management exchange service requests and service management reports over the service management interface. These service requests and management reports are used to: (1) configure/monitor the ground side of the RF link and Space Link protocol processing associated with the interface between the SLEC and the Spacecraft; (2) configure/monitor data handling within the SLEC; and (3) configure/monitor service delivery parameters for the interfaces between the SLEC and ground applications.

In addition, the Mission Management establishes an association with the Onboard Management component of the Spacecraft to configure and monitor the spacecraft side of the interface. This association uses the same set of communication services that other mission applications use. Figure 2 illustrates the associations and interfaces involved in providing the SLE Services.

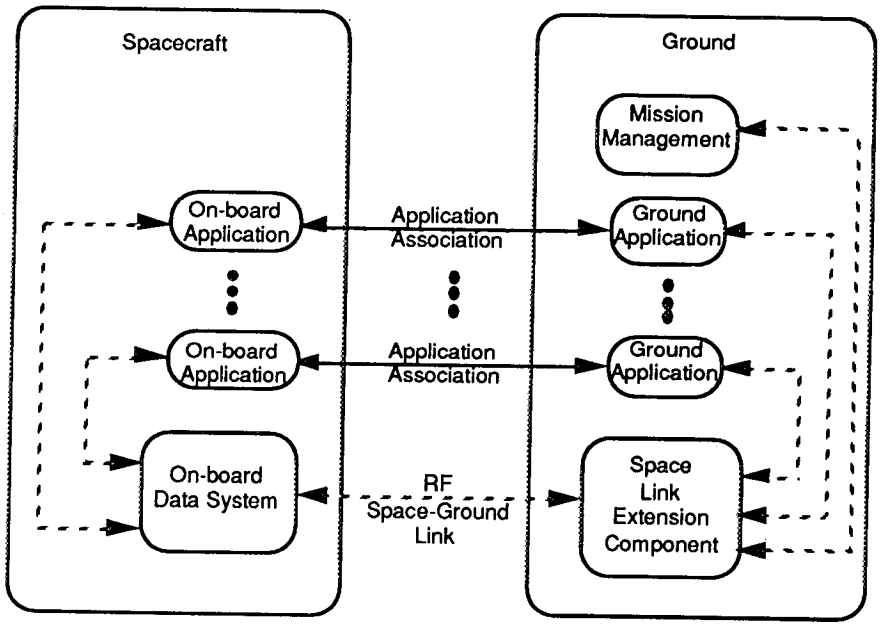

Figure 2 - SLE Associations and Interfaces

Cross Support Concepts

SLE services provide access to the ground termination of Space Link services from a remote ground-based system. They extend the various Space Link services as defined in CCSDS Space Link recommendations. This "extension" has three aspects: distance, information, and time. An SLE service may be completed at a location geographically separated from the place where the RF signal is received. Information is added to the Space Link Service Data Units (SL-SDUs) to compensate for the use of managed information over the Space Link or information about conditions at the time of receipt. Information may also be added to ensure the data will be useful at a later time. The added information is called "annotation."

The systems performing an SLE service may belong to different entities. These entities may include a different organization within the mission's own Space Agency or an organization from a different Space Agency. The supporting organizations may be of varying size or structure (e.g., Space Agency, space flight center, facility). The notion of cross support can be generalized to any situation in which multiple organizations are involved in supplying SLE Services.

As illustrated in Figure 3, the systems performing an SLE service are grouped into *Service Complexes* by the organizations that implement them. Each service complex has two components, a *Service Provision* component and a management component. The Service Provision component contains the processing functions implemented by that Service Complex. The management component manages the Service Provision component. The management of an SLE Service is distributed between Service Complexes and the Mission. The management component of a Service Complex is called *Complex Management.* The component of Mission Management responsible for management of SLE services is called *Utilization Management.* Service Management is accomplished through the management of the functions performed by the individual Service Complexes that provide the SLE services.

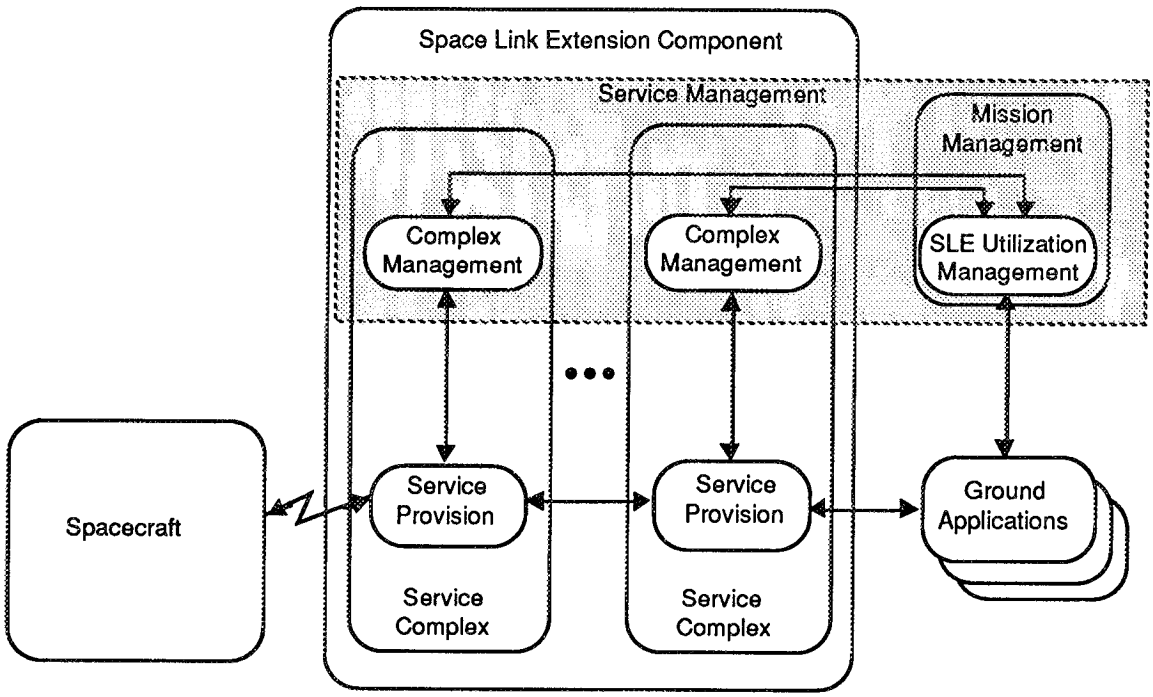

Figure 3 - SLEC Complex Interfaces

If a service is provided by multiple Service Complexes, Utilization Management coordinates with Complex Management in the multiple Service Complexes to provide the services required by a mission. Utilization Management must also coordinate and resolve conflict among multiple service users. Complex Management represents the functions performed within the Service Complex in a standard way, in terms of the SLE services provided by the complex (not in terms of the equipment used to provide those services), and without Service Complex-internal details. Complex Management provides the "firewall" that hides the complexity of the Service Complex.

Cross Support Services

Cross support may occur between ground applications and the SLEC. It may also occur between Service Complexes within the SLEC. The SLEC builds on the Space Link Services by standardizing the SLE and Service Management protocols and services. Such standardization allows a mission to interface with the SLEC, concatenating SLE services by interconnecting Service Complexes within the SLEC, no matter how or where the services are implemented. The SLE Services support both the Advanced Orbiting Systems (AOS) and Conventional Systems, Packet Telemetry (PT) and Telecommand (TC). The following list identifies the SLE services:

- Return All Frames (AOS and PT)
- Return Insert (AOS)
- Master Channel Frames (AOS and PT)
- Master Channel Frame Secondary Header (PT)
- Master Channel Operations Control Field (PT)
- Virtual Channel Frame Secondary Header (PT)
- Virtual Channel Operations Control Field (AOS and PT)
- Return Virtual Channel Access (AOS and PT)
- Return Bitstream (AOS)
- Return Space Packet (AOS and PT)
- Data Set Processing (AOS and PT)
- Return Internet (AOS)
- Forward Virtual Channel Access (AOS)
- Frame Data Routing (TC)
- Forward Bitstream (AOS)
- Forward Space Packet (AOS and TC)
- Forward Primary Header plus VCDU (AOS and TC)
- Telecommand Frame (TC)
- Forward Coded VCDU (AOS)
- CLTU (TC)
- Forward Internet (AOS)
- Forward Insert (AOS)

Cross Support Scenario

An example of cross support is illustrated in Figure 4. In this example, Agency A sends data from its spacecraft to multiple ground stations, which perform all data processing functions through the extraction of Frame Data. However, not all these ground stations belong to Agency A. The data is also transmitted to a ground station owned by Agency B which processes the data in two separate complexes. Essentially, the first complex performs the Space Link processing and delivers all frames to the second. Both Agencies deliver space Packets to Agency A's Data Processing Complex. While this does not affect the service interface, it may affect the management interfaces between the Agencies.

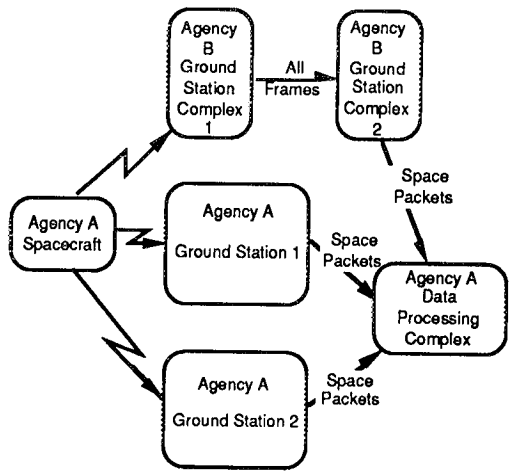

Figure 4 - Cross Support Example

Cross Support Lifecycle

Cross support of a mission involves a *Support Contract* between Agencies. A Support Contract is an agreement between a mission and one or more Agencies providing cross support. The Support Contract life cycle is divided into four phases: Agreement, Negotiation, Implementation, and Utilization.

The Agreement phase consists of the early interactions that set the stage for the technical definition of the cross support. The Agencies agree on objectives of Service Management interface and legal and financial responsibilities.

During the Negotiation phase, in the Support Contract is negotiated by the Agencies. It defines the services to be supported by the Service Complex over the lifetime of the Support Contract. The contract establishes the outer bounds of resources accessible by, and privileges extended to, the mission.

The Implementation phase is the time allowed for the Service Complexes to acquire, develop, and configure the resources necessary to satisfy the Support Contract. The Service Complexes perform testing to ensure conformance with CCSDS standards and compatibility with peer processes.

During the Utilization phase, a Service Complex provides one or more *Service Packages* to the mission. A Service Package consists of the service instances and channels in a single service complex that provide all or part of a service to a user. A Service Package duration corresponds to a Space Link session, or a "Pass."

Each Service Package has four phases: Preparation, Setup, Execution, and Debrief. Different Service Packages may be in different phases concurrently. For each Service Package the following actions occur:

- Preparation phase - Parameter values are selected for all parameters within bounds of service specified during the Negotiation phase including any schedule information applicable to a particular upcoming Execution phase.

- Setup phase - Initiation of a service, testing of service interfaces, and refinement of service parameters are performed by the Service Complex to ensure that the service selected during the Preparation phase can actually be provided during the upcoming Execution phase.

- Execution phase - Exchange of space data or the delivery of event, alarm, and status reports may take place between Service Complexes and between a Service Complex and a user.

- Debrief phase - Accounting and performance information about the Service Package Execution Phase is delivered to Service Management and/or the service user

Complementary CCSDS Work

A CCSDS Report, *Standard Terminology, Conventions, and Methodology* (TCM) (CCSDS, 1994c), provides terminology and conventions appropriate to the development of CCSDS Space Link Extension Services.

The TCM establishes a common vocabulary based on internationally standard terms and conventions for describing systems and their interactions, from conceptual level through the level at which specific technologies, protocols, and applications are applied to the development of CCSDS recommendations. It specifies the use of Abstract Service Definition

Conventions (ASDC) (ISO/IEC, 1992), a standard set of conventions that complement the better-known International Organization for Standardization (ISO) Open System Interconnection (OSI) service definition conventions. This common vocabulary and methodology can be used as a foundation for expressing concepts of operation and architectural specifications, leading to the definition of specific SLE Services and protocol specifications. All SLE Cross Support documents adhere to the TCM.

A Reference Model is also being developed by CCSDS for use in defining SLE services. The *SLE Reference Model* (CCSDS, 1994b) provides a common basis for the development of SLE Service recommendations. It provides the reference for maintaining consistency between all SLE Services. It provides descriptions as well as the provision of multiple SLE Services. The Reference Model also shows the relationships among the SLE services, the Space Link services that they extend, and the ground communication services on which they depend.

The Reference Model defines the common functionality, and provides the descriptive tools to specify service-specific functionality for a Service Complex. Examples of Service Complex functionality include: extensions to communication functions (e.g., annotation, addressing); data handling functions (e.g., data capture, post-pass retrieval); and management functions (e.g., Pass set-up, fault isolation).

CCSDS is currently working on the service specification for a single SLE Service. The Return All Frames service specification (CCSDS, 1994d) describes the most basic SLE service in the return (space-to-ground) direction. The Return All Frames service acquires, demodulates, frame-synchronizes, and decodes all CCSDS link layer frames (Packet Telemetry Transfer Frames or Virtual Channel Data Units) of a physical channel and delivers those frames to the users of the service. The service provides both on-line (i.e., near real time) and off-line (i.e., delayed or buffered) data transfer modes to accommodate the variety of access methods typical of actual space mission operations scenarios. The Return All Frames service is summarized in a companion SpaceOps '94 paper (Uhrig et al., 1994).

Future Work

CCSDS will publish Green Books for the Standard Terminology, Conventions, and Methodology and Cross Support Concept documents and Blue Books for the Reference Model and Return All Frames Service Specification documents. CCSDS Panel 3 also expects to develop service specification Blue Books for all Space Link Extension cross support services.

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