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Space data and information transfer systems — Space link extension (SLE) — Return-channel-frames service specification

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INTERNATIONAL STANDARD

ISO 22670

Third edition
2021-06

Space data and information transfer systems — Space link extension (SLE) — Return-channel-frames service specification

Systèmes de transfert des informations et données spatiales — Extension de liaisons spatiales (SLE) — Service de réseau pour liaison retour

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Foreword

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This document was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 911.2-B-3, August 2016) and was adopted (without modifications) by Technical Committee ISO/TC 20, *Space vehicles,* Subcommittee SC 13, *Space data and information transfer systems*.

This third edition cancels and replaces the second edition (ISO 22670:2013), which has been technically revised.

The main changes compared to the previous edition are as follows:

— adds clarifications and corrections;

— adds production status annex.

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1 INTRODUCTION

1.1 PURPOSE OF THIS RECOMMENDED STANDARD

The purpose of this Recommended Standard is to define the Space Link Extension (SLE) Return Channel Frames (RCF) service in conformance with the SLE Reference Model (reference [1]). The RCF service is an SLE transfer service that delivers to a mission user all telemetry frames from one master channel or one virtual channel.

NOTE – Reference [1] defines the Return Master Channel Frames (Rtn MC Frames) service and the Return Virtual Channel Frames (Rtn VC Frames) service as two distinct services. Subsequent study has indicated that it is preferable to define one service that provides the functionality of both. The RCF service defined here does just that. It is anticipated that a future issue of reference [1] will take the same approach, deleting the Rtn MC Frames and Rtn VC Frames services and replacing them with the RCF service.

1.2 SCOPE

This Recommended Standard defines, in an abstract manner, the RCF service in terms of:

a) the operations necessary to provide the service;

b) the parameter data associated with each operation;

c) the behaviors that result from the invocation of each operation; and

d) the relationship between, and the valid sequence of, the operations and resulting behaviors.

It does not specify:

a) individual implementations or products;

b) the implementation of entities or interfaces within real systems;

c) the methods or technologies required to acquire telemetry frames from signals received from a spacecraft;

d) the methods or technologies required to provide a suitable environment for communications; or

e) the management activities required to schedule, configure, and control the RCF service.

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1.3 APPLICABILITY

1.3.1 APPLICABILITY OF THIS RECOMMENDED STANDARD

This Recommended Standard provides a basis for the development of real systems that implement the RCF service. Implementation of the RCF service in a real system additionally requires the availability of a communications service to convey invocations and returns of RCF service operations between RCF service users and providers. This Recommended Standard requires that such a communications service must ensure that invocations and returns of operations are transferred:

a) in sequence;

b) completely and with integrity;

c) without duplication;

d) with flow control that notifies the application layer in the event of congestion; and

e) with notification to the application layer in the event that communications between the RCF service user and the RCF service provider are disrupted, possibly resulting in a loss of data.

It is the specific intent of this Recommended Standard to define the RCF service in a manner that is independent of any particular communications services, protocols, or technologies.

1.3.2 LIMITS OF APPLICABILITY

This Recommended Standard specifies the RCF service that may be provided by an SLE Complex for inter-Agency cross support. It is neither a specification of, nor a design for, real systems that may be implemented for the control and monitoring of existing or future missions.

1.4 RATIONALE

The goal of this Recommended Standard is to create a standard for interoperability between the tracking stations or ground data handling systems of various Agencies and the consumers of spacecraft telemetry.

1.5 DOCUMENT STRUCTURE

1.5.1 ORGANIZATION

This document is organized as follows:

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a) section 0 presents the purpose, scope, applicability and rationale of this Recommended Standard and lists the definitions, conventions, and references used throughout the Recommended Standard;

b) section 2 provides an overview of the RCF service including a functional description, the service management context, and protocol considerations;

c) section 3 specifies the operations of the RCF service;

d) section 4 specifies the dynamic behavior of the RCF service in terms of the state transitions of the RCF service provider;

e) annex A provides a formal specification of RCF service data types using Abstract Syntax Notation One (ASN.1);

f) annex B specifies the relationship of the RCF service provision to the production status;

g) annex C provides a conformance matrix that defines what capabilities must be provided for an implementation to be considered compliant with this Recommended Standard;

h) annex D lists all terms used in this Recommended Standard and identifies where they are defined;

i) annex E lists all acronyms used within this document;

j) annex F provides a list of informative references.

1.5.2 SLE SERVICES DOCUMENTATION TREE

This Recommended Standard is based on the cross support model defined in the SLE Reference Model (reference [1]). It expands upon the concept of an SLE transfer service as an interaction between an SLE Mission User Entity (MUE) and an SLE transfer service provider for the purpose of providing the RCF transfer service.

This Recommended Standard is part of a suite of documents specifying the SLE services. The SLE services constitute one of the three types of Cross Support Services:

a) Part 1: SLE Services;

b) Part 2: Ground Domain Services;

c) Part 3: Ground Communications Services.

The basic organization of the SLE services documentation is shown in figure 1-1. The various documents are described in the following subsections.

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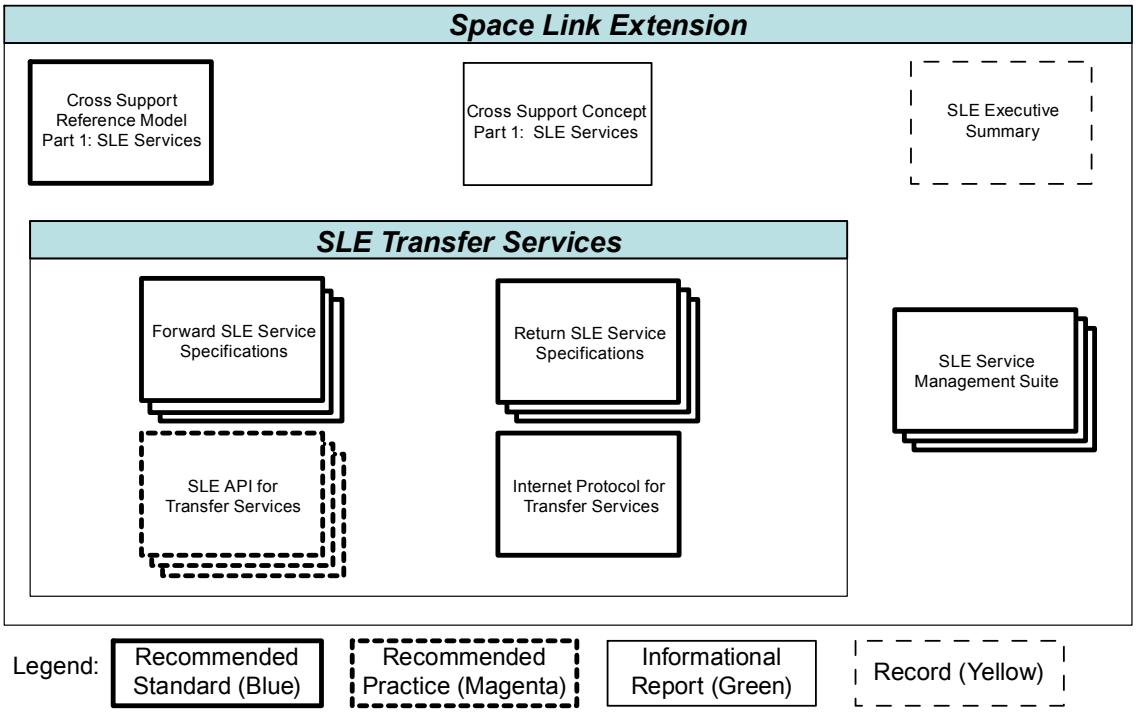

Figure 1-1: SLE Services Documentation

a) *Cross Support Concept—Part 1: Space Link Extension Services* (reference [F2]): a Report introducing the concepts of cross support and the SLE services;

b) *Cross Support Reference Model—Part 1: Space Link Extension Services* (reference [1]): a Recommended Standard that defines the framework and terminology for the specification of SLE services;

c) *SLE Return Service Specifications*: a set of Recommended Standards that will provide specification of all return link SLE services (this Recommended Standard is one of the specifications in that set);

d) *SLE Forward Service Specifications*: a set of Recommended Standards that will provide specification of all forward link SLE services;

e) *SLE API for Transfer Services Specifications:* a set of Recommended Practices that provide specifications of an Application Program Interface; a set of Recommended Standards that provide specifications of an Application Program Interface and a mapping to TCP/IP as underlying communications service for SLE services;

f) *Internet Protocol for Transfer Services:* defines a protocol for transfer of SLE Protocol Data Units using TCP/IP as underlying communications service for SLE services;

g) *SLE Service Management Specifications*: a set of Recommended Standards that establish the basis of SLE service management.

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1.6 DEFINITIONS, NOMENCLATURE, AND CONVENTIONS

1.6.1 DEFINITIONS

1.6.1.1 Definitions from Open Systems Interconnection (OSI) Basic Reference Model

This Recommended Standard makes use of a number of terms defined in reference [6]. The use of those terms in this Recommended Standard shall be understood in a generic sense, i.e., in the sense that those terms are generally applicable to technologies that provide for the exchange of information between real systems. Those terms are:

a) abstract syntax;

b) application entity;

c) application layer;

d) application process;

e) flow control;

f) Open Systems Interconnection (OSI);

g) real system;

h) Service Access Point (SAP).

1.6.1.2 Definitions from Abstract Syntax Notation One

This Recommended Standard makes use of the following terms defined in reference [7]:

a) Abstract Syntax Notation One (ASN.1);

b) object identifier;

c) (data) type;

d) (data) value.

NOTE – In annex A of this Recommended Standard, ASN.1 is used for specifying the abstract syntax of RCF service operation invocations and returns. The use of ASN.1 as a descriptive language is intended to support the specification of the abstract RCF service; it is not intended to constrain implementations. In particular, there is no requirement for implementations to employ ASN.1 encoding rules. ASN.1 is simply a convenient tool for formally describing the abstract syntax of RCF service operation invocations and returns.

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1.6.1.3 Definitions from TM Synchronization and Channel Coding

This Recommended Standard makes use of the following terms defined in reference [2]:

a) Attached Sync Marker;

b) Reed-Solomon check symbols;

c) Reed-Solomon code.

1.6.1.4 Definitions from TM Space Data Link Protocol

This Recommended Standard makes use of the following term defined in reference [3]:

a) Frame Error Control Field (FECF);

b) TM Transfer Frame.

1.6.1.5 Definitions from AOS Space Data Link Protocol

This Recommended Standard makes use of the following terms defined in reference [4]:

a) AOS Transfer Frame;

b) Frame Error Control Field (FECF);

1.6.1.6 Definitions from SLE Reference Model

This Recommended Standard makes use of the following terms defined in reference [1]:

a) abstract binding;

b) abstract object;

c) abstract port;

d) abstract service;

e) invoker;

f) Mission Data Operation System (MDOS);

g) Mission User Entity (MUE);

h) offline delivery mode;

i) online delivery mode;

j) operation;

k) performer;

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l) physical channel;

m) return data;

n) Return All Frames channel (RAF channel);

o) Return All Frames service (RAF service);

p) Return Master Channel Frame Service (MC service)

q) Return Virtual Channel Frame Service (VC Frame service)

r) service agreement;

s) service provider (provider);

t) service user (user);

u) SLE Complex;

v) SLE Complex Management;

w) SLE data channel;

x) SLE Functional Group (SLE-FG);

y) SLE Protocol Data Unit (SLE-PDU);

z) SLE Service Data Unit (SLE-SDU);

aa) SLE service package;

bb) SLE transfer service instance;

cc) SLE transfer service production;

dd) SLE transfer service provision;

ee) SLE Utilization Management;

ff) space link;

gg) space link data channel;

hh) Space Link Data Unit (SL-DU);

ii) space link session.

1.6.1.7 Additional Definitions

1.6.1.7.1 Association

An association is a cooperative relationship between an SLE service-providing application entity and an SLE service-using application entity. An association is formed by the

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exchange of SLE protocol data units through the use of an underlying communications service.

1.6.1.7.2 Communications Service

A communications service is a capability that enables an SLE service-providing application entity and an SLE service-using application entity to exchange information.

NOTE – If an SLE service user and an SLE service provider are implemented using different communications services, then interoperability between them is possible only by means of a suitable gateway. Adherence to this Recommended Standard ensures, at least in principle, that it is possible to construct such a gateway.

1.6.1.7.3 Confirmed Operation

A confirmed operation is an operation that requires the performer to return a report of its outcome to the invoker.

1.6.1.7.4 Delivery Criteria

Delivery criteria are rules that determine whether a data unit acquired from the space link by an SLE service provider shall be delivered to a user.

NOTE – For RCF service, the delivery criteria are:

a) the Earth Receive Time (ERT) of the frame is within the period defined by the start and stop times specified in the RCF-START operation;

b) the spacecraft identifier (SCID) of the frame matches the SCID of the global VCID specified in the RCF-START operation; and

c) the Virtual Channel Identifier (VCID) of the frame matches the VCID of the global VCID specified in the RCF-START operation.

1.6.1.7.5 Frame Error Control Field

The Frame Error Control Field (FECF) of a frame is the FECF of a TM Transfer Frame (reference [3]) or the FECF of an AOS Transfer Frame (reference [4]), as applicable.

1.6.1.7.6 Frame Version Number

The frame version number is either the transfer frame version number (reference [3]) or the version number in the AOS transfer frame primary header (reference [4]).

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NOTE – The definitions of frame version number given in references [3] and [4] are equivalent. If a CCSDS-compatible telemetry frame is known to contain no errors, the frame version number enables one to distinguish between a transfer frame and an AOS transfer frame.

1.6.1.7.7 Initiator

The initiator is the object that issues the request to bind to another object (the responder).

NOTE – In other words, the initiator is always the invoker of the request to bind to another object. Therefore, in the context of the request to bind, the terms 'initiator' and 'invoker' refer to the same object and are synonyms.

1.6.1.7.8 Invocation

The invocation of an operation is the making of a request by an object (the invoker) to another object (the performer) to carry out the operation.

1.6.1.7.9 Master Channel

The sequence of all telemetry frames with the same Transfer Frame Version Number (TFVN) and the same SCID on the same physical channel constitutes a master channel.

NOTE – Depending on the TFVN, the definition of SCID is as given in either reference [3] or reference [4].

1.6.1.7.10 Parameter

A parameter of an operation is data that may accompany the operation's invocation or return.

NOTE – The term parameter is also used to refer to mission-dependent configuration information used in the production or provision of the service.

1.6.1.7.11 Performance

The performance of an operation is the carrying out of the operation by an object (the performer).

1.6.1.7.12 Port Identifier

A port identifier identifies a source or a destination in a communications system.

NOTE – See 2.6.4.5 for more information.

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1.6.1.7.13 Responder

The responder is the object that receives a request to bind and completes the binding (if possible) with the initiator in order for a service association to exist between the two objects.

NOTE – In other words, the responder is always the performer of the binding. Therefore, in the context of binding, the terms 'responder' and 'performer' refer to the same object and are synonyms.

1.6.1.7.14 Return

The return of an operation is a report, from the performer to the invoker, of the outcome of the performance of the operation.

1.6.1.7.15 Service Instance Provision Period

A service instance provision period is the time during which a service instance (i.e., the capability to transfer one or more SLE data channels of a given type) is scheduled to be provided.

NOTE – Reaching of the beginning of this period constitutes the event 'start of service instance provision period' (see 4.2.2).

1.6.1.7.16 Spacecraft Identifier

The spacecraft identifier (SCID) of a telemetry frame is as defined in reference [3] if the frame is a TM Transfer Frame or as defined in reference [4] if the frame is an AOS Transfer Frame.

1.6.1.7.17 Telemetry Frame

A telemetry frame is a TM Transfer Frame (as defined in reference [3]) or an AOS Transfer Frame (as defined in reference [4]). In case a distinction of the frame versions is necessary, the full term as per references [3] or [4] is used.

1.6.1.7.18 Transfer Frame Version Number

The Transfer Frame Version Number (TFVN) is either the TFVN as defined in reference [3] or the TFVN as defined in reference [4].

NOTE – The definitions of TFVN given in references [3] and [4] are equivalent. If a CCSDS-compatible telemetry frame is known to contain no errors, the TFVN enables one to distinguish between a TM Transfer Frame and an AOS Transfer Frame.

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1.6.1.7.19 Unconfirmed Operation

An unconfirmed operation is an operation that does not require a report of its outcome to be returned to the invoker by the performer.

1.6.1.7.20 Virtual Channel

All telemetry frames with the same TFVN, the same SCID, and the same virtual channel identifier (VCID) on the same physical channel constitute a virtual channel.

1.6.1.7.21 Virtual Channel Identifier

The virtual channel identifier (VCID) of a telemetry frame is as defined in reference [3] if the telemetry frame is a TM Transfer Frame or as defined in reference [4] if the telemetry frame is an AOS Transfer Frame.

1.6.2 NOMENCLATURE

The following conventions apply throughout this Recommended Standard:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

1.6.3 CONVENTIONS

1.6.3.1 Specification of Operations

1.6.3.1.1 General

Section 3 of this Recommended Standard specifies the operations that constitute the RCF service. The specification of each operation is divided into subsections as described in 1.6.3.1.2 through 1.6.3.1.4.

1.6.3.1.2 Purpose Subsection

The Purpose subsection provides a brief description of the purpose of the operation. Additionally, it indicates whether the operation may be invoked by the user, provider, or both; whether the operation is confirmed or unconfirmed; and whether there are any constraints on when the operation may be invoked.

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1.6.3.1.3 Invocation, Return, and Parameters Subsection

The Invocation, Return, and Parameters subsection describes the parameters associated with each operation, including their semantics. A accompanying the description of each operation lists all parameters associated with the operation and, for both the invocation and return, whether the parameter is always present, always absent, or conditionally present.

For parameters that are conditionally present, the parameter description specifies the conditions for the presence or absence of the parameter. The condition is generally based on the value of another parameter in the same invocation or return; for example, in the return of an operation, the `diagnostic` parameter is present if and only if the value of the `result` parameter is 'negative result'. For a conditional parameter in a return, the condition may be based on the value of a parameter in the corresponding invocation.

In the table, the following convention is used to indicate whether a parameter is always present, always absent, or conditionally present:

M	Always present
C	Conditionally present
Blank	Always absent

NOTE – Even though a parameter may be characterized as always present, its description may specify that its value is permitted to be 'null' or 'unused' or the like.

1.6.3.1.4 Effects Subsection

The Effects subsection describes the effects an operation has on the invoker, the performer, the association between them, or any combination thereof. The details of how those effects occur or the mechanisms used are outside the scope of this Recommended Standard.

1.6.3.2 Typographic Conventions

1.6.3.2.1 Operation Names

Names of RCF service operations appear in uppercase and begin with the characters 'RCF-' (e.g., RCF-TRANSFER-DATA).

1.6.3.2.2 Parameter Names

In the main text, names of parameters of RCF service operations generally appear in lowercase and are typeset in a fixed-width font (e.g., `responder-port-identifier`). In annex A, the corresponding name is formed by omitting any hyphens contained in the name and using mixed-case (e.g., `responderPortIdentifier`).

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1.6.3.2.3 Value Names

The values of many parameters discussed in this Recommended Standard are represented by names. In the main text, those names are shown in quotation marks (e.g., 'no such service instance'). The corresponding name in annex A is formed by omitting any hyphens or white space contained in the name and using mixed-case (e.g., `noSuchServiceInstance`). The actual value associated with the name is constrained by the type of the parameter taking on that value. Parameter types are specified in annex A of this Recommended Standard.

NOTE – The name of a value does not imply anything about its type. For example, the value 'no such service instance' has the appearance of a character string but might be assigned to a parameter whose type is 'integer'.

1.6.3.2.4 State Names

This Recommended Standard specifies the states of RCF service providers. States may be referred to by number (e.g., state 2) or by name. State names are always shown in quotation marks (e.g., 'active').

1.6.3.2.5 SLE-PDU Names

The names of SLE-PDUs appear in mixed-case (e.g., rcfBindInvocation).

1.6.3.2.6 Data Type Definitions

Data type definitions for the RCF service are presented in annex A in the form of a set of ASN.1 modules. Regardless of the conventions used elsewhere in this Recommended Standard, the text of the ASN.1 modules is typeset entirely in a fixed-width font.

1.6.3.3 Other Conventions

This Recommended Standard uses the conventions specified in reference [1].

1.7 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommended Standard. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommended Standard 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 Recommended Standards.

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NOTES

1 A list of informative references is provided in annex F.

2 This document takes advantage of the harmonized terminology introduced by restructured documentation of the space link protocols (references [2], [3], and [4]). From an interoperability point of view, they do not introduce any incompatibilities with respect to the original set of space link protocol documents (references [F3], [F4], and [F5]).

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

[2] *TM Synchronization and Channel Coding*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.0-B-2. Washington, D.C.: CCSDS, August 2011.

[3] *TM Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 132.0-B-2. Washington, D.C.: CCSDS, September 2015.

[4] *AOS Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.0-B-3. Washington, D.C.: CCSDS, September 2015.

[5] *Time Code Formats*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 301.0-B-4. Washington, D.C.: CCSDS, November 2010.

[6] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[7] *Information Technology—Abstract Syntax Notation One (ASN.1): Specification of Basic Notation*. 4th ed. International Standard, ISO/IEC 8824-1:2008. Geneva: ISO, 2008.

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2 DESCRIPTION OF THE RETURN CHANNEL FRAMES SERVICE

2.1 OVERVIEW

The RCF service enables the user of the service to obtain all telemetry frames from one master channel or one virtual channel. A master channel consists of all telemetry frames with the same Transfer Frame Version Number (TFVN) and the same spacecraft identifier (SCID) on the same physical channel. A virtual channel consists of all telemetry frames with the same TFVN, the same SCID, and the same virtual channel identifier (VCID) on the same physical channel. A telemetry frame is a TM Transfer Frame or a AOS Transfer Frame. A space link physical channel carries one stream of telemetry frames separated by attached sync markers. A physical channel may be comprised of one or more master channels, each of which may be comprised of one or more virtual channels. A complete specification of these concepts is provided in references [2], [3], and [4].

For delivery to the user, each frame acquired from the space link is encapsulated in an SLE SDU that also carries annotation, i.e., additional information such as the Earth Receive Time (ERT) of the frame. In general, the RCF service delivers frames to the user in the order in which they were received from the space link.

The operations defined in section 3 of this Recommended Standard enable an RCF service user to interact with an RCF service provider to:

a) establish an association between the user and the provider;

b) receive annotated telemetry frames from one master channel or from one virtual channel;

c) obtain notifications and reports regarding the status, configuration and performance of the service;

d) temporarily suspend and later re-start the delivery of telemetry frames from the same master channel or any of the permitted virtual channels;

e) change the values of certain parameters that affect the behavior of the service; and

f) release an association.

In any given service instance, only one master channel, or only one VC, or a single master channel plus a set of VCs (where the set may have a single member), is permitted. Only the permitted master channel or one of the permitted virtual channels is delivered to the user at a time.

The provision of RCF service for one master channel or one virtual channel for access by one service user constitutes one instance of service. The provision of RCF service for one master channel or one virtual channel to multiple service users and the provision of RCF service for multiple master channels or multiple virtual channels concurrently to one or more service users are permitted but are specified to constitute multiple service instances.

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2.2 SPACE LINK EXTENSION REFERENCE MODEL

2.2.1 INTRODUCTION

The RCF service is specified within the framework defined by the SLE Reference Model (reference [1]). The following subsections summarize selected concepts from the SLE Reference Model.

2.2.2 ABSTRACT OBJECT

An abstract object is a functional entity that interacts with other abstract objects. Objects are of different types, which determine their function and behavior. Objects are characterized by their interfaces, which are called abstract ports, and the operations that are made available through those interfaces. One object may provide multiple abstract ports.

2.2.3 ABSTRACT SERVICE

An abstract service is the capability provided by a set of operations that an abstract object exposes at one or more of its abstract ports.

NOTE – The concept of an abstract service is to be distinguished from the concept of an (N)-service as defined in the OSI Basic Reference Model (reference [6]). The definition of (N)-service is in terms of the capability provided by one layer in the OSI architecture to the layer above it. The definition of abstract service is in terms of the capability provided by one abstract object to another abstract object. In a cross support scenario where one Agency is providing an SLE service to another Agency, the object that provides the service typically is associated with one Agency, and the object that uses the service typically is associated with the other Agency.

2.2.4 ABSTRACT BINDING

When two abstract ports have an association established between them, they are said to be bound. The act of establishing such an association is called abstract binding. One object (the initiator) invokes a bind operation that is accepted (or rejected) by another object (the responder).

2.2.5 SERVICE USER/PROVIDER

An object that offers a service to another by means of one or more of its ports is called a service provider (provider). The other object is called a service user (user). An object may be a provider of some services and a user of others.

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The terms user and provider are used to distinguish the roles of two interacting objects. In this Recommended Standard, when two objects are involved in provision of a service, the object closer to the space link is considered to be the provider of the service, and the object further from the space link is considered to be the user.

2.2.6 OPERATION

An operation is a procedure or task that one object (the invoker) can request of another (the performer) through a bound port pair. The terms invoker and performer are used to describe the interaction between two objects as the operations that constitute the service occur. One object invokes an operation that is performed by the other. For most services, each object invokes some operations and performs others.

2.3 SERVICE MANAGEMENT

SLE service management determines the number and schedule of RCF service instances to be provided, the resources required to enable those service instances, and the initial configuration of all service instances and their supporting resources. SLE service management is the subject of separate CCSDS Recommended Standards.

The SLE Reference Model (reference [1]) distinguishes between service provision and service production:

a) service provision makes available to the user the operations necessary to obtain the service;

b) service production transforms a space link channel to an RCF channel, possibly using the service provision and production of another SLE provider or the equivalent capability.

Certain configuration parameters are associated with provision of RCF services, while others are associated with production. Changes to RCF provision configuration parameters (e.g., `requested-global-VCID`) affect only a single service instance; the values of such parameters are initialized by service management when the service instance is created, but may be modified subsequently by the user through RCF service operations specified in this Recommended Standard. Changes to RCF production configuration parameters (e.g., bit rate, frame length, coding type) potentially affect multiple service instances or potentially impact SLE Complex resources; consequently, those parameters may be modified only through service management.

RCF service may be user-initiated (i.e., the user invokes the bind operation) or provider-initiated (i.e., the provider invokes the bind operation). A particular instance of RCF service supports either user initiation or provider initiation but not both. The form of initiation that applies to a particular service instance is set by service management.

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The SLE Reference Model defines two delivery modes: online delivery mode and offline delivery mode. Online delivery mode indicates that the provision of service is generally coincident in time with the space link session, whereas offline delivery mode indicates that the telemetry frames acquired during a space link session are provided to the user some time after the end of the space link session. Within the online delivery mode, the SLE Reference Model defines two quality factors: timeliness and completeness. Within this RCF service specification, the two variants of online delivery are regarded distinct delivery modes: online timely and online complete. Both assume the use of a reliable communications service. They differ in that the timely mode allows for the controlled discarding of telemetry frames at the application layer if it is not possible to deliver those telemetry frames within a certain amount of time after they are acquired from the space link (e.g., because of communications service backlog). While the RCF service is defined for the complete online delivery mode, the timely online delivery mode, or the offline delivery mode, any particular instance of RCF service supports only one of those modes. The delivery mode applicable to a particular service instance is set by service management.

2.4 ARCHITECTURE MODEL—FUNCTIONAL VIEW

2.4.1 RETURN FRAME PROCESSING FUNCTIONAL GROUP

The Return Frame Processing Functional Group (RFP-FG, shown in figure 2-1) is the SLE functional group (SLE-FG) that produces the RCF service. As shown in the figure, the RFP-FG provides other services in addition to the RCF service. This Recommended Standard addresses only the RCF service; the other services are to be defined in companion Recommended Standards.

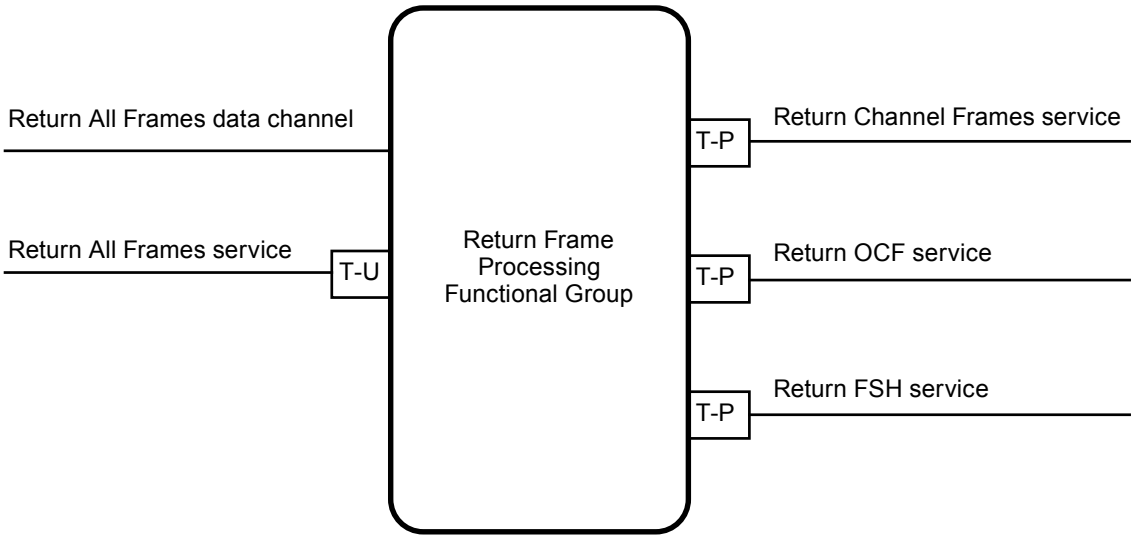

Figure 2-1: Return Frame Processing SLE-FG

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As described in reference [1], the RFP-FG consumes a Return All Frames (RAF) channel and provides RCF service. The RAF channel is provided to the RFP-FG either (a) directly from a Return Space Link Processing Functional Group (RSLP-FG) in the same SLE Complex, or (b) through an instance of RAF transfer service that is provided by a different SLE Complex. The RAF channel consists of a stream of SLE-SDUs that encapsulate the telemetry frames acquired from one space link physical channel. From this input, the RFP-FG produces one or more RCF channels. Each RCF channel consists of a stream of SLE-SDUs. Most of these SLE-SDUs encapsulate telemetry frames from the master channel or virtual channel specified by the user of the RCF service; such SLE-SDUs also carry annotation information associated with the frame (e.g., the ERT of the frame). Other SLE-SDUs in an RCF channel carry notifications of the occurrences of certain events that may pertain to the RCF service (e.g., loss of frame synchronization on the physical channel associated with this instance of RCF service).

An RCF channel produced by the RFP-FG is delivered to a user by means of the RCF service. More specifically, the RFP-FG performs the following functions with respect to RCF service:

a) consumes one RAF channel;

b) demultiplexes the RAF channel into its component master channels, demultiplexes the master channels into their component virtual channels, annotates each frame in each channel to form RCF SLE-SDUs, and injects the resulting RCF SLE-SDU into RCF channels;

c) optionally, stores (and subsequently retrieves) sufficient data to reconstruct the RCF channels for delivery through one or more offline RCF service instances;

d) makes RCF channels available to online and offline RCF service instances to effect the provision of RCF service.

The telemetry frames delivered by the RCF service are encapsulated in SLE-SDUs. RCF SLE-SDUs that encapsulate telemetry frames are annotated with information that pertains to that specific frame. The annotation consists of:

a) the ERT of the frame;

b) an identifier that indicates the antenna used to acquire the frame;

c) a parameter that characterizes the data link continuity of this frame with respect to the preceding frame on the same master or virtual channel;

d) an optional octet string that may be used to provide additional, non-standard annotations that are mutually agreed to by the SLE Complex providing the service and the Mission Data Operations System (MDOS) associated with the user of the service.

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NOTES

1 The RCF service processes and delivers only telemetry frames that are error-free. The determination that a frame is error-free is based on the frame quality annotation provided by the RAF service production: a frame is considered error-free if it was annotated by the RAF service production with a frame quality of 'good'. The RAF service production annotates a frame as 'good' if the frame contains only valid codewords of the Reed-Solomon or Low-Density Parity-Check (LDPC) code or—if the frame is not Reed-Solomon or LDPC encoded—if the Frame Error Control Field (FECF) decodes successfully. The condition stated above for `frame-quality` being set to 'good' applies both in case when only Reed-Solomon encoding is used as well as when Reed-Solomon is the outer code of the concatenated coding scheme being applied.

2 As defined by this Recommended Standard, telemetry frames do not include the attached sync marker but are delimited by them.

2.4.2 RCF SERVICE PRODUCTION AND PROVISION

One instance of RCF service production (or, one RFP-FG instance) may be associated with multiple RCF service instances. RCF production is concerned with the production of RCF channels independent of any particular instance of service. In contrast, RCF service provision is concerned with delivering an RCF channel to an RCF service user. Service provision addresses such matters as when service is provided (e.g., service start and stop times), how service is provided (e.g., user-initiated or provider-initiated), and delivery service (e.g., whether the delivery mode is timely online, complete online, or offline).

RCF service production receives the input telemetry frames encapsulated in RAF SLE-SDUs. If the complete production process, i.e., RAF and RCF production are performed within a single SLE Complex, then the RAF SLE-SDUs are possibly not exposed on an interface but exist only conceptually inside the return link production. If a separate SLE Complex hosts the RAF production process, then the RAF SLE-SDUs are made available by that complex by means of the RAF service exposed on the SLE Complex interface.

RCF service production receives the input telemetry frames encapsulated in RAF SLE-SDUs. The RCF service production performed by the RFP-FG separates the RAF SLE-SDUs by master channel and virtual channel to form RCF SLE-SDUs. The SLE-SDUs generated by RCF service production are delivered to the service user by means of the RCF service operations defined in section 3, which also provide additional functionality to facilitate the provision of RCF service. In turn, the RCF service operations are realized as SLE Protocol Data Units (SLE-PDUs) that are exchanged between the RCF service provider and the RCF service user by means of an underlying communications service. Typically, an SLE-PDU corresponds to the invocation or return of an RCF operation. (Because of the buffering mechanisms described in 3.1.9, there are certain exceptions; for example, multiple RCF-TRANSFER-DATA invocations may be mapped to a single SLE-PDU.) The general relationship between RAF SLE-SDUs, RCF SLE-SDUs, and RCF SLE-PDUs is illustrated in

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figure 2-2. This figure assumes that as in the example shown in figure 2-3 all return service production is implemented within a single SLE Complex. This may or may not be the case. For instance, one SLE Complex could host the RCF production process and use the RAF service provided by another SLE Complex. In that case, the latter SLE Complex would consume the space link channel, i.e., receive the SL-DUs while the two SLE Complexes would exchange RAF SLE-PDUs.

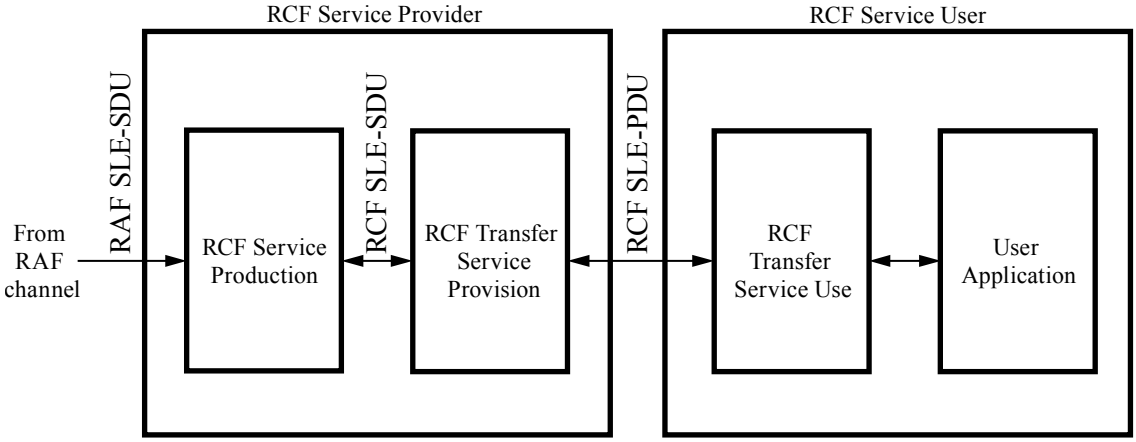

Figure 2-2: RCF Service Production and Provision

For the online delivery mode, production and provision of the RCF service by the provider occur, at least in part, concurrently with the space link session. For the offline delivery mode, service production and provision are detached, with service provision occurring some time after the end of the space link session. In the offline case, data acquired during the space link session are stored for later delivery by an offline service instance.

2.5 ARCHITECTURE MODEL—CROSS SUPPORT VIEW

The management and control of the production and provision of SLE transfer services is described in general terms in reference [1]. Figure 2-3 shows an example operational scenario and the related binding of RCF transfer service ports and SLE management ports. This scenario shows an SLE Complex with one Return Space Link Processing SLE-FG instance and one Return Frame Processing SLE-FG instance providing two instances of RCF service to an MDOS.

NOTE – Although not shown in this scenario, other combinations are possible. For example, it is also possible to have several RFP-FG instances, each consuming a different RAF channel and each providing one or more instances of service. It is also possible for the RSLP-FG and the RFP-FG to be located in different SLE Complexes. In such a case, the RAF channel would be provided to the RFP-FG via an RAF transfer service instance.

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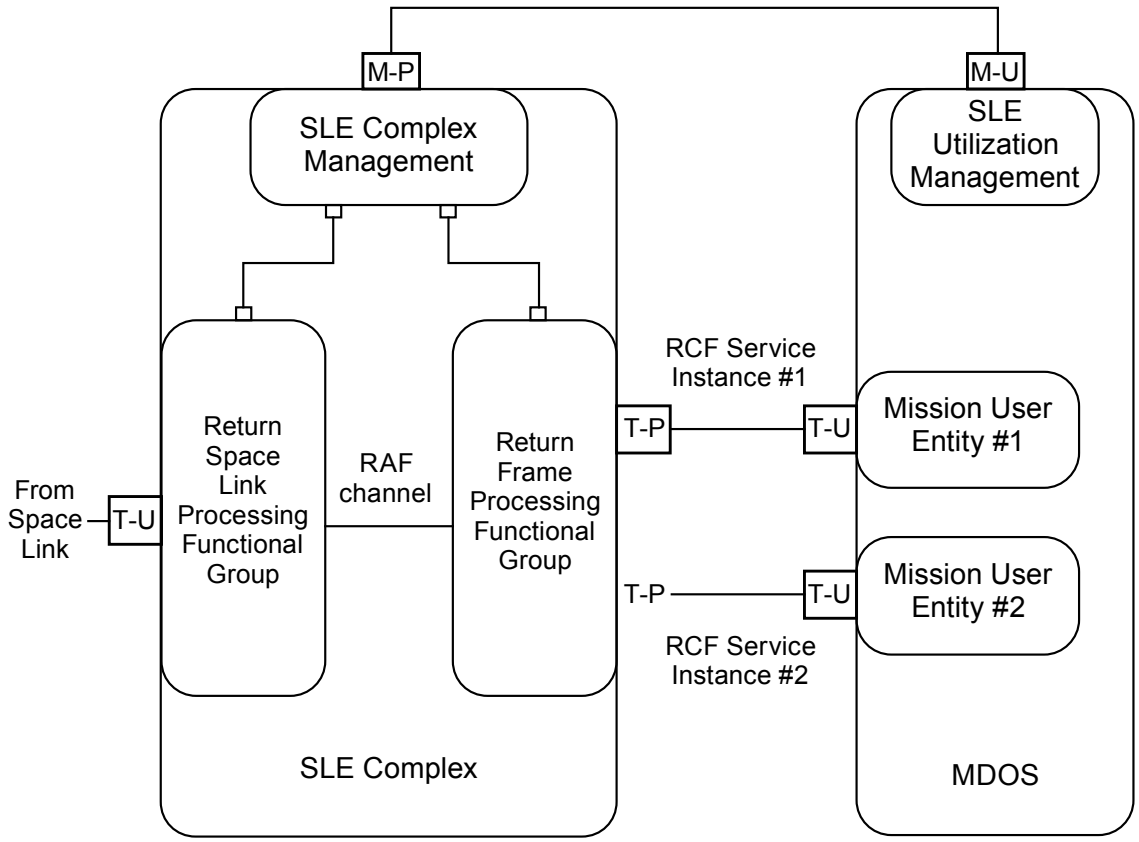

Figure 2-3: Example of the Management and Provision of RCF Service

2.6 FUNCTIONAL DESCRIPTION

2.6.1 GENERAL

Subsections 2.6.2 through 2.6.4 describe the RCF service with respect to scheduling, configuration, underlying services, provider states, and protocol considerations.

2.6.2 SCHEDULING AND CONFIGURATION

SLE Utilization Management negotiates with SLE Complex Management to establish mutually agreed upon SLE service packages. Among other things, SLE service packages specify what service instances are to be provided, when those services are to be provided, and what resources are needed to enable those services.

Service packages also specify the initial values of mission-dependent parameters required for service production and provision. RCF service provision parameters include such things as the scheduled start and stop times of the RCF service instance provision period and the delivery mode.

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Service production is guaranteed to occur only as needed to support service packages that have been scheduled and mutually agreed upon by SLE Complex Management and SLE Utilization Management. Service provision occurs only within the bounds of the agreed upon schedule of service instances and only during those periods when there is an association between the service provider and the service user.

2.6.3 UNDERLYING SERVICES

The RCF service is based on the functionality provided by the SLE RAF service production (reference [1]) or an equivalent capability. The RAF service production (or its equivalent) may be provided by the same SLE Complex that provides the RCF service or by a different SLE Complex. Additionally, provision of RCF service depends on service management for scheduling, resources, and configuration, and on the availability of a suitable communications service to enable the exchange of information between the RCF service user and provider.

2.6.4 PROTOCOL DESCRIPTION

2.6.4.1 RCF Operations

The operations that constitute the RCF service are listed in table 2-1. Section 3 of this Recommended Standard provides the detailed specification of these operations.

Table 2-1: RCF Operations

Operation	Invoked By	Purpose	Confirmed
RCF-BIND	User or provider	To establish an association with the peer	Yes
RCF-UNBIND	User or provider	To release an association previously established by an RCF-BIND operation	Yes
RCF-START	User	To request that the SLE service provider start the delivery of telemetry frames	Yes
RCF-STOP	User	To request that the SLE service provider stop the delivery of telemetry frames	Yes
RCF-TRANSFER-DATA	Provider	To transfer a telemetry frame to the SLE service user	No
RCF-SYNC-NOTIFY	Provider	To notify the user of an event affecting production or provision of the RCF service	No

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Operation	Invoked By	Purpose	Confirmed
RCF-SCHEDULE-STATUS-REPORT	User	To request that the provider send a status report immediately or periodically or to stop such reporting	Yes
RCF-STATUS-REPORT	Provider	To send a status report to the user	No
RCF-GET-PARAMETER	User	To ascertain the value of an SLE service parameter (see 3.10.2.5.1)	Yes
RCF-PEER-ABORT	User or Provider	To notify the peer that the local SLE application detected an error that requires the association to be terminated	No

2.6.4.2 States of the Service Provider

Once an RCF service instance is created, the RCF service provider is in one of three states, as follows:

a) State 1 (‘unbound’): In state 1, all resources required to enable the provision of the RCF service have been allocated, and all objects required to provide the service have been instantiated. However, no association yet exists between the user and the provider (i.e., the RCF transfer service provider port is not bound).

b) State 2 (‘ready’): In state 2, an association has been established between the user and the provider, and they may interact by means of the operations described in section 3 of this Recommended Standard. However, the delivery of telemetry frames (by means of the RCF-TRANSFER-DATA operation) is not permitted. The user may enable the delivery of telemetry frames by means of the appropriate service operation (RCF-START); that, in turn, will cause the provider to transition to state 3 (‘active’) and enable frame delivery.

c) State 3 (‘active’): State 3 is identical to state 2 (‘ready’) except that telemetry frames that meet the delivery criteria specified by the user by means of the RCF-START operation are delivered to the user as they become available. The service continues in this state until the user invokes the RCF-STOP operation to suspend frame delivery and transition back to state 2 (e.g., in response to an ‘end of data’ notification from the service provider signaling that the space link session has ended and all available frames have been delivered) or all RCFs meeting the user selected delivery criteria (see 1.6.1.7.4) have been sent).

A simplified RCF service provider state transition diagram is shown in figure 2-4. A detailed state transition matrix is provided in section 4.

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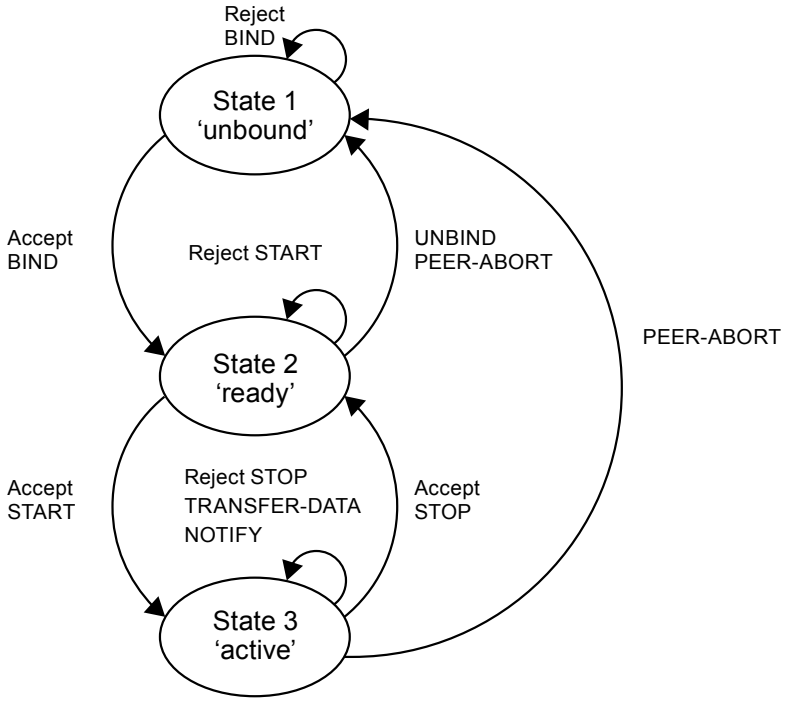

Figure 2-4: Simplified RCF Service Provider State Transition Diagram

2.6.4.3 Termination of Association

An association is released normally when an RCF-UNBIND operation is invoked by the initiator of the association and performed by the responder. An association may be aborted by either the user or the provider by means of the RCF-PEER-ABORT operation. An association also may be aborted due to certain failures of the communications service; such failures are signaled to the local application by the 'protocol abort' event described in 4.1.5.

2.6.4.4 Effects of Termination

When an association is released or aborted, the invocation of further operations by the user or the provider is not permitted. As a consequence, the delivery of frames stops as soon as the RCF-STOP or RCF-PEER-ABORT invocation has been processed by the RCF service provider. The user and provider may re-establish an association via a new RCF-BIND operation if that is consistent with the schedule for the provision of service. However, status information from the prior association is not preserved and is not available to the new association except that:

a) if the delivery mode is complete online, the content of the online frame buffer (see 3.1.9) is persistent except if in the RCF-UNBIND invocation the `unbind-reason` parameter is set to 'end';

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b) if the delivery mode is offline, the contents of the offline frame buffer (see 3.1.9) is persistent;

c) statistics reported by means of the RCF-STATUS-REPORT operation (see 3.9) are accumulated for the entire service instance provision period.

2.6.4.5 Technology-specific Aspects

This Recommended Standard defines the RCF service. Provision of the RCF service in a real system also requires a specification of how the RCF service defined here is mapped to a communications service such that all invocations and returns of RCF service operations can be conveyed between the user and the provider. In order not to restrict the applicability of this Recommended Standard to a specific communications technology, as few assumptions as possible have been made about the characteristics of the underlying communications service (see 1.3.1).

The RCF service interface between the user and the provider is specified in this Recommended Standard in terms of the operations that the service provides. Those operations are realized by mapping the operation invocations and returns to protocol data units that can be exchanged by means of the underlying communications service. This Recommended Standard conceptualizes such a mapping in two parts. First, RCF service operation invocations and returns (defined in section 3) are mapped to SLE-PDUs (defined in annex A). Second, SLE-PDUs are mapped to protocol data units that can be exchanged by means of the underlying communications service. The mapping of RCF service operation invocations and returns to SLE-PDUs is specified by this Recommended Standard. The mapping of SLE-PDUs to an underlying communications service is intentionally outside the scope of this Recommended Standard (e.g., so that the RCF service may be mapped to more than one communications technology). In order to achieve interoperability, the user and provider must conform not only to this Recommended Standard but also to an agreed upon specification of the mapping of the RCF service to the underlying communications service. Figure 2-5 illustrates a communications realization of the RCF service that results from such a mapping. The specification of such mappings is the subject of separate CCSDS Recommended Standards.

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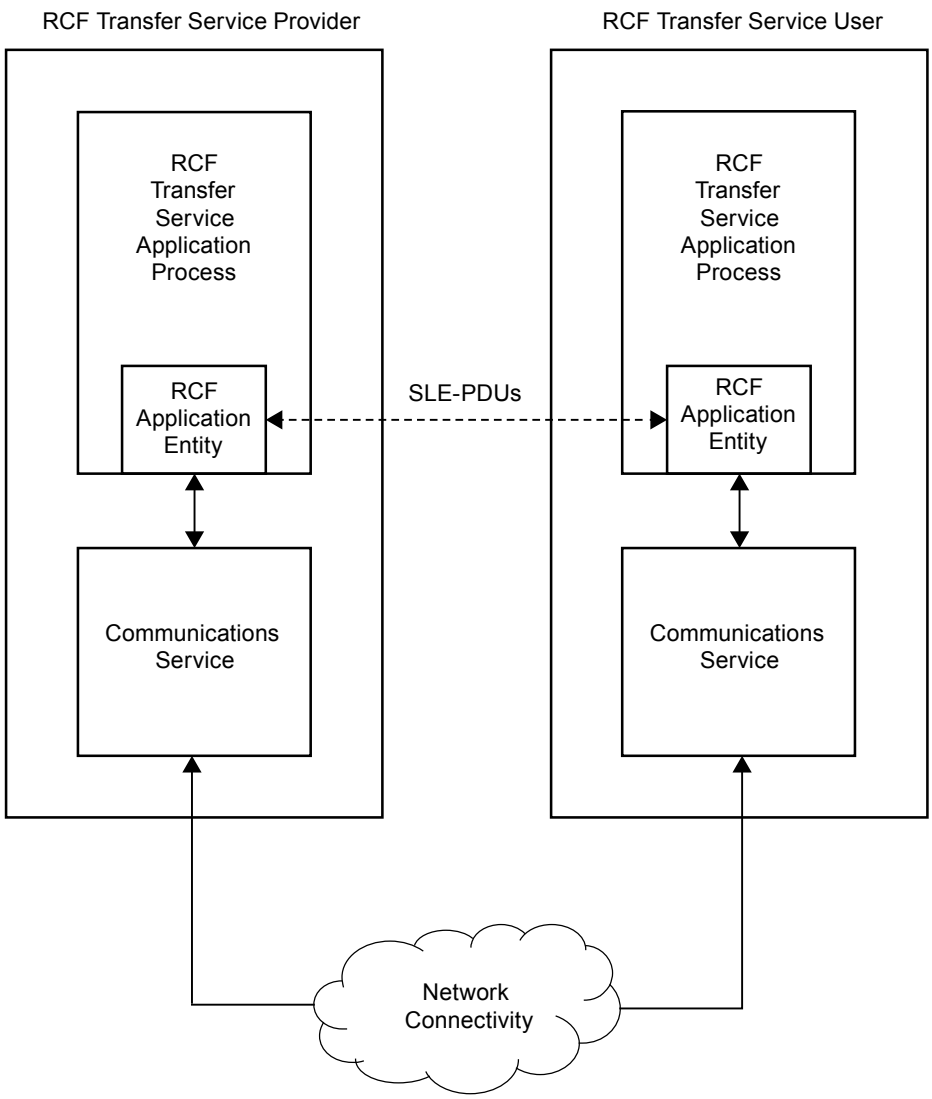

Figure 2-5: Communications Realization of RCF Service

The specification of a mapping of the RCF service onto a particular communications service must address such things as:

a) selection of communication networks to ensure connectivity;

b) compatible configuration of protocol stacks;

c) specification of port-identifiers and their translation onto the underlying communications service; and

d) specification of security related information.

Because the operations of the RCF service are relatively simple, once an association is in place between the service user and the service provider, the technology-specific elements

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involved in the exchange of SLE-PDUs are generally minor. However, the way an association is established (i.e., the binding) tends to vary significantly depending on the communications technology in use. Nonetheless, the RCF-BIND and RCF-UNBIND operations as specified in this document are intended to be 'technology neutral'. This neutrality is achieved as described in the following subsections.

For purposes of the communications mapping, the endpoints of an SLE association are identified by port identifiers, namely, an 'initiator port identifier' and a 'responder port identifier'. The port identifiers represent all the technology-specific addressing information needed to establish communications between the user and provider and to route SLE-PDUs between them. The initiator port identifier identifies the endpoint that will invoke the RCF-BIND operation (initiator). The responder port identifier identifies the endpoint that will perform the RCF-BIND operation (responder). Generally speaking, the information represented by a port identifier consists of:

a) information needed in order to route data between two real systems over a communications channel or network; and

b) information needed in order to route data within a real system to a particular application entity.

For example, the information represented by a port identifier might be the combination of an Internet Protocol (IP) network address and a Transmission Control Protocol (TCP) port number or the combination of an OSI network address and an associated set of Service Access Points (SAPs).

The exact relationship between SLE port identifiers and communications ports provided by the underlying communications service must be specified by the mapping of the RCF service to the underlying communications service. If the underlying communications service is connection-oriented, then the mapping may specify a one-to-one relationship between SLE associations and communications connections; however, that is not required. For example, two SLE associations involving the same pair of SLE endpoints may share a single connection. In that case, it is the responsibility of the mapping of the RCF service to the underlying communications service to specify how the SLE-PDUs of one association are distinguished from the SLE-PDUs of the other association.

One possible mapping of the SLE transfer service to the TCP/IP communications service is specified in [F6]. As part of this mapping, also issues such as sizing of TCP buffers in accordance with the bandwidth-delay product of the communication link and ways to manage relative priority of transfer services concurrently using the same connectivity are to be addressed.

In order for an SLE association to be established, SLE Complex Management and SLE Utilization Management must agree beforehand on the responder port identifier for the association. The responder needs the information represented by the responder port identifier to ensure that resources are allocated to recognize and respond to an RCF-BIND

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invocation for that association. The initiator needs the information to ensure that the RCF-BIND invocation will be communicated to the appropriate responder.

In general, it is not necessary for SLE Complex Management and SLE Utilization Management to agree beforehand on the initiator port identifier for the association. Rather, the initiator should communicate that information to the responder in conjunction with the RCF-BIND invocation. The exact means by which the initiator port identifier is provided to the responder is technology-specific and must be specified by the mapping of the RCF service to the underlying communications service.

The responder port identifier is included as a parameter of the RCF-BIND operation. Generally speaking, that is unnecessary; it is only necessary that SLE application communicate the information represented by the port identifiers to the underlying communications service. The responder port identifier is provided as a parameter of the RCF-BIND operation to allow for the possibility that the implementation of a gateway might be simplified by the inclusion of this parameter in the RCF-BIND operation.

The information represented by the responder port identifier is technology-specific. In order to define the RCF-BIND operation in a way that is not technology-specific, the `responder-port-identifier` parameter of the RCF-BIND operation is defined to be a logical name. A logical name is an arbitrary identifier that has an appropriately chosen and agreed upon translation to technology-specific information. Prior to the beginning of the service instance provision period, SLE Complex Management and SLE Utilization must mutually agree upon the value of the responder port identifier (and its translation) applicable to that service instance. The actual process of translating logical names to technology-specific information is considered a local matter. The translation methodology may rely on simple techniques such as look-up tables or may use more elaborate mechanisms such as naming or directory services.

The above discussion describes the case that both the user and provider applications are implemented using the same communications service. It is possible to achieve interoperability even if the user and provider use different communications services. However, in that case interoperability requires the use of an appropriate gateway.

2.6.4.6 Buffering

2.6.4.6.1 General

Buffering mechanisms used by the RCF protocol are described in subsections 2.6.4.6.2 and 2.6.4.6.3. They are formally specified by the requirements in 3.1.9 and the state transition matrix in section 4.

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2.6.4.6.2 Transfer Buffer

As described in 2.6.4.5, RCF operations (specified in section 3) are mapped to SLE-PDUs (specified in annex A) that are conveyed to the peer SLE entity by means of the underlying communications service. In general, there is a one-to-one mapping between SLE-PDUs and the invocations or returns of RCF operations. However, that is not always the case. In particular, the RCF protocol provides that multiple RCF-TRANSFER-DATA and RCF-SYNC-NOTIFY operations may be mapped to a single SLE-PDU (viz., the SLE-PDU named RcfTransferBuffer in annex A). In terms of the RCF service, the release of the RcfTransferBuffer to the communications service provider is equivalent to the near-simultaneous invocation of multiple RCF-TRANSFER-DATA and RCF-SYNC-NOTIFY operations. These operations are invoked in the order in which the original annotated telemetry frames and synchronous notifications occur. However, the RCF service provider concatenates them in a buffer, the content of which forms a single RcfTransferBuffer SLE-PDU. This SLE-PDU is the service data unit passed to the communications provider.

The primary rationale for this approach is as follows: when the data rate on the space link exceeds the available communications bandwidth or when the ground communication link is congested or unavailable for a period of time, use of the complete online delivery mode may lead to the accumulation of a large backlog of undelivered data, resulting in the delivery of data past the point of usefulness. The timely online delivery mode is an alternative that limits the size of the backlog that is allowed to accumulate by discarding data that cannot be delivered within a certain time. Furthermore, when data is discarded, it is discarded 'in chunks', i.e., as a sufficiently large block of contiguous frames rather than as random frames here and there. In general, this approach maximizes the usefulness of the data that is delivered.

This result is achieved as follows: as the RCF service provider acquires telemetry frames and as events that must be synchronously notified occur, that information is stored in a buffer named the transfer buffer. The size of this buffer is set by service management to achieve the appropriate level of 'chunking' of data; this size corresponds to the maximum-sized RcfTransferBuffer SLE-PDU that will be passed to the communications service provider. (This size must also be compatible with the size of the service data units that can be handled by the underlying communications service.) When data is inserted into the transfer buffer, if the transfer buffer was previously empty, a timer, named the release timer, is started. The release timer counts down from an initial time value, named the latency limit, that is set by service management. If the transfer buffer becomes full or if the release timer expires, the entire transfer buffer, in the form of one RcfTransferBuffer SLE-PDU, is passed to the communications service provider as one service data unit. If new data needs to be inserted into the transfer buffer, but the transfer buffer is full and cannot be passed to the communications service provider because of congestion of the communications service, then the entire transfer buffer is discarded as one unit. When this happens, the new data is inserted into the newly emptied transfer buffer, along with a synchronous notification that some data was intentionally discarded due to timeliness considerations.

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Strictly speaking, the transfer buffer is only required in the case of timely online delivery mode. However, the transfer buffer mechanism has a secondary benefit: it allows for 'tuning' of the size of the service data units that are normally passed to the communications service provider. In some cases, this may contribute to enabling the communications service to operate more efficiently. Thus, the transfer buffer is used in all delivery modes. However, in the case of complete online delivery mode and offline delivery mode, data in the transfer buffer is never discarded. Rather, the contents of the transfer buffer are held until they can be passed to the communications service provider. Any backlog that may accumulate is handled by means of the online frame buffer or offline frame buffer (see 2.6.4.6.3).

2.6.4.6.3 Online Frame Buffer and Offline Frame Buffer

In the case of the timely online delivery mode, the only buffering that occurs is that provided by the transfer buffer. For complete online delivery mode and for offline delivery mode, additional buffering is needed because of the nature of the service. Since the complete online delivery mode is supposed to deliver all data even in the case of extended communications service outages or congestion, and since the offline delivery mode is supposed to deliver all data even several days after the space link session, more extensive buffering is required for these modes. This buffering is provided by means of the online frame buffer or the offline frame buffer, respectively. These buffers are relatively large and intended to hold all data (i.e., RCF-TRANSFER-DATA and, in the case of online delivery mode, RCF-SYNC-NOTIFY) for significant periods of time. In the case of complete online delivery mode, the online frame buffer is intended to overcome limitations of the communications service: bandwidth limitations, outages, and congestion. In the case of offline delivery mode, the offline frame buffer is intended to enable data to be delivered hours or days after the completion of the space link session. The exact size of these buffers is set by service management. It is normally expected that the online frame buffer is sufficiently large to hold all data that might be accumulated during one space link session and that the offline frame buffer is sufficiently large to hold all data that might be accumulated during several space link sessions.

NOTE – Synchronous notifications are generally not provided in offline mode, so the data associated with such notifications is not stored in the offline frame buffer.

Figure 2-6 illustrates the differences between timely online delivery mode, complete online delivery mode, and offline delivery mode with respect to the buffers that are used.

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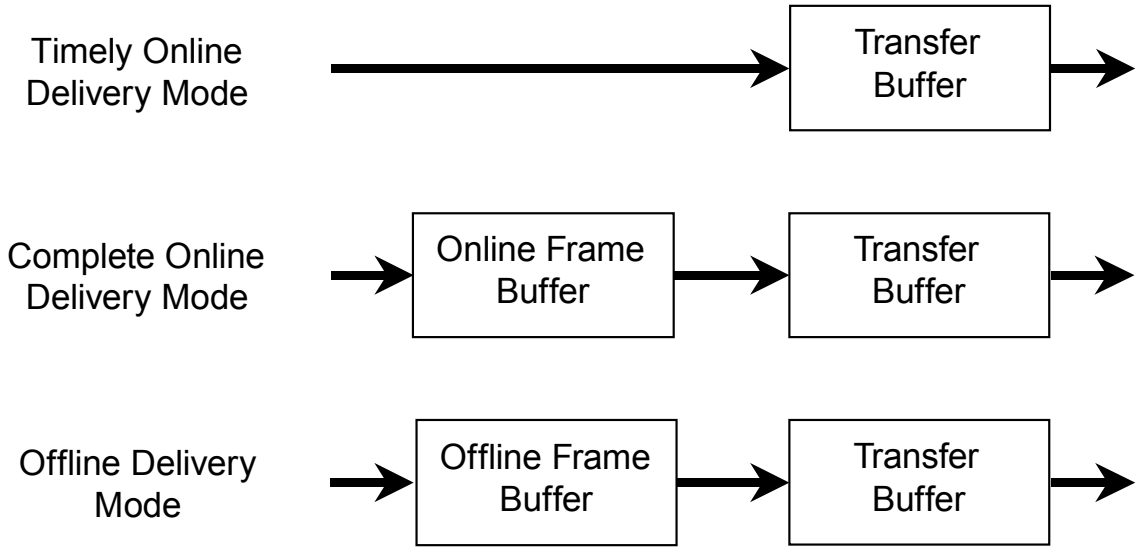

Figure 2-6: Buffers and Delivery Modes

2.7 OPERATIONAL SCENARIO

The following subsections illustrate a typical operational scenario for a user-initiated, online delivery mode RCF service instance:

a) Prior to the actual provision of service, start and stop times for both the space link session and the associated RCF service instance are mutually agreed upon by SLE Complex Management and SLE Utilization Management. Configuration and other information needed to enable the service are also agreed upon. Included in the configuration information for the planned RCF service instance is a list of global VCIDs that identifies the master channel and virtual channels in this master channel that are permitted to be selected by the user of RCF service by means of the RCF-START invocation.

b) Some time before the scheduled start time of the RCF service instance, the service instance is created by SLE Complex Management. Initially, the service provider is in state 1 (‘unbound’). At the scheduled start time of the space link session, the SLE Complex acquires the signal from the spacecraft and initiates the production of RCF service. Typically (but not necessarily) the start time of the service instance provision period will precede by a small margin the start time of the space link session to allow the user to bind to the service before the start of the space link session.

c) The user invokes the RCF-BIND operation to establish an association.

d) The provider transitions from state 1 to state 2 (‘ready’) and returns a report of the successful completion of the bind operation to the user.

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e) The user may now check parameters that control service provision by means of the RCF-GET-PARAMETER operation.

f) If the user is interested in obtaining periodic status reports, the RCF-SCHEDULE-STATUS-REPORT operation may be invoked to configure status reporting.

g) The user invokes the RCF-START operation to enable data flow. The RCF-START identifies the master channel or virtual channel to be transferred by the service instance. The selected master channel or virtual channel must be contained in the set of permitted channels (see item a) above).

h) The provider transitions from state 2 to state 3 ('active') and confirms the RCF-START operation to the user. As telemetry frames that meet the delivery criteria established by the user become available, they are delivered to the user by means of RCF-TRANSFER-DATA operations. In addition, notifications may be delivered by means of RCF-SYNC-NOTIFY operations, and requested status reports are delivered by means of RCF-STATUS-REPORT operations.

i) When all available frames are delivered, the provider will invoke the RCF-SYNC-NOTIFY operation to provide an 'end of data' notification. The 'end of data' notification may be triggered, for example, because the space link session ended and all frames have been delivered, or because the user specified a value for the `stop-time` parameter when invoking the RCF-START operation.

j) By invoking the RCF-STOP operation the user will cause the provider to transition to state 2 ('ready'). The user may then ask for another master channel or virtual channel by invoking another RCF-START operation or may terminate the association by invoking RCF-UNBIND.

2.8 SECURITY ASPECTS OF THE SLE RCF TRANSFER SERVICE

2.8.1 SECURITY BACKGROUND/INTRODUCTION

The SLE transfer services explicitly provide authentication and access control. Additional security capabilities, if required, are levied on the underlying communication services that support the SLE transfer services. The SLE transfer services are defined as layered application services operating over underlying communication services that must meet certain requirements but which are otherwise unspecified. Selection of the underlying communication services over which real SLE implementations connect is based on the requirements of the communicating parties and/or the availability of CCSDS-standard communication technology profiles and proxy specifications. Different underlying communication technology profiles are intended to address not only different performance requirements but also different security requirements. Missions and service providers are expected to select from these technology profiles to acquire the performance and security capabilities appropriate to the mission. Specification of the various underlying communication technologies, and in particular their associated security provisions, are outside the scope of this Recommended Standard.

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The SLE RCF transfer service transfers data that originates on a mission spacecraft. As such, the SLE RCF transfer service has custody of the data for only a portion of the end-to-end data path between mission spacecraft and MDOS. Consequently the ability of an SLE transfer service to secure the transfer of mission spacecraft data is limited to that portion of the end-to-end path that is provided by the SLE transfer service (i.e., the terrestrial link between the MDOS and the ground termination of the space-ground link to the mission spacecraft). End-to-end security must also involve securing the data as it crosses the space-ground link, which can be provided by some combination of securing the mission data itself (e.g., encryption of the mission data within CCSDS space packets) and securing the space-ground link (e.g., encryption of the physical space-ground link). Thus while the SLE RCF transfer service plays a role in the end-to-end security of the data path, it does not control and cannot ensure that end-to-end security. This component perspective is reflected in the security provisions of the SLE transfer services.

2.8.2 STATEMENTS OF SECURITY CONCERNS

This section identifies RCF transfer service support for capabilities that responds to these security concerns in the areas of data privacy, data integrity, authentication, access control, availability of resources, and auditing.

2.8.2.1 Data Privacy (also known as Confidentiality)

This SLE RCF transfer service specification does not define explicit data privacy requirements or capabilities to ensure data privacy. Data privacy is expected to be ensured outside of the SLE transfer service layer, by the mission application processes that communicate over the SLE transfer service, in the underlying communication service that lies under the SLE transfer service, or some combination of both. For example, mission application processes might apply end-to-end encryption to the contents of the CCSDS space link data units carried as data by the SLE transfer service. Alternatively or in addition, the network connection between the SLE entities might be encrypted to provide data privacy in the underlying communication network.

2.8.2.2 Data Integrity

The SLE RCF transfer service defines and enforces a strict sequence of operations that constrain the ability of a third party to inject operation invocations or returns into the transfer service association between a service user and provider (see 4.2.2). This constrains the ability of a third party to seize control of an active RCF transfer service instance without detection.

The SLE RCF transfer service requires that the underlying communication service transfer data in sequence, completely and with integrity, without duplication, with flow control that notifies the application layer in the event of congestion, and with notification to the application layer in the event that communication between the service user and the service

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provider is disrupted (see 1.3.1). No specific mechanisms are identified, as they will be an integral part of the underlying communication service.

2.8.2.3 Authentication

This SLE RCF transfer service specification defines authentication requirements (see 3.1.5), and defines `initiator-identifier`, `responder-identifier`, `invoker-credentials`, and `performer-credentials` parameters of the service operation invocations and returns that are used to perform SLE transfer service authentication. The procedure by which SLE transfer service operation invocations and returns are authenticated is described in annex F of the Cross Support Service Green Book (reference [F2]). The SLE transfer service authentication capability can be selectively set to authenticate at one of three levels: authenticate every invocation and return, authenticate only the BIND operation invocation and return, or perform no authentication. Depending upon the inherent authentication available from the underlying communication network, the security environment in which the SLE service user and provider are operating, and the security requirements of the spaceflight mission, the SLE transfer service authentication level can be adapted by choosing the SLE operation invocation and returns that shall be authenticated. Furthermore the mechanism used for generating and checking the credentials and thus the level of protection against masquerading (simple or strong authentication) can be selected in accordance with the results of a threat analysis.

2.8.2.4 Access Control

This SLE RCF transfer service specification defines access control requirements (see 3.1.4), and defines `initiator-identifier` and `responder-identifier` parameters of the service operation invocations and returns that are used to perform SLE transfer service access control. The procedure by which access to SLE transfer services is controlled is described in annex F of the Cross Support Service Green Book (reference [F2]).

2.8.2.5 Availability of Resources

The SLE transfer services are provided via communication networks that have some limit to the resources available to support those SLE transfer services. If these resources can be diverted from their support of the SLE transfer services (in what is commonly known as ‘denial of service’) then the performance of the SLE transfer services may be curtailed or inhibited. This SLE RCF transfer service specification does not define explicit capabilities to prevent denial of service. Resource availability is expected to be ensured by appropriate capabilities in the underlying communication service. The specific capabilities will be dependent upon the technologies used in the underlying communication service and the security environment in which the transfer service user and provider operate.

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2.8.2.6 Auditing

This SLE RCF transfer service specification does not define explicit security auditing requirements or capabilities. Security auditing is expected to be negotiated and implemented bilaterally between the spaceflight mission and the service provider.

2.8.3 POTENTIAL THREATS AND ATTACK SCENARIOS

The SLE RCF transfer service depends on unspecified mechanisms operating above the SLE transfer service (between a mission spacecraft application process and its peer application process on the ground), underneath the SLE transfer service in the underlying communication service, or some combination of both, to ensure data privacy (confidentiality). If no such mechanisms are actually implemented, or the mechanisms selected are inadequate or inappropriate to the network environment in which the mission is operating, an attacker could read the spacecraft telemetry data contained in the RCF protocol data units as they traverse the WAN between service user and service provider.

The SLE RCF transfer service constrains the ability of a third party to seize control of an active SLE transfer service instance, but it does not specify mechanisms that would prevent an attacker from intercepting the protocol data units and replacing the contents of the `data` parameter. The prevention of such a replacement attack depends on unspecified mechanisms operating above the SLE transfer service (between a mission spacecraft application process and its peer application process on the ground), underneath the SLE transfer service in the underlying communication service, in bilaterally agreed extra capabilities applied to the SLE transfer service (e.g., encryption of the `data` parameter) or some combination of the three. If no such mechanisms are actually implemented, or the mechanisms selected are inadequate or inappropriate to the network environment in which the mission is operating, an attacker could substitute telemetry data without detection.

If the SLE transfer service authentication capability is not used and if authentication is not ensured by the underlying communication service, attackers may somehow obtain valid `initiator-identifier` values and use them to initiate SLE transfer service instances by which they could gain access to spacecraft telemetry data.

The SLE RCF transfer service depends on unspecified mechanisms operating in the underlying communication service to ensure that the supporting network has sufficient resources to provide sufficient support to legitimate users. If no such mechanisms are actually implemented, or the mechanisms selected are inadequate or inappropriate to the network environment in which the mission is operating, an attacker could prevent legitimate users from receiving telemetry from their spacecraft.

If the provider of SLE RCF transfers service provides no security auditing capabilities, or if a user chooses not to employ auditing capabilities that do exist, then attackers may delay or escape detection while stealing or altering telemetry data.

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2.8.4 CONSEQUENCES OF NOT APPLYING SECURITY

The consequences of not applying security to the SLE RCF transfer service are possible degradation and loss of ability to receive telemetry from the spacecraft, or the substitution of altered telemetry data.

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3 RCF SERVICE OPERATIONS

NOTE – This section (3) specifies the processing of valid SLE-PDUs (i.e., those that are recognized as the invocation or return of an RCF service operation). Subsection 3.1 specifies behaviors that are generally applicable to all operations. Subsections 3.2 through 3.11 specify individual operations. Handling of invalid SLE-PDUs is specified in 4.1.

3.1 GENERAL CONSIDERATIONS

3.1.1 RESULT OF OPERATIONS

3.1.1.1 All confirmed operations shall report on the outcome of the operation in a return, except as specified otherwise in section 4.

3.1.1.2 All returns shall include a `result` parameter that indicates whether the outcome of the operation was successful ('positive result') or unsuccessful ('negative result').

3.1.1.3 In the event of a 'negative result', the return shall also include a `diagnostic` parameter, the value of which is descriptive of the reason for the 'negative result'.

NOTE – Possible values of the `diagnostic` parameter are listed in the description of each operation.

3.1.1.4 A `diagnostic` parameter value of 'other reason' shall be returned only if no other value in the list adequately describes the reason for the 'negative result'.

3.1.2 PARAMETER TYPES

The types of all parameters shall conform to the abstract syntax specified in annex A.

NOTE – Some parameter types in annex A are chosen such that possible future extensions of the range of allowed values of a parameter will not cause a type mismatch. For example, parameters that logically are of the 'enumerated' type may be specified as being of the 'named integer' type.

3.1.3 PARAMETER CHECKING

3.1.3.1 Validity checks shall be performed on the values of parameters associated with an operation.

NOTE – Rules governing the validity of parameter values are included in the specification of individual operations. General reasons for regarding a parameter value as invalid are specified in the following subsections.

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