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

*Systèmes de transfert des données et informations spatiales —
Extension de liaisons spatiales (SLE) — Service de retour par tout
réseau*

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This document was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 911.1-B-4, 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 fourth edition cancels and replaces the third edition (ISO 22669:2013), which has been technically revised.

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

- adds clarifications and corrections;
- adds production status annex;
- updates specifications to accommodate recent additions to the CCSDS Recommended Standards for coding and synchronization.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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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 All Frames (RAF) service in conformance with the SLE Reference Model (reference [1]). The RAF service is an SLE transfer service that delivers to a mission user all telemetry frames from one space link physical channel.

1.2 SCOPE

This Recommended Standard defines, in an abstract manner, the RAF 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 RAF service.

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 RAF service. Implementation of the RAF service in a real system additionally requires the availability of a communications service to convey invocations and returns of RAF service operations between RAF 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;

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- 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 RAF service user and the RAF service provider are disrupted, possibly resulting in a loss of data.

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

1.3.2 LIMITS OF APPLICABILITY

1.3.2.1 Relationship to Real Systems

This Recommended Standard specifies the RAF 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.

1.3.2.2 RAF Service and Telemetry Channel Coding

Telemetry channel coding on the space link is specified by references [2], [3], and [4]. The provision of RAF service requires, as specified in reference [2], that, at any given time, the coding options must be the same for all frames on a physical channel.

Reference [F5] allowed multiplexing of coded Transfer Frames (encoded with the Reed-Solomon code) with non-coded Transfer Frames on a Physical Channel. This is not allowed anymore by recommendations in force.

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 RAF service including a functional description, the service management context, and protocol considerations;
- c) section 3 specifies the operations of the RAF service;
- d) section 4 specifies the dynamic behavior of the RAF service in terms of the state transitions of the RAF service provider;
- e) annex A provides a formal specification of RAF service data types using Abstract Syntax Notation One (ASN.1);
- f) annex B specifies the relationship of the RAF 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 RAF 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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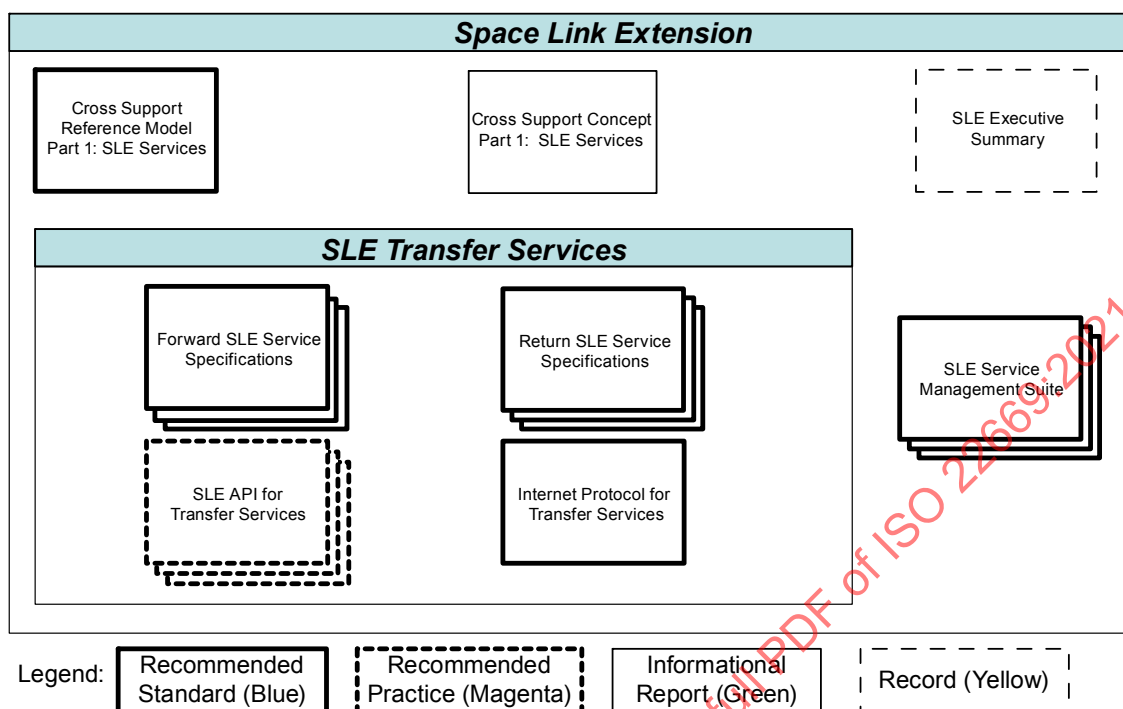


Figure 1-1: SLE Services Documentation

- Cross Support Concept—Part 1: Space Link Extension Services* (reference [F2]): a Report introducing the concepts of cross support and the SLE services;
- 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;
- 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);
- SLE Forward Service Specifications*: a set of Recommended Standards that will provide specification of all forward link SLE services;
- 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;
- 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;
- SLE Service Management Specifications*: a set of Recommended Standards that establish the basis of SLE service management.

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 [8]. 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 [9]:

- 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 RAF service operation invocations and returns. The use of ASN.1 as a descriptive language is intended to support the specification of the abstract RAF 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 RAF 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) codeblock;
- c) convolutional code;
- d) pseudo-randomization;
- e) Reed-Solomon check symbols;
- f) Reed-Solomon code;
- g) turbo code.

1.6.1.4 Definitions from TM Space Data Link Protocol

This Recommended Standard makes use of the following term defined in reference [5]:

- 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 [6]:

- a) Cyclic Redundancy Code (CRC);
- b) AOS Transfer Frame;
- c) 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;
- l) physical channel;
- m) return data;
- n) Return All Frames channel (RAF channel);
- o) Return All Frames service (RAF service);
- p) service agreement;
- q) service provider (provider);
- r) service user (user);
- s) SLE Complex;
- t) SLE Complex Management;
- u) SLE data channel;
- v) SLE Functional Group (SLE-FG);
- w) SLE Protocol Data Unit (SLE-PDU);
- x) SLE Service Data Unit (SLE-SDU);
- y) SLE service package;
- z) SLE transfer service instance;
- aa) SLE transfer service production;
- bb) SLE transfer service provision;
- cc) SLE Utilization Management;
- dd) space link;
- ee) space link data channel;
- ff) Space Link Data Unit (SL-DU);
- gg) space link session.

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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 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 RAF 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 RAF-START operation; and
- b) the frame quality of the frame matches the requested frame quality specified in the RAF-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 [5]), or the FECF of an AOS Transfer Frame (reference [6]), as applicable.

1.6.1.7.6 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.

1.6.1.7.7 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.

1.6.1.7.8 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.

1.6.1.7.9 Performance

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

1.6.1.7.10 Port Identifier

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

NOTE – See 2.6.4.5 for more information.

1.6.1.7.11 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.

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1.6.1.7.12 Return

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

1.6.1.7.13 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).

1.6.1.7.14 Spacecraft Identifier

The spacecraft identifier (SCID) of a telemetry frame is as defined in reference [5] if the frame is a TM Transfer Frame or as defined in reference [6] if the frame is an AOS Transfer Frame.

1.6.1.7.15 Telemetry Frame

A (telemetry) frame is a transfer frame TM Transfer Frame (as defined in reference [5]) or an AOS Transfer Frame (as defined in reference [6]). In case a distinction of the frame versions is necessary, the full term as per references [5] or [6] is used.

1.6.1.7.16 Transfer Frame Version Number

The Transfer Frame Version Number (TFVN) is either the TFVN as defined in reference [5] or the TFVN as defined in reference [6].

NOTE – The definitions of TFVN given in references [5] and [6] 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.

1.6.1.7.17 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.

1.6.2 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 RAF 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.

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 table 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.

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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 RAF service operations appear in uppercase and begin with the characters ‘RAF-’ (e.g., RAF-TRANSFER-DATA).

1.6.3.2.2 Parameter Names

In the main text, names of parameters of RAF 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`).

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 RAF 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., rafBindInvocation).

1.6.3.2.6 Data Type Definitions

Data type definitions for the RAF 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.

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], [5], and [6]). 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.

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- [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] *Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.2-B-1. Washington, D.C.: CCSDS, March 2012.
- [4] *CCSDS Space Link Protocols over ETSI DVB-S2 Standard*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.3-B-1. Washington, D.C.: CCSDS, March 2013.
- [5] *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.
- [6] *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.
- [7] *Time Code Formats*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 301.0-B-4. Washington, D.C.: CCSDS, November 2010.
- [8] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.
- [9] *Information Technology—Abstract Syntax Notation One (ASN.1): Specification of Basic Notation*. 4th ed. International Standard, ISO/IEC 8824-1:2008. Geneva: ISO, 2008.

2 DESCRIPTION OF THE RETURN ALL FRAMES SERVICE

2.1 OVERVIEW

The RAF service enables the user of the service to obtain all telemetry frames from one space link physical channel. A telemetry frame is a TM Transfer Frame or an AOS Transfer Frame. A space link physical channel carries one stream of telemetry frames separated by attached sync markers. For delivery to the user, each frame acquired from the space link is encapsulated in a SLE SDU that also carries annotation (i.e., additional information such as the ERT of the frame).

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

- a) establish an association between the user and the provider;
- b) receive annotated telemetry frames;
- 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;
- e) change the values of certain parameters that affect the behavior of the service; and
- f) release an association.

The provision of RAF service derived from one space link physical channel for access by one service user constitutes one instance of service. The provision of RAF service from one physical channel to multiple service users and the provision of RAF service concurrently to one or more service are permitted but are specified to constitute multiple service instances.

2.2 SPACE LINK EXTENSION REFERENCE MODEL

2.2.1 INTRODUCTION

The RAF 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.

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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 [8]). 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.

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 RAF 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 the RF channel to the RAF data channel.

Certain configuration parameters are associated with provision of RAF service while others are associated with production. Changes to RAF provision configuration parameters (e.g., quality of service) 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 RAF service operations specified in this Recommended Standard. Changes to RAF 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.

RAF 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 RAF 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.

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 RAF 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 frames within a certain amount of time after they are acquired from the space link (e.g., because of communications service backlog). While the RAF service is defined for the complete online delivery mode, the timely online delivery mode, or the offline delivery mode, any particular instance of RAF service supports only one of those modes. The delivery mode applicable to a particular service instance is set by service management.

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2.4 ARCHITECTURE MODEL—FUNCTIONAL VIEW

2.4.1 RETURN SPACE LINK PROCESSING FUNCTIONAL GROUP

The Return Space Link Processing Functional Group (shown in figure 2-1) is the SLE functional group (SLE-FG) that produces the RAF service and the Return Insert service. The latter service is not addressed by this Recommended Standard but is defined in reference [1].

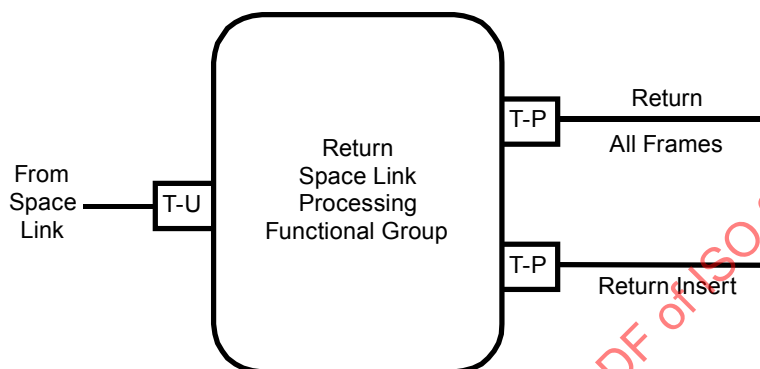


Figure 2-1: Return Space Link Processing SLE-FG

As described in reference [1], the Return Space Link Processing Functional Group consumes a space link data channel consisting of a stream of space link data units (SL-DUs). It produces an SLE data channel (viz., an RAF channel) consisting of a stream of SLE service data units (SLE-SDUs) for delivery to users. The SL-DUs are the telemetry frames carried on the space link physical channel. Most SLE-SDUs encapsulate an SL-DU; such SLE-SDUs also carry annotation information associated with that SL-DU (e.g., its ERT). Other SLE-SDUs carry notifications of the occurrences of certain events while the RAF service is being produced (e.g., loss of frame synchronization). More specifically, the Return Space Link Processing Functional Group performs the following functions with respect to RAF service:

- a) utilizes the underlying antenna steering, microwave amplification, and receiver tuning capabilities of the ground element to acquire a radio frequency (RF) carrier channel;
- b) demodulates a physical channel, consisting of a stream of digital symbols, from the RF carrier channel;
- c) synchronizes and recovers telemetry frames from the physical channel;
- d) performs convolutional decoding, removal of pseudo-randomization, Frame Error Control Field decoding, Reed-Solomon, Low-Density Parity-Check (LDPC), or Turbo decoding (see references [2]), Serially Concatenated Convolutional turbo Coding (see reference [3]), and European Telecommunications Standards Institute (ETSI) Digital Video Broadcast – Satellite2 (DVB-S2) Standard (see reference [4]);

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- e) annotates each frame to form an RAF SLE-SDU and injects the resulting RAF SLE-SDU into the RAF channel associated with the physical channel from which the frame was extracted;
- f) optionally, stores (and subsequently retrieves) sufficient data to reconstruct the RAF channel for delivery through one or more offline RAF service instances;
- g) makes the RAF channel available to online and offline RAF service instances to enable the provision of RAF service.

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

- a) the ERT of the frame;
- b) an identifier that indicates the antenna used to acquire the frame;
- c) an indication of whether the frame contains detected, uncorrectable bit errors;
- d) a parameter that characterizes the data link continuity of this frame with respect to the preceding frame on the space link;
- e) 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.

In the case that an acquired frame is Reed-Solomon encoded, including the outer encoding of the concatenated coding scheme, and the frame quality is 'good' (i.e., the frame is decoded successfully), then the Reed-Solomon check symbols are removed from the frame prior to its encapsulation into the SLE-SDU. If the frame quality of a Reed-Solomon encoded frame is 'erred' (i.e., the frame is undecodable), then the entire frame, including the Reed-Solomon check symbols, is encapsulated into the SLE-SDU for delivery to the user.

If the acquired frame is not Reed-Solomon encoded and found 'erred' based on the evaluation of the FECF or for the case of LDPC encoding based on checking the validity of the codeword, then the result of the decoding process or, in case of uncoded frames, the frame as acquired, is encapsulated into the SLE-SDU for delivery to the user (see 3.6.2.8).

NOTES

- 1 SLE Return Space Link Processing and references [2], [3] and require that, at any given time, the coding options and length must be same for all frames on a physical channel.
- 2 Acquisition of a frame implies that the attached sync markers preceding and following the frame are identified, exhibit the same data polarity, and delimit the correct number of bits.

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

2.4.2 RAF SERVICE PRODUCTION AND PROVISION

One instance of RAF service production (or, one instance of the Return Space Link Processing SLE-FG) may be associated with multiple RAF service instances. RAF production is concerned with the acquisition of frames from the space link and their annotation to form a stream of SLE-SDUs independent of any particular instance of service. In contrast, RAF service provision is concerned with delivering the stream of SLE-SDUs to an RAF 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 quality of service (e.g., whether frames containing known bit errors are delivered to the user).

The SLE-SDUs generated by RAF service production are delivered to the service user by means of the RAF service operations defined in section 3, which also provide additional functionality to facilitate the provision of RAF service. In turn, the RAF service operations are realized as SLE protocol data units (SLE-PDUs) that are exchanged between the RAF service provider and the RAF service user by means of an underlying communications service. Typically, an SLE-PDU corresponds to the invocation or return of an RAF operation. (Because of the buffering mechanisms described in 3.1.9, there are certain exceptions; for example, multiple RAF-TRANSFER-DATA invocations may be mapped to a single SLE-PDU.) The general relationship between SL-DUs, SLE-SDUs, and SLE-PDUs is illustrated in figure 2-2.

NOTE – SLE-SDUs correspond to the parameters of the RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY operations defined in section 3.

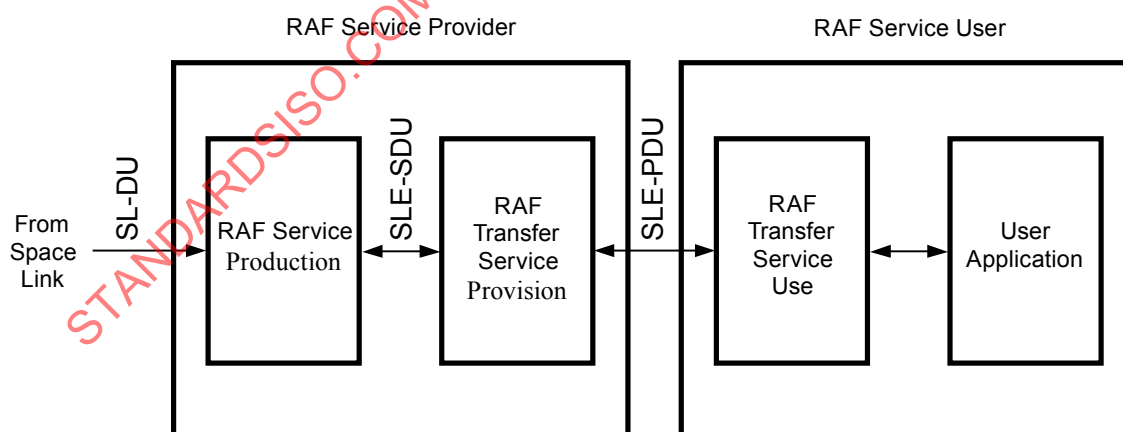


Figure 2-2: RAF Service Production and Provision

For the online delivery mode, production and provision of the RAF 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 RAF transfer service ports and SLE management ports. This scenario shows an SLE Complex with one Return Space Link Processing SLE-FG instance providing two instances of RAF service to a Mission Data Operations System.

NOTE – Although not shown in this scenario, many other combinations are possible. For example, it is also possible to have several SLE-FG instances, each consuming a different physical channel and each providing one or more instances of service.

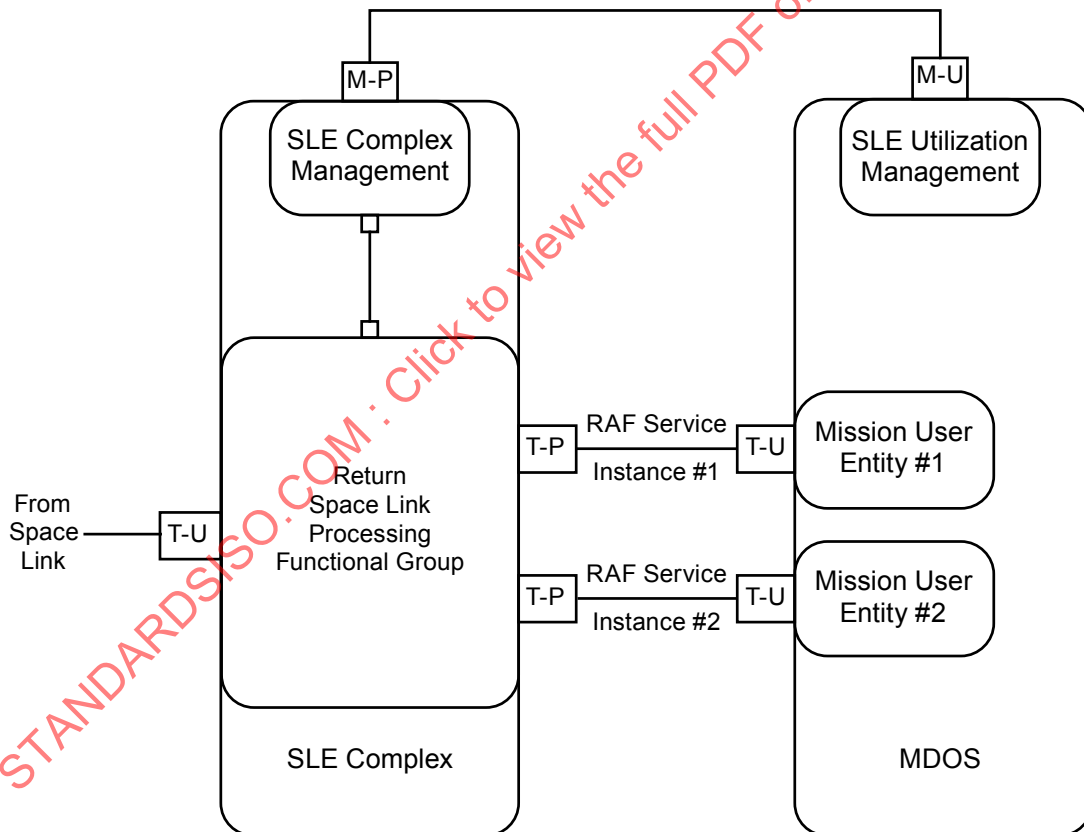


Figure 2-3: Example of the Management and Provision of RAF Service

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2.6 FUNCTIONAL DESCRIPTION

2.6.1 GENERAL

Subsection 2.6.2 through 2.6.4 describes the RAF 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. RAF service production parameters include such things as the frequency of the RF carrier channel, the modulation type, the bit rate, the telemetry channel coding in use, and the scheduled start and stop times of the space link session. RAF service provision parameters include such things as the scheduled start and stop times of the RAF service instance provision period and the delivery mode.

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 RAF service does not depend on any other SLE transfer service. Provision of RAF Transfer service does depend on:

- a) service management for scheduling, resources, and configuration;
- b) the availability of a suitable communications service to enable the exchange of information between the RAF service user and provider; and
- c) the functioning of RAF production resources (e.g., receiver, decoder, frame synchronizer) that acquire frames from the space link.

2.6.4 PROTOCOL DESCRIPTION

2.6.4.1 RAF Operations

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

Table 2-1: RAF Operations

| Operation | Invoked By | Purpose | Confirmed |
|----------------------------|------------------|--|-----------|
| RAF-BIND | User or provider | To establish an association with the peer | Yes |
| RAF-UNBIND | User or provider | To release an association previously established by an RAF-BIND operation | Yes |
| RAF-START | User | To request that the SLE service provider start the delivery of telemetry frames | Yes |
| RAF-STOP | User | To request that the SLE service provider stop the delivery of telemetry frames | Yes |
| RAF-TRANSFER-DATA | Provider | To transfer a telemetry frame to the SLE service user | No |
| RAF-SYNC-NOTIFY | Provider | To notify the user of an event affecting production or provision of the RAF service | No |
| RAF-SCHEDULE-STATUS-REPORT | User | To request that the provider send a status report immediately or periodically or to stop such reporting | Yes |
| RAF-STATUS-REPORT | Provider | To send a status report to the user | No |
| RAF-GET-PARAMETER | User | To ascertain the value of an SLE service parameter (see 3.10.2.5.1) | Yes |
| RAF-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 RAF service instance is created, the RAF 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 RAF 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 RAF 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 RAF-TRANSFER-DATA operation) is not permitted. The user may enable the delivery of telemetry frames by means of the appropriate service operation

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(RAF-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 all telemetry frames are delivered to the user as they become available. The service continues in this state until the user invokes the RAF-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 RAFs meeting the user selected delivery criteria (see 1.6.1.7.4) have been sent).

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

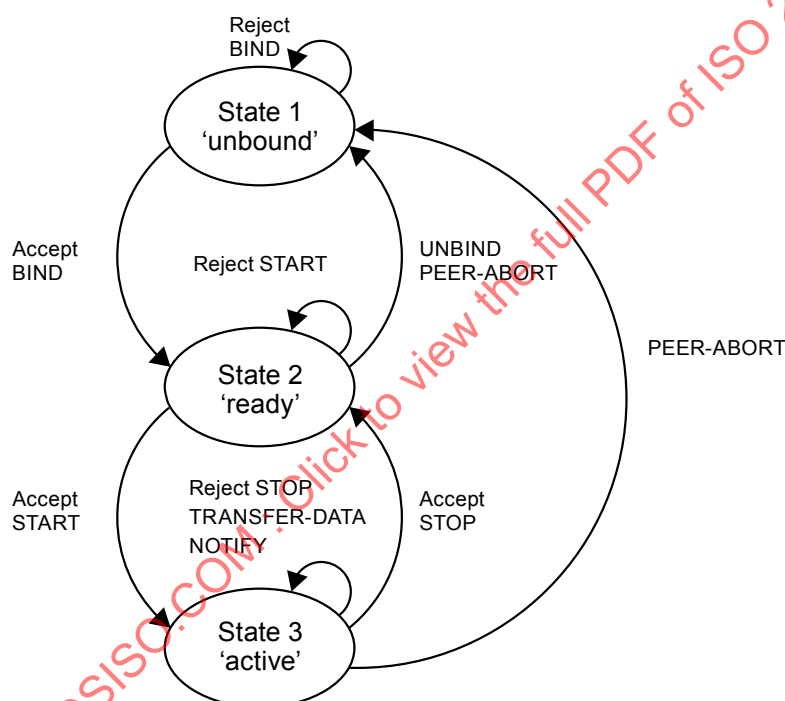


Figure 2-4: Simplified RAF Service Provider State Transition Diagram

2.6.4.3 Termination of Association

An association is released normally when an RAF-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 RAF-PEER-ABORT operation. An association also may be aborted because of 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 RAF-STOP or RAF-PEER-ABORT invocation has been processed by the RAF service provider. The user and provider may re-establish an association via a new RAF-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 RAF-UNBIND invocation the `unbind-reason` parameter is set to 'end';
- b) if the delivery mode is offline, the content of the offline frame buffer (see 3.1.9) is persistent;
- c) statistics reported by means of the RAF-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 RAF service. Provision of the RAF service in a real system also requires a specification of how the RAF service defined here is mapped to a communications service such that all invocations and returns of RAF 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 RAF 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, RAF 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 RAF 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 RAF 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 RAF service to the underlying communications service. Figure 2-5 illustrates a communications realization of the RAF service that results from such a mapping. The specification of such mappings is the subject of separate CCSDS Recommended Standards.

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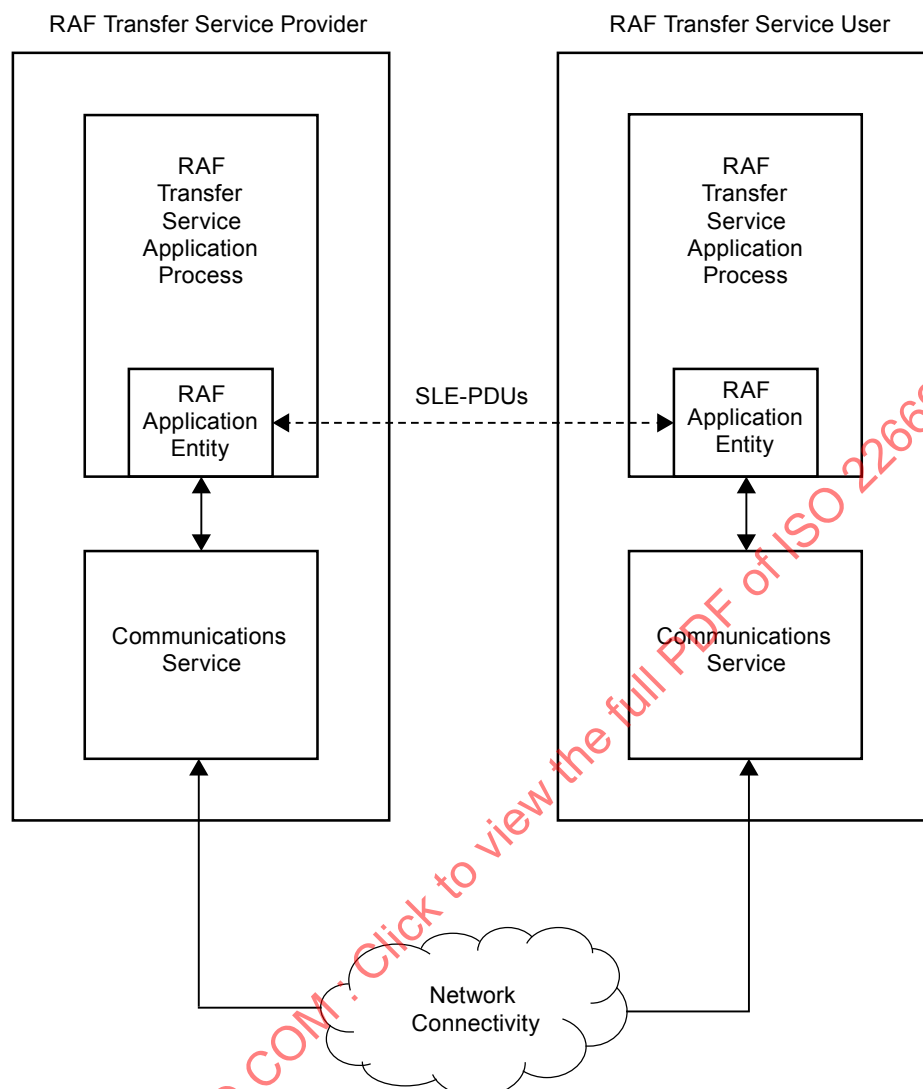


Figure 2-5: Communications Realization of RAF Service

The specification of a mapping of the RAF 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 RAF service are relatively simple, once an association is in place between the service user and the service provider, the technology-specific elements

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 RAF-BIND and RAF-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 RAF-BIND operation (initiator). The responder port identifier identifies the endpoint that will perform the RAF-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 RAF 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 RAF 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 RAF-BIND

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invocation for that association. The initiator needs the information to ensure that the RAF-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 RAF-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 RAF service to the underlying communications service.

The responder port identifier is included as a parameter of the RAF-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 RAF-BIND operation to allow for the possibility that the implementation of a gateway might be simplified by the inclusion of this parameter in the RAF-BIND operation.

The information represented by the responder port identifier is technology-specific. In order to define the RAF-BIND operation in a way that is not technology-specific, the `responder-port-identifier` parameter of the RAF-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 RAF 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.

2.6.4.6.2 Transfer Buffer

As described in 2.6.4.5, RAF 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 RAF operations. However, that is not always the case. In particular, the RAF protocol provides that multiple RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY operations may be mapped to a single SLE-PDU (viz., the SLE-PDU named `RafTransferBuffer` in annex A). In terms of the RAF service, the release of the `RafTransferBuffer` to the communications service provider is equivalent to the near-simultaneous invocation of multiple RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY operations. These operations are invoked in the order in which the original annotated telemetry frames and synchronous notifications occur. However, the RAF service provider concatenates them in a buffer, the content of which forms a single `RafTransferBuffer` 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 RAF 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 `RafTransferBuffer` 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 `RafTransferBuffer` 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.

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,

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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., RAF-TRANSFER-DATA and, in the case of online delivery mode, RAF-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 deliver mode, and offline delivery mode with respect to the buffers that are used.

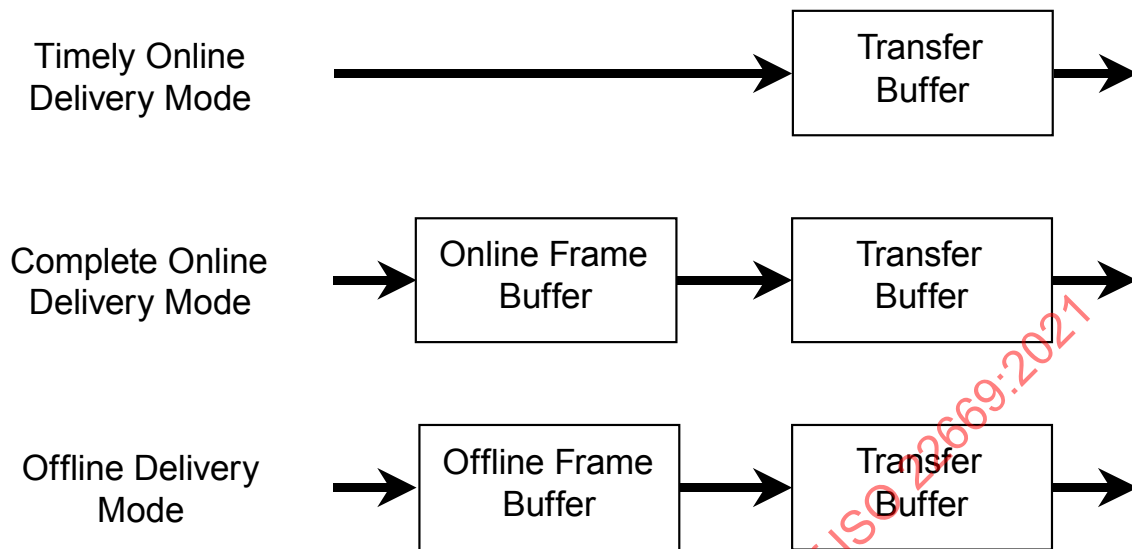


Figure 2-6: Buffers and Delivery Modes

2.7 OPERATIONAL SCENARIO

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

- a) Prior to the actual provision of service, start and stop times for both the space link session and the associated RAF 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.
- b) Some time before the scheduled start time of the RAF 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 RAF 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 RAF-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.
- e) The user may now check parameters that control service provision by means of the RAF-GET-PARAMETER operation.
- f) If the user is interested in obtaining periodic status reports, the RAF-SCHEDULE-STATUS-REPORT operation may be invoked to configure status reporting.

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- g) The user invokes the RAF-START operation to enable data flow.
- h) The provider transitions from state 2 to state 3 ('active') and confirms the RAF-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 RAF-TRANSFER-DATA operations. In addition, notifications may be delivered by means of RAF-SYNC-NOTIFY operations, and requested status reports are delivered by means of RAF-STATUS-REPORT operations.
- i) When all available frames are delivered, the provider will invoke the RAF-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 RAF-START operation.
- j) By invoking the RAF-STOP operation the user will cause the provider to transition to state 2 ('ready'). The user may then ask for another set of frames by invoking another RAF-START command or may terminate the association by invoking RAF-UNBIND.

2.8 SECURITY ASPECTS OF THE SLE RAF 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.

The SLE RAF transfer service transfers data that originates on a mission spacecraft. As such, the SLE RAF 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 RAF 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 RAF 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 RAF 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 RAF 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 RAF transfer service instance without detection.

The SLE RAF 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 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 RAF 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

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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 RAF 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 RAF 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.

2.8.2.6 Auditing

This SLE RAF 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 RAF 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 RAF protocol data units as they traverse the WAN between service user and service provider.

The SLE RAF 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 RAF 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 RAF 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.

2.8.4 CONSEQUENCES OF NOT APPLYING SECURITY

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

3 RAF 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 RAF 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 subsections 3.1.3.2 through 3.1.3.6.

3.1.3.2 A parameter value shall be treated as invalid if it is outside the range or not in the set of values currently permitted by service management for the given parameter.

NOTE – A conforming implementation shall be capable of supporting the full range or set of values as specified in annex A.

3.1.3.3 A parameter value shall be treated as invalid if it is in conflict with the value of another parameter in the same invocation.

NOTE – For example, the value of the `start-time` parameter in an invocation of `RAF-START` is invalid if it is later than the value of the `stop-time` parameter.

3.1.3.4 If a parameter value is not valid, the operation shall not be performed, and, for confirmed operations, a report of 'negative result' shall be returned to the invoker.

3.1.3.5 Except as noted in 3.2.2.11, checks for invalid parameters or for other conditions that can cause a report of 'negative result' should be performed in the order in which diagnostics are listed in the descriptions of the operations, and the diagnostic parameter should be set to the value defined for the first problem found.

3.1.3.6 In the case that an implementation does not adhere to the sequence of checks as specified by the sequence of diagnostics values, such implementation shall specify the sequence in which the checks are actually performed.

3.1.4 ACCESS CONTROL

3.1.4.1 The RAF service shall implement access control based on the identity of the initiator and responder. Access control is performed at two levels:

- a) the initiator must be registered at the responder and the responder must be registered at the initiator;
- b) the initiator and responder must be authorized for the given service instance.

3.1.4.2 The initiator shall have access to a registry of authorized responders and the responder shall have access to a registry of authorized initiators. These registries shall be maintained by SLE Complex Management and SLE Utilization Management, respectively.

3.1.4.3 Service management shall specify the authorized initiator and responder for each service instance.

3.1.4.4 The initiator and responder shall indicate their identity by setting the parameters `initiator-identifier` and `responder-identifier` in the `RAF-BIND` operation to the values assigned by service management.

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3.1.5 AUTHENTICATION

NOTE – Requirements for security depend on the application and the environment of the SLE Complexes and the MDOS (e.g., whether closed or public networks are used or if access is only from physically restricted areas). In many environments, security may be provided by the communications service, transparently to the SLE application. This Recommended Standard does not preclude the use of security features that are provided by the communications service or the local environment, nor does it assume the availability of such features.

3.1.5.1 The RAF service shall provide the following options with respect to the level of authentication of invocations and returns of operations:

- a) 'all': all RAF invocations and returns, except the invocation of RAF-PEER-ABORT, shall be authenticated;
- b) 'bind': only the RAF-BIND invocation and return shall be authenticated;
- c) 'none': no RAF invocations or returns shall be authenticated.

3.1.5.2 SLE Complex Management and SLE Utilization Management shall agree on the level of authentication to be required for an association between a service user and a service provider and shall configure both entities accordingly.

3.1.5.3 SLE Complex Management and SLE Utilization Management shall agree on the algorithm used to generate and check credentials parameters and shall make this algorithm known to the service user and service provider together with associated parameters such as passwords or keys as necessary for the selected algorithm.

NOTES

- 1 The specification of the algorithms themselves is outside the scope of this Recommended Standard.
- 2 The `initiator-identifier` and `responder-identifier` parameters of the RAF-BIND operation identify the user and provider and therefore the applicable authentication level and algorithm necessary to generate and check credentials.

3.1.5.4 For operations for which authentication is required by the terms of the agreement between SLE Complex Management and SLE Utilization Management:

- a) invocations shall include an `invoker-credentials` parameter to permit the performer to authenticate the invocation;
- b) returns shall include a `performer-credentials` parameter to permit the invoker to authenticate the return.

3.1.5.5 For operations for which authentication is not required, the `invoker-credentials` or `performer-credentials` parameter should be set to the value 'unused' to signify that the invocation or return does not carry credentials.

3.1.6 BLOCKING AND NON-BLOCKING OPERATIONS

3.1.6.1 To support applications that may need to invoke several operations concurrently, the parameter `invoke-ID` is specified for all confirmed operations except RAF-BIND and RAF-UNBIND.

NOTES

- 1 The `invoke-ID` parameter allows the invoker to correlate a particular return to the invocation that prompted it.
- 2 Confirmed operations that include the `invoke-ID` parameter are non-blocking operations; those that do not are blocking operations. Unconfirmed operations are always non-blocking.

3.1.6.2 After invoking a blocking operation, the invoker shall not invoke another operation for the same service instance until the return from the blocking operation is received; except that, if the return is not received in a timely manner, the invoker may invoke RAF-PEER-ABORT to terminate the association.

3.1.6.3 After invoking a non-blocking operation, the invoker may invoke another operation without waiting for the return from the first invocation.

3.1.6.4 The value of the `invoke-ID` parameter shall be an invoker-supplied arbitrary integer value that shall be returned, unchanged, by the performer.

3.1.6.5 An error condition shall exist if an invocation includes an `invoke-ID` whose value is the same as that of another invocation that is awaiting confirmation within the context of the same service instance.

3.1.6.6 To ensure that the RAF service behaves in a predictable manner, the effects of operations shall be as though the operations were performed in the order that their invocations were received by the performer.

3.1.6.7 The invoker may choose not to exploit the non-blocking capability and always wait for the return from a non-blocking operation before invoking another operation.

NOTE – An invoker wishing to operate in blocking mode (i.e., to invoke a new operation only when the return from the previous operation has been received) may use a constant value for the `invoke-ID` parameter. As long as a return is still outstanding, the performer will reject any further invocations.

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3.1.6.8 Compliance with this Recommended Standard does not require the performer to process invocations concurrently; however, the performer must accept invocations from a non-blocking invoker and buffer and serialize them by local means not visible externally.

3.1.7 TIME

3.1.7.1 The time reference for all parameters containing a time value shall be based on Coordinated Universal Time (UTC).

NOTE – The type of all time parameters is specified in annex A.

3.1.7.2 The `earth-receive-time` parameter (see 3.6.2.3) shall be expressed using the CCSDS Day Segmented (CDS) time code (reference [7]) with an epoch of 1958-01-01, and a 16-bit day segment. Depending on the RAF service provider capabilities and/or the supported mission requirements, the time tag may have either a resolution of microseconds or a resolution of picoseconds.

NOTE – The service user is expected to accept the `earth-receive-time` parameter in either resolution the provider might deliver.

3.1.7.3 The `earth-receive-time` parameter shall be accurate to within one millisecond or better.

3.1.8 SETTING OF PARAMETERS

An RAF provider shall permit setting of the service configuration parameters as specified in table 3-1.

The range or set of values a parameter may assume is constrained by specification of its data type (see annex A).

Service management may further constrain the allowed values for a given service instance.

Table 3-1: Setting of RAF Service Configuration Parameters

| Parameter | Service Management | RAF-START Operation | RAF-SCHEDULE-STATUS-REPORT Operation |
|-----------------------------------|--------------------|---------------------|--------------------------------------|
| delivery-mode | X | | |
| latency-limit | X | | |
| minimum-reporting-cycle | X | | |
| permitted-frame-quality-set | X | | |
| reporting-cycle | | | X |
| requested-frame-quality | | X | |
| return-timeout-period | X | | |
| service-instance-provision-period | X | | |
| service-version-number | X | | |
| transfer-buffer-size | X | | |

NOTES

- 1 The user can ascertain the current value of the parameters presented in table 3-11 by means of the RAF-GET-PARAMETER operation.
- 2 This Recommended Standard also refers to parameters that are set by service management, but are not listed in table 3-1. These parameters cannot be ascertained by means of the RAF-GET-PARAMETER operation.
- 3 The methods used by service management to control service provision and service production parameters are outside the scope of this Recommended Standard.

3.1.9 DELIVERY MODES**3.1.9.1 Timely Online Delivery Mode**

3.1.9.1.1 For timely online delivery mode, the RAF service provider shall store frames acquired from the space link and certain information associated with those frames (as per 3.6.2) in a buffer called the transfer buffer. The stored information shall be an RAF-TRANSFER-DATA invocation or the equivalent thereof.

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3.1.9.1.2 The extraction of an RAF from the RF channel that matches the delivery criteria and thus the possibility to build an RAF-TRANSFER-DATA invocation constitutes the ‘data available’ event (see 4.2.2) in timely online delivery mode.

NOTE – For convenience, the following subsections are written as if the contents of the transfer buffer consist of an ordered list of records of type `RafTransferDataInvocation` (see A2.7) or type `RafSyncNotifyInvocation` (see 3.1.9.1.2 and A2.7). However, that is not intended to constrain how the transfer buffer is implemented in a real system. It is sufficient that a real system provide the externally visible behaviors that are specified herein.

3.1.9.1.3 Upon the occurrence of any of several events that cause a change to or disruption of the data being provided to the service instance, the RAF service provider shall store a synchronous notification record of the event in the transfer buffer. The notification record shall be an RAF-SYNC-NOTIFY invocation or the equivalent thereof. The notification record shall be stored in the transfer buffer after the last annotated frame acquired before the event and before the first annotated frame acquired following the event. The events and associated information that are stored shall be as defined in 3.7; in particular, at the end of the space link session, an ‘end of data’ `RafSyncNotifyInvocation` shall be stored following the last `RafTransferDataInvocation`.

3.1.9.1.4 If the transfer buffer was empty before the service provider inserted an `RafTransferDataInvocation` or `RafSyncNotifyInvocation` record into the transfer buffer, the service provider shall start a timer for the transfer buffer. This timer shall be named the release timer.

3.1.9.1.5 The duration from the time that the release timer is started until it expires is given by the parameter `latency-limit`, the value of which shall be set by service management.

3.1.9.1.6 For a given instance of RAF service, the transfer buffer shall accommodate a set number of `RafTransferDataInvocation` and/or `RafSyncNotifyInvocation` records. That number, given by the parameter `transfer-buffer-size`, shall be set by service management.

3.1.9.1.7 The contents of the transfer buffer shall be passed to the communications service (in the form of one `RafTransferBuffer` SLE-PDU) and the transfer buffer shall be cleared as soon as one of the following conditions is met:

- a) the buffer is full (i.e., the number of `RafTransferDataInvocation` and/or `RafSyncNotifyInvocation` records contained in the buffer is equal to the value of the `transfer-buffer-size` parameter); or
- b) the release timer expires; or
- c) an `RafSyncNotifyInvocation` ‘end of data’ record was inserted into the transfer buffer.

3.1.9.1.8 The `RafTransferBuffer` SLE-PDU shall contain the records in the same sequence as they were inserted into the transfer buffer.

3.1.9.1.9 If the underlying communications service generates backpressure because of congestion (e.g., it does not accept the RafTransferBuffer SLE-PDU or would block the RAF service provider from continuing), the RAF service provider shall discard this RafTransferBuffer SLE-PDU and clear the transfer buffer. It shall then insert a 'data discarded due to excessive backlog' RafSyncNotifyInvocation record into the transfer buffer and restart the release timer.

3.1.9.1.10 When the 'data discarded due to excessive backlog' RafSyncNotifyInvocation record is inserted into the transfer buffer, the size of the transfer buffer shall be incremented by one. That new size shall remain in effect until the contents of the transfer buffer are passed to the communications service, after which the transfer buffer size shall be decremented by one.

NOTE – The temporary increment in the transfer buffer size ensures a minimum of telemetry flow in case of congestion. Otherwise, only 'data discarded due to excessive backlog' notifications might be sent in case a buffer size of one was specified.

3.1.9.1.11 When the RAF service provider accepts an RAF-STOP invocation from the user, it shall immediately build from the transfer buffer contents an RafTransferBuffer SLE-PDU and shall immediately pass that to the communications service, subject to the provisions in 3.1.9.1.9.

3.1.9.1.12 The transfer buffer shall be cleared whenever the association is aborted.

3.1.9.1.13 Only RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY invocations shall be buffered through the transfer buffer. The invocations or returns of all other operations shall be asynchronous (in the sense that they are not required to be invoked or returned in sequence with respect to the delivery of the contents of the transfer buffer). Therefore, they shall be invoked or returned as soon as possible without regard to the contents of the transfer buffer.

3.1.9.2 Complete Online Delivery Mode

3.1.9.2.1 For complete online delivery mode, the RAF service provider shall store frames acquired from the space link and certain information associated with those frames (as per 3.6.2) in a buffer called the online frame buffer. The stored information shall be an RAF-TRANSFER-DATA invocation or the equivalent thereof.

3.1.9.2.2 The availability of such RAF-TRANSFER-DATA invocation or the equivalent thereof at the output of the online RAF buffer for insertion into the transfer buffer constitutes the 'data available' event (see 4.2.2) in complete online delivery mode.

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NOTES

- 1 Complete online delivery mode attempts to deliver all acquired frames, in order, with minimum delay consistent with the available ground communications bandwidth. Complete online delivery requires that the online frame buffer be sufficiently large to deal with communications service delays, outages, and bandwidth limitations.
- 2 For convenience, the following subsections are written as if the contents of the online frame buffer and the transfer buffer consist of an ordered list of records of type `RafTransferDataInvocation` (see A2.7) or type `RafSyncNotifyInvocation` (see 3.1.9.2.2 and A2.7). However, that is not intended to constrain how the online frame buffer or the transfer buffer is implemented in a real system. It is sufficient that a real system provide the externally visible behaviors that are specified herein.

3.1.9.2.3 Upon the occurrence of any of several events that cause a change to or disruption of the data being provided to the service instance, the RAF service provider shall store a synchronous notification record of the event in the online frame buffer. The notification record shall be an `RAF-SYNC-NOTIFY` invocation or the equivalent thereof. The notification record shall be stored following the last annotated frame acquired before the event and before the first annotated frame acquired following the event. The events and associated information that are stored shall be as defined in 3.7; in particular, at the end of the space link session, an ‘end of data’ `RafSyncNotifyInvocation` shall be stored following the last `RafTransferDataInvocation`.

3.1.9.2.4 The RAF service provider shall start to fill the online frame buffer as soon as both the service instance provision period and the space link session have started and frames are being acquired from the space link.

3.1.9.2.5 While the RAF service provider is in state 3 (‘active’) and the transfer buffer is not full, the provider shall remove `RafTransferDataInvocation` and `RafSyncNotifyInvocation` records from the online frame buffer and insert them, in the same sequence, into the transfer buffer.

3.1.9.2.6 If the transfer buffer was empty before the service provider inserted an `RafTransferDataInvocation` or `RafSyncNotifyInvocation` record into the transfer buffer, the service provider shall start a timer for the transfer buffer. This timer shall be named the release timer.

3.1.9.2.7 The duration from the time that the release timer is started until it expires is given by the parameter `latency-limit`, the value of which shall be set by service management.

3.1.9.2.8 For a given instance of RAF service, the transfer buffer shall accommodate a set number of `RafTransferDataInvocation` and/or `RafSyncNotifyInvocation` records. That number, given by the parameter `transfer-buffer-size`, shall be set by service management.

3.1.9.2.9 As soon as the transfer buffer is full or an ‘end of data’ RafSyncNotifyInvocation record is inserted into the transfer buffer or the provider has accepted an RAF-STOP invocation or the ‘release timer expired’ event was generated, the service provider shall stop extracting RafTransferData or RafSyncNotify records from the online frame buffer and build an RafTransferBuffer SLE-PDU from the transfer buffer contents. The provider shall attempt to pass this SLE-PDU to the communications service until it is accepted.

NOTE – As to obtain a complete data delivery, the user must not ignore RAF-TRANSFER-DATA invocations arriving after the user having invoked RAF-STOP and possibly RAF-UNBIND.

3.1.9.2.10 When the communications service provider has accepted the RafTransferBuffer SLE-PDU, the RAF service provider shall clear the transfer buffer and resume removing frames and synchronous notifications from the online frame buffer as described above.

3.1.9.2.11 The RAF service provider shall continue to remove RafTransferDataInvocation and RafSyncNotifyInvocation records from the online frame buffer, insert them into the transfer buffer, and pass the contents of the transfer buffer to the communications service as long as the service instance remains in state 3 (‘active’).

3.1.9.2.12 In the complete online delivery mode, the transfer buffer shall be cleared and removal of frames and synchronous notifications from the online frame buffer shall stop whenever the association is aborted.

NOTE – A frame that has been extracted from the online frame buffer for insertion into the transfer buffer cannot be extracted again. Consequently, requirement 3.1.9.2.12 implies that a truly complete delivery can only be achieved within a given association. Recovery from data loss caused by an abort of the association can only be accomplished by using the offline delivery mode. Such data loss could be avoided by means of an application-to-application acknowledgement mechanism, but at the expense of a serious throughput performance degradation. Considering that the resulting gap can be filled by means of the offline delivery mode, the option offering better performance and simpler implementation was chosen.

3.1.9.2.13 The RAF service provider shall continue to store acquired frames and notification records in the online frame buffer until the end of the service instance provision period, regardless of the state of the service instance and regardless of whether an association with the service user is established except if the association has been orderly released by means of an RAF-UNBIND invocation with the `unbind-reason` parameter set to ‘end’. In that case, the online frame buffer shall be cleared.

3.1.9.2.14 In the case that the user invokes the RAF-STOP operation or the association becomes unbound, the user may, after re-binding if necessary, invoke a new RAF-START operation, with a start time in the past, to effect delivery of the data buffered in the online frame buffer. Any frames with an ERT older than the start time specified in the RAF-

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START operation and any notifications falling into the same interval shall be removed from the online frame buffer.

NOTE – Re-binding will not be possible if the association was unbound with the `unbind-reason` parameter set to 'end', as that requires the Service Provider to delete the service instance and to release all resources associated with the service instance.

3.1.9.2.15 If the online frame buffer becomes full (e.g., because an extended communications outage prevents it from being emptied), the provider shall discard RafTransferDataInvocation and RafSyncNotifyInvocation records from the online frame buffer in oldest-first order. The number of frames to be discarded in such event is set by service management. The RAF service provider shall also insert an RafSyncNotifyInvocation record indicating a 'data discarded' event into the transfer buffer as soon as this is possible. Extraction of RafTransferDataInvocation and RafSyncNotifyInvocation records from the online frame buffer shall then resume as before.

NOTE – For the complete online delivery mode, it is intended that the size of the online frame buffer be selected such that overflow of the buffer is a very rare event.

3.1.9.2.16 If the service user, in the RAF-START invocation, requests a start time earlier than any frame still held in the online frame buffer, the provider shall deliver the earliest data available.

3.1.9.2.17 At the end of the scheduled service instance provision period, the contents of the online frame buffer shall be discarded.

3.1.9.2.18 Only RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY invocations shall be buffered through the online frame buffer and the transfer buffer. The invocations or returns of all other operations shall be asynchronous (in the sense that they are not required to be invoked or returned in sequence with respect to the delivery of the contents of the online frame buffer). Therefore, they shall be invoked or returned as soon as possible without regard to the contents of the online frame buffer or the transfer buffer.

3.1.9.2.19 During complete online service provision, the RAF service provider shall extract RafTransferDataInvocation and RafSyncNotify records from the online frame buffer, insert them into the transfer buffer, and pass RafTransferBuffer SLE-PDUs to the communications service without undue delay, subject only to limitations imposed by the underlying communications service, or to any maximum data rate limitation ('metering') that may be imposed through service management.

3.1.9.2.20 For complete online delivery mode, the size of the online frame buffer, the transfer buffer and the release timer shall be determined by arrangement between SLE Complex Management and SLE Utilization Management and shall be set by service management.

3.1.9.3 Offline Delivery Mode

3.1.9.3.1 Any frame acquired from the space link that may need to be provided through an offline delivery mode service instance, as well as certain information associated with the frame (as per 3.6.2), shall be stored in a buffer called the offline frame buffer. The stored information shall be an RAF-TRANSFER-DATA invocation or the equivalent thereof. There should be one offline frame buffer for all service instances associated with a particular service agreement. This implies that any deletion of telemetry in the offline frame buffer affects all offline SIs that exist for the associated service agreement and any deletion of telemetry in the offline frame buffer does not affect any SI that exists under a different service agreement.

3.1.9.3.2 The availability of an RAF-TRANSFER-DATA invocation or the equivalent thereof at the output of the offline RAF buffer for insertion into the transfer buffer constitutes the 'data available' event (see 4.2.2) in offline delivery mode.

NOTE – For convenience, the following subsections are written as if the contents of the offline frame buffer and the transfer buffer consist of an ordered list of records of type `RafTransferDataInvocation` (see A2.7). However, that is not intended to constrain how the offline frame buffer or the transfer buffer is implemented in a real system. It is sufficient that a real system provide the externally visible behaviors that are specified herein.

3.1.9.3.3 There may be a significant delay from the time when a frame is acquired from the space link until that frame is available for delivery through an offline delivery mode service instance. Every service provider shall document the characteristics of their service with respect to that delay.

3.1.9.3.4 When an RAF-START operation is invoked in the context of an offline delivery mode RAF service instance, the RAF service provider shall extract `RafTransferDataInvocation` records from the offline frame buffer and insert them into the transfer buffer. Such extraction shall begin with the `RafTransferDataInvocation` record in the offline frame buffer with the earliest ERT that is equal to or later than the start time designated in the RAF-START invocation. Subsequent `RafTransferDataInvocation` records shall be extracted from the offline frame buffer and inserted into the transfer buffer in the same order in which they were originally received from the space link.

3.1.9.3.5 Extraction of `RafTransferDataInvocation` records from the offline frame buffer and their insertion into the transfer buffer shall continue until:

- a) the transfer buffer is full;
- b) a frame is retrieved with an ERT that is later than the stop time in the RAF-START invocation (in which case an 'end of data' notification shall be generated and inserted into the transfer buffer);
- c) the user invokes the RAF-STOP operation; or

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d) the association is aborted.

3.1.9.3.6 As soon as the transfer buffer is full or an 'end of data' RafSyncNotifyInvocation record is inserted into the transfer buffer, or the RAF service provider has accepted an RAF-STOP invocation the service provider shall stop extracting RafTransferData records from the offline RAF buffer, build an RafTransferBuffer SLE-PDU from the contents of the transfer buffer. The provider shall attempt to pass this SLE-PDU to the communications service until it is accepted. The RafTransferBuffer SLE-PDU shall contain the RafTransferDataInvocation records in the same order as they were originally received from the space link.

3.1.9.3.7 Once the RafTransferBuffer SLE-PDU has been accepted by the communications service, the RAF service provider shall clear the transfer buffer. It shall also resume extracting frames from the offline frame buffer unless the 'end of data' notification was generated.

3.1.9.3.8 In the offline delivery mode, the transfer buffer shall be cleared and extraction of frames from the offline frame buffer shall stop whenever the association is aborted.

3.1.9.3.9 In the case that the user invokes the RAF-STOP operation or the association becomes unbound, the user may, after re-binding if necessary, invoke a new RAF-START operation, specifying a new ERT interval for which frames shall be delivered from the offline frame buffer. The start and stop times of such an RAF-START invocation may be earlier, later, or the same as the start and stop times of any previous RAF-START invocation, provided that they are valid start and stop times as specified in 3.4.

3.1.9.3.10 If the user, in the RAF-START invocation, requests a start time earlier than any frame still held in the offline frame buffer, the provider shall deliver frames beginning with the earliest data available. If there are no frames with an ERT in the interval specified by the start and stop times of the RAF-START invocation, then only the 'end of data' notification shall be delivered.

3.1.9.3.11 Except for 'end of data' notifications as described above, synchronous notifications shall not be provided in the offline delivery mode.

3.1.9.3.12 Only RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY invocations shall be buffered through the offline frame buffer. Except for the RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY invocations, the invocations or returns of all other operations shall be asynchronous (in the sense that they are not required to be invoked or returned in sequence with respect to the delivery of the contents of the offline frame buffer). Therefore, they shall be invoked or returned as soon as possible without regard to the contents of the offline frame buffer or the transfer buffer.

3.1.9.3.13 During offline service provision, the RAF service provider shall extract RafTransferDataInvocation records from the offline frame buffer, insert them into the transfer buffer, and pass RafTransferBuffer SLE-PDUs to the communications service without undue delay, subject only to limitations imposed by the underlying communications service, or to

any maximum data rate limitation ('metering') that may be imposed through service management.

3.1.9.3.14 The size of the offline frame buffer and the transfer buffer shall be determined by arrangement between SLE Complex Management and SLE Utilization Management and shall be set by service management.

3.1.9.3.15 Every service provider shall document its policy regarding when, or under what circumstances, records in the offline frame buffer are deleted.

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3.2 RAF-BIND

3.2.1 PURPOSE

3.2.1.1 The RAF-BIND operation shall be used to establish an association between the initiator and the responder.

3.2.1.2 For every instance of RAF service, service management shall establish whether that instance of service is to be user-initiated or provider-initiated:

- a) for a user-initiated service instance, only the service user is permitted to invoke the RAF-BIND operation;
- b) for a provider-initiated service instance, only the service provider is permitted to invoke the RAF-BIND operation.

3.2.1.3 The responder shall return a report of the outcome of the performance of the RAF-BIND operation to the initiator.

3.2.1.4 Except as provided in 3.2.1.5, the invoker of RAF-BIND shall not invoke any further operations for this service instance until the return from the responder is received.

3.2.1.5 If the return from RAF-BIND is not received after a sufficiently long time, the initiator may attempt to recover by invoking the RAF-PEER-ABORT operation followed by another RAF-BIND.

NOTE – The length of the duration that constitutes ‘a sufficiently long time’ is determined by service management.

3.2.1.6 The RAF-BIND operation is valid only in state 1 (‘unbound’).

3.2.2 INVOCATION, RETURN, AND PARAMETERS

3.2.2.1 General

The parameters of the RAF-BIND operation shall be present in the invocation and return as specified in table 3-2.

3.2.2.2 `invoker-credentials`

The `invoker-credentials` parameter shall provide information that enables the performer to authenticate the RAF-BIND invocation (see 3.1.5).

Table 3-2: RAF-BIND Parameters

| Parameter | Invocation | Return |
|-----------------------------|------------|--------|
| invoker-credentials | M | |
| performer-credentials | | M |
| initiator-identifier | M | |
| responder-identifier | | M |
| responder-port-identifier | M | |
| service-type | M | |
| version-number | M | C |
| service-instance-identifier | M | |
| result | | M |
| diagnostic | | C |

3.2.2.3 performer-credentials

The **performer-credentials** parameter shall provide information that enables the invoker to authenticate the return from the performance of RAF-BIND (see 3.1.5).

3.2.2.4 initiator-identifier

The **initiator-identifier** parameter shall identify the authority on whose behalf the initiating SLE application is initiating the association.

NOTES

- 1 The **initiator-identifier** parameter permits the responder to determine if the RAF-BIND operation is being invoked by the authorized initiator for this service instance.
- 2 Each value of the **initiator-identifier** parameter is associated with exactly one authentication level and exactly one authentication scheme.
- 3 If authentication based on credentials is used, this parameter may be redundant since the **initiator-identifier** value may be one constituent of the **invoker-credentials** parameter. However, the encoding may differ, and it may be convenient to have this parameter available in 'clear text' form.

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3.2.2.5 responder-identifier

The **responder-identifier** parameter shall identify the authority on whose behalf the responding SLE application is acting.

NOTES

- 1 The **responder-identifier** parameter permits the initiator to determine if the RAF-BIND return is from the authorized responder for this service instance.
- 2 Each value of the **responder-identifier** parameter is associated with exactly one authentication level and exactly one authentication scheme.
- 3 If authentication based on credentials is used, this parameter may be redundant since the **responder-identifier** value may be one constituent of the **performer-credentials** parameter. However, the encoding may differ, and it may be convenient to have this parameter available in 'clear text' form.

3.2.2.6 responder-port-identifier

NOTE – The **responder-port-identifier** parameter is included in the RAF-BIND invocation to support its possible use by particular kinds of gateways. It is used by such gateways to complete the association with the responding SLE application entity, and it is not intended to be used by the responding SLE application entity itself. Beyond this statement, the behavior of such gateways is outside the scope of this Recommended Standard.

3.2.2.6.1 The **responder-port-identifier** parameter shall specify the port identifier of the responding SLE application entity with which the initiator seeks to establish an association.

3.2.2.6.2 The responding SLE application entity shall ignore the value of the **responder-port-identifier** parameter for purposes of determining the validity of the invocation.

NOTES

- 1 The value of the **responder-port-identifier** parameter is a logical name that can be translated into the technology-specific addressing information required to establish a connection with the responder using the agreed upon communications service. See 2.6.4.5 for more information.
- 2 SLE Complex Management and SLE Utilization Management must have previously agreed on the **responder-port-identifier** and its translation that is applicable to a particular instance of service.

- 3 The `responder-port-identifier` parameter is included in the RAF-BIND invocation to support its possible use by particular kinds of gateways. Implementations not requiring this parameter can ignore its value.
- 4 In case the `responder-port-identifier` parameter is required to establish the association between user and provider, but its value is incorrectly set, the RAF-BIND invocation will in general fail without return. This will trigger the 'return timeout' event on the invoker side. As specified in 4.1.3, the invoker will abort the association by invoking the RAF-PEER-ABORT operation with the diagnostic parameter set to 'return timeout'.

3.2.2.7 **service-type**

3.2.2.7.1 The **service-type** parameter shall specify the type of service that will be provided if the bind operation succeeds.

3.2.2.7.2 For RAF service, the value of `service-type` shall be 'Rtn All Frames'.¹

3.2.2.8 **version-number**

3.2.2.8.1 The **version-number** parameter shall identify the version number of the RAF service specification that is to govern this association if RAF-BIND succeeds.

3.2.2.8.2 `version-number` is conditionally present in the return based on the `result` parameter:

- a) if the value of `result` is 'positive result', `version-number` shall be present in the return;
- b) if the value of `result` is 'negative result', `version-number` shall not be present in the return.

3.2.2.8.3 If the value of the `result` parameter is 'positive result', the responder shall either:

- a) accept the version proposed by the initiator by putting the same version number into the return; or,
- b) if the responder supports version negotiation, propose a lower (earlier) version number by putting the lower number into the return.

¹ For the RAF-BIND operation, the `service-type` parameter is redundant, because the only valid value of `service-type` is 'Rtn All Frames'. However, it is anticipated that future work by CCSDS may result in RAF-BIND being superseded by a generic SLE-BIND operation that is invoked with any one of several SLE service types. The RAF-BIND `service-type` parameter is provided in an attempt to facilitate such a change.

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3.2.2.8.4 If a provider does not support version negotiation, the `version-number` value it will accept during the BIND operation is configured by means of the managed parameter `service-version-number` (see table 3-1).

3.2.2.8.5 If the responder implementation does not support the requested version and does not support a lower version (or does not support version negotiation), the responder shall reject the bind with the `diagnostic` parameter set to 'version not supported'.

3.2.2.8.6 If the responder proposes a lower version and the initiator implementation does not support version negotiation or does not support the version proposed by the responder, the initiator shall unbind the association.

3.2.2.8.7 The value of the `version-number` parameter for the RAF service defined by this issue of this Recommended Standard shall be '5'.

NOTE – The version negotiation process as outlined above is feasible only as long as future versions of the RAF service do not modify the specification of the RAF-BIND operation.

3.2.2.9 service-instance-identifier

The **service-instance-identifier** parameter shall uniquely identify this service instance within the scope of the service-providing SLE Complex.

3.2.2.10 result

The **result** parameter shall specify the result of the RAF-BIND operation and shall contain one of the following values:

- a) 'positive result'—the RAF-BIND invocation is accepted by the responder, and the association is established;
- b) 'negative result'—the RAF-BIND invocation is rejected by the responder for the reason specified in the `diagnostic` parameter, and the association is not established.

3.2.2.11 diagnostic

3.2.2.11.1 If `result` is 'negative result', the **diagnostic** parameter shall be present in the return, and its value shall be one the following:

- a) 'access denied'—the value of the `initiator-identifier` parameter is not recognized by the responder (e.g., the value does not identify the authorized initiator of any service instance known to the responder);

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- b) 'service type not supported'—the value of the `service-type` parameter of the RAF-BIND invocation does not identify a service type supported by the responder;
- c) 'version not supported'—the responder does not support the requested version, and the responder implementation does not permit version negotiation or does not support any version of the service lower than the one requested by the initiator;
- d) 'no such service instance'—the requested service instance is not defined in any agreed upon service package known to the responder;
- e) 'already bound'—the service instance is already bound via a different association;
- f) 'service instance not accessible to this initiator'—the authorized initiator for the service instance identified by the `service-instance-identifier` parameter does not match the initiator identified by the `initiator-identifier` parameter of the RAF-BIND invocation;
- g) 'inconsistent service type'—the value of the `service-type` parameter of the RAF-BIND invocation is not 'Rtn All Frames', or the value of the `service-type` parameter does not match the service type of the service instance identified by the `service-instance-identifier` parameter;
- h) 'invalid time'—the RAF-BIND operation was invoked outside the service instance provision period of the service instance identified by the `service-instance-identifier` parameter;
- i) 'out of service'—the responder has been taken out of service for an indefinite period by management action (i.e., RAF production status is 'halted', see 3.7.2.4);
- j) 'other reason'—the reason for the negative result will have to be found by other means.

NOTES

- 1 In some implementations, under some circumstances, it may not be possible for the intended performer to provide a return in the event of the conditions indicated by diagnostics d), h), or i).
- 2 Implementations should consider that, under some conditions, RAF-BIND may fail with no return (e.g., if the value of the `responder-port-identifier` parameter is incorrect).

3.2.2.11.2 If `result` is 'positive result', the diagnostic parameter shall not be present in the return.

3.2.3 EFFECTS

3.2.3.1 If `result` is 'positive result', the RAF-BIND operation shall have the following effects:

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- a) An association between the user and the provider shall be established.
- b) The provider shall transition from state 1 ('unbound') to state 2 ('ready').
- c) All service parameters shall be set to the initial values determined by service management.
- d) Upon receipt of the positive return, the user may proceed to invoke other RAF service operations (e.g., to configure the service and begin data transfer).

3.2.3.2 If `result` is 'negative result', the RAF-BIND operation shall have the following effects:

- a) An association between the user and the provider shall not be established.
- b) The provider shall remain in state 1 ('unbound').
- c) Upon receipt of the negative return:
 - 1) The initiator should examine the `diagnostic` parameter for the cause.
 - 2) The initiator may attempt to re-invoke the RAF-BIND.

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3.3 RAF-UNBIND

3.3.1 PURPOSE

3.3.1.1 The initiator shall invoke the RAF-UNBIND operation to release an association previously established by RAF-BIND.

3.3.1.2 The responder shall return a report of the outcome of the performance of the RAF-UNBIND operation to the initiator.

3.3.1.3 Except as provided in 3.3.1.4, the initiator shall not invoke any further operations for this service instance until the return from RAF-UNBIND is received; nor shall it perform any further operations invoked by the responder; nor shall it return to the responder any further reports of the outcome of operations invoked by the responder.

NOTE – The initiator may invoke the RAF-UNBIND operation even if it did not yet receive all returns from previously invoked operations. The initiator should be aware that the responder may choose not to send any further returns as soon as it has received the RAF-UNBIND invocation. It may then happen that the RAF-UNBIND return is not received before one of the missing returns causes a ‘missing return’ timeout (see section 4).

3.3.1.4 If the return from RAF-UNBIND is not received after a sufficiently long time, the initiator should invoke the RAF-PEER-ABORT operation to abort the association.

NOTES

- 1 The length of the duration that constitutes ‘a sufficiently long time’ is determined by service management.
- 2 Following receipt of the return from RAF-UNBIND or following the invocation of RAF-PEER-ABORT, the initiator may issue another RAF-BIND if otherwise permitted (e.g., if the end of the service instance provision period has not been reached).

3.3.1.5 The RAF-UNBIND operation is valid only in state 2 (‘ready’).

3.3.1.6 The RAF-UNBIND operation shall be invoked only by the initiator (i.e., the invoker of the RAF-BIND operation that established this association).

3.3.2 INVOCATION, RETURN, AND PARAMETERS

3.3.2.1 General

The parameters of the RAF-UNBIND operation shall be present in the invocation and return as specified in table 3-3.

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Table 3-3: RAF-UNBIND Parameters

| Parameter | Invocation | Return |
|-----------------------|------------|--------|
| invoker-credentials | M | |
| performer-credentials | | M |
| unbind-reason | M | |
| result | | M |

3.3.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the performer to authenticate the RAF-UNBIND invocation (see 3.1.5).

3.3.2.3 performer-credentials

The **performer-credentials** parameter shall provide information that enables the invoker to authenticate the return from the performance of RAF-UNBIND (see 3.1.5).

3.3.2.4 unbind-reason

3.3.2.4.1 The **unbind-reason** parameter shall indicate the reason the RAF-UNBIND operation is being invoked.

3.3.2.4.2 If the RAF-UNBIND operation is invoked by the user, the **unbind-reason** parameter shall take one of the following values:

- a) 'end'—the user has obtained all frames that are needed or expected and is releasing the association normally; the provider may delete the service instance and release all resources associated with it;

NOTE — If **unbind-reason** is 'end', any subsequent attempt to invoke RAF-BIND will fail even if the service instance provision period has not expired, since the service provider may release the resources allocated to that service instance. In particular, the service instance will be removed and therefore be no longer accessible. Also, in case of complete online delivery mode, the online frame buffer will be discarded.

- b) 'suspend'—the user is suspending usage of this service instance for an unspecified period of time; the user may or may not re-bind to the provider to continue data transfer at some time prior to the end of the service instance provision period;
- c) 'version not supported'—the user does not support the version of the RAF service proposed by the provider in the return from RAF-BIND; this value of **unbind-**

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`reason` shall be used only if the RAF-UNBIND is the first operation invoked following the RAF-BIND;

- d) 'other'—the reason for the release will have to be found by other means.

3.3.2.4.3 If the RAF-UNBIND operation is invoked by the provider, the `unbind-reason` parameter shall take one of the following values:

- a) 'end'—the provider has transferred all available frames to the user and is releasing the association normally; the provider shall not attempt to re-bind to the user in the context of this service instance;
- b) 'suspend'—the provider is suspending service provision for an unspecified period of time; the provider may attempt to re-bind to the user to continue data transfer at some time prior to the end of the service instance provision period;
- c) 'version not supported'—the provider does not support the version of the RAF service proposed by the user in the return from RAF-BIND; this value of `unbind-reason` shall be used only if the RAF-UNBIND is the first operation invoked following the RAF-BIND;
- d) 'other'—the reason for the release will have to be found by other means.

3.3.2.5 result

The **result** parameter shall specify the result of the RAF-UNBIND operation and shall always contain the following value:

'positive result'—the RAF-UNBIND operation has been performed by the responder, and the association is released.

NOTES

- 1 If RAF-UNBIND is invoked while the provider is not in the 'ready' state, the responder invokes RAF-PEER-ABORT; if the authentication level is 'all' and the invocation of RAF-UNBIND cannot be authenticated, the responder ignores it; but there is no situation in which the response to the invocation of RAF-UNBIND is to return 'negative result'.
- 2 The `result` parameter is returned for the RAF-UNBIND operation, even though the only permitted value is 'positive result', for consistency with other confirmed operations.
- 3 RAF-UNBIND is a confirmed operation in order to provide a definite indication to the initiator that the responder has performed the operation and the association is released.

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3.3.3 EFFECTS

The RAF-UNBIND operation shall have the following effects:

- a) The association between the initiator and the responder shall be released, and the initiator and the responder shall cease to communicate with each other.
- b) The provider shall transition to state 1 ('unbound').
- c) If `unbind-reason` is 'end', the provider may delete the service instance and release its resources.
- d) If `unbind-reason` is not 'end', the initiator may attempt to re-bind at any time prior to the end of the service instance provision period.

NOTE – The performance of RAF-UNBIND for a particular service instance does not necessarily terminate the associated RAF production process (e.g., if `unbind-reason` is not 'end' and the delivery mode is complete online or if another service instance is dependent on the production).

3.4 RAF-START

3.4.1 PURPOSE

3.4.1.1 The user shall invoke the RAF-START operation to request that the provider begin the delivery of telemetry frames.

3.4.1.2 The provider shall return a report of the outcome of the performance of the RAF-START operation to the user.

3.4.1.3 Following a successful RAF-START, the provider shall deliver telemetry frames acquired from the space link to the user as quickly as those frames are available.

NOTES

- 1 Frames are delivered to the user by means of the RAF-TRANSFER-DATA operation (see 3.6).
- 2 Communications service delays may affect the rate at which available frames are delivered.

3.4.1.4 All frames delivered following the RAF-START but prior to the next RAF-STOP (see 3.5) shall be delivered in the order in which they were received from the space link.

3.4.1.5 The user may specify, as parameters of the RAF-START invocation, the ERTs of the first and last telemetry frames that are to be delivered by the provider.

3.4.1.6 The time parameters may be changed during an association by invoking an RAF-STOP followed by an RAF-START with new time parameters.

NOTE – This capability is intended primarily to support the offline delivery mode.

3.4.1.7 RAF-START is valid only in state 2 ('ready') and shall be invoked only by the user.

3.4.2 INVOCATION, RETURN, AND PARAMETERS

3.4.2.1 General

The parameters of the RAF-START operation shall be present in the invocation and return as specified in table 3-4.

3.4.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the performer to authenticate the RAF-START invocation (see 3.1.5).

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Table 3-4: RAF-START Parameters

| Parameter | Invocation | Return |
|-------------------------|------------|--------|
| invoker-credentials | M | |
| performer-credentials | | M |
| invoke-ID | M | M |
| start-time | M | |
| stop-time | M | |
| requested-frame-quality | M | |
| result | | M |
| diagnostic | | C |

3.4.2.3 performer-credentials

The **performer-credentials** parameter shall provide information that enables the invoker to authenticate the return from the performance of RAF-START (see 3.1.5).

3.4.2.4 invoke-ID

The RAF service provider shall return unchanged the user-supplied value of the **invoke-ID** parameter (see 3.1.6.1).

3.4.2.5 start-time

3.4.2.5.1 The value of the **start-time** parameter shall be 'null', or it shall be a time value that indicates that only frames with an ERT equal to or later than **start-time** shall be delivered.

3.4.2.5.2 For the online delivery mode, only frames acquired during the space link session associated with this service instance shall be delivered, regardless of the value of **start-time**.

3.4.2.5.3 For the offline delivery mode, the provider shall deliver all available frames that meet the delivery criteria regardless of the space link session in which they were acquired.

3.4.2.5.4 For the online delivery mode, if **start-time** is 'null', the data transfer shall begin with the next frame that is acquired from the space link.

3.4.2.5.5 For the offline delivery mode, **start-time** must not be 'null'.

3.4.2.5.6 To be valid, **start-time** must satisfy the following criteria:

- a) for the online delivery mode, `start-time` must be equal to or later than the start time of the service instance provision period for this service instance;
- b) for the online delivery mode, `start-time` must be earlier than the end time of the service instance provision period for this service instance;
- c) `start-time` must be earlier than `stop-time` (see 3.4.2.6).

NOTE – The provider is able to deliver only frames that have been acquired from the space link. For example, in an online service instance, if `start-time` is earlier than the start time of the space link session, the first frame that is delivered will be the first frame acquired after the start of the space link session.

3.4.2.6 `stop-time`

3.4.2.6.1 The value of the `stop-time` parameter shall be 'null', or it shall be a time value that indicates that delivery of frames should cease when the next frame that would be delivered has an ERT later than `stop-time`.

3.4.2.6.2 For the online delivery mode, only frames acquired during the space link session associated with this service instance shall be delivered, regardless of `stop-time`.

3.4.2.6.3 For the offline delivery mode, the provider shall deliver all available frames that meet the delivery criteria regardless of the space link session in which they were acquired.

3.4.2.6.4 For the online delivery mode, if `stop-time` is 'null', the provider shall continue to transfer all frames that are acquired from the space link and satisfy the delivery criteria until either the user invokes an RAF-STOP operation or the association is released or aborted.

3.4.2.6.5 For the offline delivery mode, `stop-time` must not be 'null'.

3.4.2.6.6 To be valid, `stop-time` must satisfy the following criteria:

- a) `stop-time` must be later than the `start-time` (see 3.4.2.5);
- b) for the online delivery mode, `stop-time`, if not 'null', must be earlier than or equal to the end time of the service instance provision period for this service instance;
- c) for the offline delivery mode, `stop-time` plus the offline processing latency must be earlier than the current time.

NOTES

- 1 Offline processing latency is the length of time after a frame is acquired from the space link before it the frame or any fields contained in the frame is available for retrieval using the offline delivery mode. The actual value of offline processing

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latency is negotiated between SLE Complex Management and SLE Utilization Management.

- 2 Offline delivery is only available for frames that already have been acquired when the RAF-START operation is invoked.

3.4.2.7 requested-frame-quality

The **requested-frame-quality** parameter specifies a criteria based on frame quality for determining whether a given frame is to be delivered to the user. Its value shall be one of the following:

- a) 'good frames only'—only frames for which delivered-frame-quality (see 3.6) is 'good' shall be delivered to the user;
- b) 'erred frames only'—only frames for which delivered-frame-quality is 'erred' shall be delivered to the user;
- c) 'all frames'—all frames, regardless of delivered-frame-quality, shall be delivered to the user.

3.4.2.8 result

The **result** parameter shall specify the result of the RAF-START operation and shall contain one of the following values:

- a) 'positive result'—the RAF-START operation has been performed by the provider, and the provider shall henceforth invoke RAF-TRANSFER-DATA operations as needed to transfer to the user all available frames that meet the specified delivery criteria;
- b) 'negative result'—the RAF-START operation has not been performed by the provider, and the provider shall not invoke any RAF-TRANSFER-DATA operations even if frames are available.

3.4.2.9 diagnostic

3.4.2.9.1 If **result** is 'negative result', the **diagnostic** parameter shall be present in the return, and its value shall be one of the following:

- a) 'duplicate Invoke-ID'—the value of the **invoke-ID** parameter is the same as the **invoke-ID** of a previous, outstanding operation;
- b) 'out of service'—the provider has been taken out of service (i.e., RAF production status is 'halted'—see 3.7.2.4) for an indefinite period by management action;

- c) 'unable to comply'—the provider is unable to transfer data at this time because of a fault affecting the provider;
- d) 'missing time value'—for the offline delivery mode, the value of `start-time` and/or `stop-time` was 'null';
- e) 'invalid start time'—the value of the `start-time` provided in the invocation is not valid;
- f) 'invalid stop time'—the value of the `stop-time` provided in the invocation is not valid;
- g) 'other reason'—the reason for the negative result will have to be found by other means.

3.4.2.9.2 If `result` is 'positive result', the `diagnostic` parameter shall not be present in the return.

3.4.3 EFFECTS

3.4.3.1 If `result` is 'positive result', the RAF-START operation shall have the following effects:

- a) the provider shall transition to state 3 ('active');
- b) in the 'active' state, the provider shall transfer frames to the user whenever they are available and satisfy the delivery criteria.

3.4.3.2 If `result` is 'negative result', the RAF-START operation shall have the following effects:

- a) the provider shall remain in state 2 ('ready') and shall not deliver frames even if they are available;
- b) if the `diagnostic` is 'unable to comply':
 - 1) the user may re-invoke the RAF-START operation at a later time within the constraints of the service instance provision period;
 - 2) if the provider's SLE Complex Management determines that being 'unable to comply' is more than a transient problem, the provider may invoke the RAF-PEER-ABORT operation.

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3.5 RAF-STOP**3.5.1 PURPOSE**

3.5.1.1 The user shall invoke the RAF-STOP operation to request that the provider stop delivering telemetry frames.

NOTE – Within the constraints of the service provision period, the user may re-enable frame delivery by invoking the RAF-START operation.

3.5.1.2 The provider shall provide a report of the outcome of the performance of the RAF-STOP operation to the user.

3.5.1.3 RAF-STOP is valid only in state 3 ('active') and shall be invoked only by the user.

3.5.2 INVOCATION, RETURN, AND PARAMETERS**3.5.2.1 General**

The parameters of the RAF-STOP operation shall be present in the invocation and return as specified in table 3-5.

Table 3-5: RAF-STOP Parameters

| Parameters | Invocation | Return |
|-----------------------|------------|--------|
| invoker-credentials | M | |
| performer-credentials | | M |
| invoke-ID | M | M |
| result | | M |
| diagnostic | | C |

3.5.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the performer to authenticate the RAF-STOP invocation (see 3.1.5).

3.5.2.3 performer-credentials

The **performer-credentials** parameter shall provide information that enables the invoker to authenticate the return from the performance of RAF-STOP (see 3.1.5).

3.5.2.4 **invoke-ID**

The RAF service provider shall return unchanged the user-supplied value of the **invoke-ID** parameter (see 3.1.6).

3.5.2.5 **result**

The **result** parameter shall specify the result of the RAF-STOP operation and shall contain one of the following values:

- a) 'positive result'—the RAF-STOP operation has been performed by the provider, and the delivery of telemetry frames to the user has ceased;
- b) 'negative result'—the RAF-STOP operation has not been performed by the provider for the reason specified by the **diagnostic** parameter, and the delivery of telemetry frames to the user continues.

3.5.2.6 **diagnostic**

3.5.2.6.1 If **result** is 'negative result', the **diagnostic** parameter shall be present in the return, and its value shall be one of the following:

- a) 'duplicate Invoke-ID'—the value of the **invoke-ID** parameter is the same as the **invoke-ID** of a previous, outstanding operation;
- b) 'other reason'—the reason for the negative result will have to be found by other means.

3.5.2.6.2 If **result** is 'positive result', the **diagnostic** parameter shall not be present in the return.

3.5.3 **EFFECTS**

3.5.3.1 If **result** is 'positive result', the RAF-STOP operation shall have the following effects:

- a) the provider shall cease invoking RAF-TRANSFER-DATA operations;
- b) the provider shall build an `RafTransferBuffer` SLE PDU from the transfer buffer contents and pass this SLE PDU to the communication service in accordance with the provision of 3.1.9;
- c) the provider shall transition to state 2 ('ready').

3.5.3.2 If **result** is 'negative result', the provider shall remain in state 3 ('active') and shall continue processing unchanged.

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3.6 RAF-TRANSFER-DATA**3.6.1 PURPOSE**

3.6.1.1 The provider shall invoke the RAF-TRANSFER-DATA operation to deliver a telemetry frame to the user.

3.6.1.2 The RAF-TRANSFER-DATA operation shall be an unconfirmed operation.

NOTE – Although RAF-TRANSFER-DATA is an unconfirmed operation, it is assumed that the communications service provides certain guarantees, as described in 1.3.1.

3.6.1.3 RAF-TRANSFER-DATA is valid only in state 3 ('active') and shall be invoked only by the provider.

3.6.2 INVOCATION AND PARAMETERS**3.6.2.1 General**

The parameters of the RAF-TRANSFER-DATA operation shall be present in the invocation as specified in table 3-6.

Table 3-6: RAF-TRANSFER-DATA Parameters

| Parameters | Invocation |
|-------------------------|------------|
| invoker-credentials | M |
| earth-receive-time | M |
| antenna-ID | M |
| data-link-continuity | M |
| delivered-frame-quality | M |
| private-annotation | M |
| data | M |

3.6.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the user to authenticate the RAF-TRANSFER-DATA invocation (see 3.1.5).

3.6.2.3 earth-receive-time

The **earth-receive-time** parameter shall contain the UTC time at which the signal event corresponding to the leading edge of the first bit of the attached sync marker that

immediately preceded this telemetry frame was presented at the phase center of the antenna used to acquire the frame.

NOTES

- 1 The first bit of the frame is the first bit following the attached sync marker.
- 2 In case of punctured coding, the number of symbols influenced by each information bit is variable, depending on the puncture pattern. Missions applying such coding need to take the resulting jitter of the `earth-receive-time` annotation with respect to the beginning of the frame into account.

3.6.2.4 **antenna-ID**

3.6.2.4.1 The **antenna-ID** parameter shall indicate which antenna of the SLE Complex was used to acquire this frame.

NOTE – `antenna-ID` is provided specifically to identify the physical location used as the reference point for the `earth-receive-time` parameter.

3.6.2.4.2 SLE Complex Management and SLE Utilization Management shall mutually agree upon the allowable values for `antenna-ID` and their interpretation.

NOTE – It is assumed that the value of the `antenna-ID` parameter is a reference to the actual location information, which is provided outside the scope of this service.

3.6.2.5 **data-link-continuity**

The **data-link-continuity** parameter shall indicate whether this frame was the direct successor of the previous frame on the space link selected by means the RAF-START operation.

NOTE – Even though this frame may have been the direct successor of the previous frame acquired from the space link, it may not be the direct successor of the previous frame delivered to the user of this service instance (e.g., because of the setting of `requested-frame-quality`, see 3.4.2.7).

3.6.2.5.1 The `data-link-continuity` parameter shall contain an integer value:

- a) a value of ‘-1’ shall indicate that this is the first frame after the start of production;
- b) a value of ‘0’ shall indicate that this frame is the direct successor to the last frame acquired from the space link by RAF production;
- c) any non-zero positive value shall indicate that this frame is not the direct successor to the last frame acquired from the space link:

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- 1) a non-zero positive value further indicates an estimate of the number of frames that were missed since the last frame acquired before this frame;
- 2) a value of '1' may be used if no better estimate is available.

3.6.2.6 delivered-frame-quality

The **delivered-frame-quality** parameter shall indicate the result of Reed-Solomon or LDPC decoding or Frame Error Control Field evaluation and shall contain one of the following values:

- a) 'good'—for Reed-Solomon or LDPC encoded frames, the frame, after decoding, consists entirely of codewords of the Reed-Solomon or LDPC code; or, for frames that are neither Reed-Solomon nor LDPC encoded, evaluation of the Frame Error Control Field indicates that the frame does not contain any errors,
- b) 'erred'—for Reed-Solomon or LDPC encoded frames, the frame, after decoding, contains at least one codeword that is not a codeword of the Reed-Solomon or LDPC code; or, for frames that are neither Reed-Solomon nor LDPC encoded, evaluation of the Frame Error Control Field indicates that the frame contains at least one error.
- c) 'undetermined' – the results of the decoding process for this frame are not specified. It may be that decoding was not performed at all, that a non-standard decoding was performed, or that a decoding was performed but the results are not provided for whatever reason. The exact meaning of this value of the parameter is implementation dependent.

NOTES

- 1 The value 'undetermined' of the parameter **delivered-frame-quality** is only provided if the RAF-START operation specifies 'all' for the **requested-frame-quality**.
- 2 Transfer frames as specified in reference [6] optionally provide a Header Frame Error Control field. This field is disregarded by the RAF service when reporting the quality of a delivered frame, i.e., the reported frame quality refers to the complete transfer frame and not to the header only.
- 3 Reed-Solomon and LDPC coding are specified in reference [2]. Encoding of the Frame Error Control Field is specified in references [5] and [6].
- 4 As indicated in 1.3.2.2, provision of RAF service and references [2], [5] and [6] require that, at any given time, the coding options and length must be the same for all frames on a physical channel.

- 5 Which type of coding is in use is managed information; i.e., it is not signaled in the data itself but must be known a priori. It is assumed that this information is conveyed through service management.

3.6.2.7 private-annotation

The **private-annotation** parameter shall be used to convey additional information that may be associated with a frame:

- a) it may be set to 'null' to indicate that there is no private annotation;
- b) if not 'null', there must be a prior arrangement between SLE Complex Management and SLE Utilization Management regarding the contents and interpretation of this parameter.

3.6.2.8 data

The value of the **data** parameter shall be the telemetry frame acquired by the provider from the space link for delivery to the user.

- a) if delivered-frame-quality is 'good', then the data parameter is a TM transfer frame or an AOS transfer frame, where
 - 1) if the frame is Reed-Solomon encoded, the Reed-Solomon check symbols are discarded;
 - 2) if the transfer frame is LDPC encoded, the parity bits and the trailing fill bits are discarded;
- b) if delivered-frame-quality is 'erred' and the frame is not Reed-Solomon encoded (i.e., it may be convolutionally encoded, turbo encoded, LDPC encoded, encoded in accordance with [3] or [4], or uncoded), then the data parameter is the data unit resulting from the decoding process except for uncoded frames where this data unit is the frame as acquired from the space link. The data unit has therefore the same length as a 'good' frame. During frame synchronization it was identified as a frame but, on FECF checking or in case of LDPC encoding on codeword validity checking, was found to contain errors;
- c) if delivered-frame-quality is 'erred' and the frame is Reed-Solomon encoded (i.e., if a candidate codeblock cannot be Reed-Solomon decoded), then the entire candidate codeblock as presented at the input to the Reed-Solomon decoder is delivered unmodified as data parameter;

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NOTE – Except for the case of Reed-Solomon encoded erred frames successful decoding of erred frames as delivered by the RAF service by means of some form of post-processing will hardly ever be possible. Such post-processing, at least for optimum performance, requires the soft symbols be delivered which would entail a significant increase of the required ground communications bandwidth. The delivery of soft symbols may be possible, but is regarded an engineering service that is outside the scope of the RAF service specified in this Recommended Standard. The Reed-Solomon decoding process is based on hard symbols and therefore the decoder input as is can be delivered as candidate codeblock. As a consequence, decoding of the erred frame as delivered by the RAF service by post-processing in case of Reed-Solomon encoding may be feasible.

- d) if `delivered-frame-quality` is 'undetermined', the `data` parameter is a data unit of the same length as a TM transfer frame or AOS transfer frame that during frame synchronization was identified as a candidate frame, but of which the coding scheme is unknown or not supported so that the frame quality cannot be determined by decoding.

NOTES

- 1 The specification in item d) above allows that the length of the candidate frame that is delivered (when `delivered-frame-quality` is 'undetermined') is implementation dependent; i.e., it may be a frame or codeblock in the symbol or bit domain.
- 2 The value of the `data` parameter does not include the attached sync marker.
- 3 TM or AOS frames handled by the RAF service may be protected by means of the Space Data Link Security Protocol [F7]. The presence or absence of such protection is transparent to the RAF service and processing of the Security Header and Security Trailer if present is deferred to applications acting on the frames as delivered by the RAF service.

3.6.3 EFFECTS

The RAF-TRANSFER-DATA operation shall have the following effects:

- a) a telemetry frame acquired by the provider from the space link shall be delivered to the user;
- b) the provider shall remain in state 3 ('active').

3.7 RAF-SYNC-NOTIFY

3.7.1 PURPOSE

3.7.1.1 The RAF service provider shall invoke the RAF-SYNC-NOTIFY operation to notify the user of the occurrence of an event affecting the production of the RAF service.

NOTE – Notification of events may be of value to the user in understanding specific provider behavior, such as an interruption in frame delivery.

3.7.1.2 The RAF-SYNC-NOTIFY operation shall be an unconfirmed operation.

3.7.1.3 The order in which the RAF-SYNC-NOTIFY and RAF-TRANSFER-DATA operations are invoked shall reflect the actual chronology of events.

NOTE – For example, if an RAF-SYNC-NOTIFY operation is invoked after one RAF-TRANSFER-DATA operation but before another, then the event indicated by the notification occurred after the ERT of the frame associated with the preceding RAF-TRANSFER-DATA but before the ERT of the frame associated with the following RAF-TRANSFER-DATA.

3.7.1.4 RAF-SYNC-NOTIFY is valid only in state 3 ('active') and shall be invoked only by the provider.

3.7.2 INVOCATION AND PARAMETERS

3.7.2.1 General

The parameters of the RAF-SYNC-NOTIFY operation shall be present in the invocation as specified in table 3-7.

Table 3-7: RAF-SYNC-NOTIFY Parameters

| Parameter | Invocation |
|---------------------|------------|
| invoker-credentials | M |
| notification-type | M |
| notification-value | C |

3.7.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the user to authenticate the RAF-SYNC-NOTIFY invocation (see 3.1.5).

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3.7.2.3 notification-type

The **notification-type** parameter shall indicate the event that the user is being notified of, and its value shall be one of the following:

- a) 'loss of frame synchronization'—the delivery of frames has been interrupted because the frame synchronization process is not able to synchronize to the stream of frames from the space link:
 - 1) the notification shall be invoked once if the frame synchronizer transitioned from 'in-lock' to 'out-of-lock' at least once during the lock status observation period that the provider applies for lock status monitoring; the length of the lock status observation period applied by the provider shall be documented;
 - 2) the provider shall minimize the latency from the time the loss of frame synchronization event occurs until the notification is invoked;
 - 3) there shall be no explicit notification when the frame synchronizer transitions from 'out-of-lock' to 'in-lock'; rather, the next invocation of RAF-TRANSFER-DATA shall implicitly indicate the occurrence of that event;
 - 4) loss of frame synchronization notifications shall not be invoked in the offline delivery mode;
- b) 'production status change'—the status of RAF production has changed:
 - 1) the notification shall be invoked when the RAF production status changes;
 - 2) the production status shall be 'running', 'halted', or 'interrupted' (see 3.7.2.4);
 - 3) production status change notifications shall not be invoked in the offline delivery mode;
- c) 'data discarded due to excessive backlog'—some data was discarded by the RAF service provider, either because of timeliness considerations (timely online mode) or because of online frame buffer overflow (complete online mode):
 - 1) if data are discarded two or more times in a row without a successful intervening delivery of frames to the user, no more than one data discarded notification shall be delivered to the user;
 - 2) data discarded notifications shall not be invoked in the offline delivery mode;
- d) 'end of data'—the provider has no more data to send.

NOTE – The 'end of data' notification is invoked in all delivery modes. For example, for an online service instance, the space link session has ended, and there are no more frames to be delivered; or, regardless of the delivery mode, all available frames between the specified start and stop times (see 3.4) have been delivered).

3.7.2.4 notification-value

3.7.2.4.1 The presence of the **notification-value** parameter in the return from RAF-SYNC-NOTIFY shall be conditional on the value of **notification-type**.

3.7.2.4.2 If **notification-type** is 'loss of frame synchronization', then **notification-value** shall be present and shall convey the following information:

- a) the UTC time when the frame synchronizer transitioned from 'in-lock' to 'out-of-lock';
- b) the current status of the carrier demodulation process, which shall be 'in-lock', 'out-of-lock', or 'unknown';
- c) the current status of the subcarrier demodulation process, which shall be 'in-lock', 'out-of-lock', 'not in use', or 'unknown';
- d) the current status of the symbol synchronization process, which shall be 'in-lock', 'out-of-lock', or 'unknown'.

NOTE – The determinations of the lock statuses of carrier demodulation, subcarrier demodulation, and symbol synchronization typically are based on measurements that are integrated over some time period. To that extent, the values reported here may reflect the statuses of the corresponding processes at a time slightly earlier than the time when the notification is invoked.

3.7.2.4.3 If **notification-type** is 'production status change', then the **notification-value** parameter shall be present, and its value shall indicate the current production status, which shall be one of the following:

- a) 'running'—the RAF production process is capable of processing a return space link physical channel, if available;
- b) 'halted'—the RAF production process is stopped and production equipment is out of service due to management action;
- c) 'interrupted'—the RAF production process is stopped due to a fault.

3.7.2.4.4 If **notification-type** is 'data discarded due to excessive backlog' or 'end of data', the **notification-value** parameter shall not be present.

3.7.3 EFFECTS

The RAF-SYNC-NOTIFY operation shall have the following effects:

- a) information about the occurrence of the specified event shall be delivered to the user;
- b) the state of the provider shall not change.

3.8 RAF-SCHEDULE-STATUS-REPORT

3.8.1 PURPOSE

3.8.1.1 The user shall invoke the RAF-SCHEDULE-STATUS-REPORT operation to request that the provider send a status report either immediately or periodically or to stop the sending of such reports.

3.8.1.2 The provider shall return a report of the outcome of the performance of the RAF-SCHEDULE-STATUS-REPORT operation to the user.

3.8.1.3 The provider shall send the requested status report(s) by means of the RAF-STATUS-REPORT operation (see 3.9).

3.8.1.4 Initially (i.e., whenever the RAF-BIND operation is performed and the provider transitions from state 1 to state 2), periodic reporting shall be stopped.

3.8.1.5 When periodic reporting is enabled, the user may change the reporting period by invoking another RAF-SCHEDULE-STATUS-REPORT operation.

3.8.1.6 The RAF-SCHEDULE-STATUS-REPORT operation shall be rejected by the provider if this service instance is configured to the offline delivery mode.

3.8.1.7 The RAF-SCHEDULE-STATUS-REPORT operation is valid only in states 2 ('ready') and 3 ('active').

3.8.1.8 The RAF-SCHEDULE-STATUS-REPORT operation shall be invoked only by the user.

3.8.2 INVOCATION, RETURN, AND PARAMETERS

3.8.2.1 General

The parameters of the RAF-SCHEDULE-STATUS-REPORT operation shall be present in the invocation and return as specified in table 3-8.

3.8.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the performer to authenticate the RAF-SCHEDULE-STATUS-REPORT invocation (see 3.1.5).

3.8.2.3 performer-credentials

The **performer-credentials** parameter shall provide information that enables the invoker to authenticate the return from the performance of RAF-SCHEDULE-STATUS-REPORT (see 3.1.5).

Table 3-8: RAF-SCHEDULE-STATUS-REPORT Parameters

| Parameters | Invocation | Return |
|-----------------------|------------|--------|
| invoker-credentials | M | |
| performer-credentials | | M |
| invoke-ID | M | M |
| report-request-type | M | |
| reporting-cycle | C | |
| result | | M |
| diagnostic | | C |

3.8.2.4 invoke-ID

The performer shall return unchanged the invoker-supplied value of the **invoke-ID** parameter (see 3.1.6).

3.8.2.5 report-request-type

3.8.2.5.1 The **report-request-type** parameter shall specify how reporting shall be done, and its value shall be one of the following:

- a) 'immediately'—send a single status report immediately;
- b) 'periodically'—send a status report every `reporting-cycle` seconds;
- c) 'stop'—do not send further status reports.

3.8.2.5.2 If `report-request-type` is 'immediately',

- a) the provider shall stop sending status reports after the immediate status report has been sent;
- b) periodic reporting may be restarted by means of another RAF-SCHEDULE-STATUS-REPORT operations.

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3.8.2.6 reporting-cycle

3.8.2.6.1 If the value of the `report-request-type` parameter is 'periodically', then the **reporting-cycle** parameter shall be present and shall specify the requested interval between status reports in seconds.

3.8.2.6.2 If the value of the `report-request-type` parameter is not 'periodically', then the `reporting-cycle` parameter shall not be present.

3.8.2.7 result

The **result** parameter shall specify the result of the `RAF-SCHEDULE-STATUS-REPORT` operation, and its value shall be one of the following:

- a) 'positive result'—the `RAF-SCHEDULE-STATUS-REPORT` operation has been performed, and the provider will send the requested report(s) or stop sending periodic status reports;
- b) 'negative result'—the `RAF-SCHEDULE-STATUS-REPORT` operation has not been performed for the reason specified in the `diagnostic` parameter. The previous setting for status reporting remains in effect.

3.8.2.8 diagnostic

3.8.2.8.1 If `result` is 'negative result', the **diagnostic** parameter shall be present in the return, and its value shall be one of the following:

- a) 'duplicate Invoke-ID'—the value of the `invoke-ID` parameter is the same as the `invoke-ID` of a previous, outstanding operation;
- b) 'not supported in this delivery mode'—the service instance is configured to the offline delivery mode;
- c) 'already stopped'—the provider is not currently providing periodic reports (applicable only when `report-request-type` is 'stop');
- d) 'invalid reporting cycle'—the requested `reporting-cycle` value is outside the range mutually agreed upon by SLE Complex Management and SLE Utilization Management;
- e) 'other reason'—the reason for rejection of the operation will have to be found by other means.

3.8.2.8.2 If `result` is 'positive result', the `diagnostic` parameter shall not be present in the return.

3.8.3 EFFECTS

3.8.3.1 If `result` is 'positive result', the `RAF-SCHEDULE-STATUS-REPORT` operation shall have the following effects, depending on the value of the `reporting-request-type` parameter:

- a) if the value of `reporting-request-type` is 'immediately':
 - 1) a status report shall be sent immediately;
 - 2) the sending of any previously requested periodic status reports shall cease;
- b) if the value of `reporting-request-type` is 'periodically':
 - 1) a status report shall sent immediately;
 - 2) subsequent status reports shall be sent at the interval specified in the `reporting-cycle` parameter;
- c) if the value of `reporting-request-type` is 'stop', periodic status reporting shall cease.

3.8.3.2 If `result` is 'negative result', the `RAF-SCHEDULE-STATUS-REPORT` operation shall have no effect, and the previous setting for status reporting shall not change.

3.8.3.3 The state of the provider shall not change.

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3.9 RAF-STATUS-REPORT**3.9.1 PURPOSE**

3.9.1.1 The provider shall invoke the RAF-STATUS-REPORT operation to send a status report to the user.

3.9.1.2 RAF-STATUS-REPORT shall be an unconfirmed operation.

3.9.1.3 Status reports shall be sent (or not sent) in accordance with user requests conveyed by means of the RAF-SCHEDULE-STATUS-REPORT operation (see 3.8).

3.9.1.4 The RAF-STATUS-REPORT operation is valid only in states 2 ('ready') and 3 ('active') and shall be invoked only by the provider.

3.9.2 INVOCATION AND PARAMETERS**3.9.2.1 General**

The parameters of the RAF-STATUS-REPORT operation shall be present in the invocation as specified in table 3-9.

Table 3-9: RAF-STATUS-REPORT Parameters

| Parameters | Invocation |
|---------------------------------------|------------|
| invoker-credentials | M |
| number-of-error-free-frames-delivered | M |
| number-of-frames-delivered | M |
| frame-sync-lock-status | M |
| symbol-sync-lock-status | M |
| subcarrier-lock-status | M |
| carrier-lock-status | M |
| production-status | M |

3.9.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the performer to authenticate the RAF-STATUS-REPORT invocation (see 3.1.5).

3.9.2.3 **number-of-error-free-frames-delivered**

The **number-of-error-free-frames-delivered** parameter shall specify the total number of telemetry frames that were annotated with a frame-quality of 'good' and delivered to the user since the start of the service instance provision period.

3.9.2.4 **number-of-frames-delivered**

The **number-of-frames-delivered** parameter shall specify the total number of telemetry frames that have been delivered to the user since the start of the service instance provision period.

3.9.2.5 **frame-sync-lock-status**

The **frame-sync-lock-status** parameter shall specify the current lock status of the frame synchronization process, the value of which shall be 'in-lock', 'out-of-lock', or 'unknown'.

3.9.2.6 **symbol-sync-lock-status**

The **symbol-sync-lock-status** parameter shall specify the current lock status of the symbol (or bit) synchronization process, the value of which shall be 'in-lock', 'out-of-lock', or 'unknown'.

3.9.2.7 **subcarrier-lock-status**

The **subcarrier-lock-status** parameter shall specify the current lock status of the subcarrier demodulation process, the value of which shall be 'in-lock', 'out-of-lock', 'not in use', or 'unknown'.

3.9.2.8 **carrier-lock-status**

The **carrier-lock-status** parameter shall specify the current lock status of the carrier demodulation process, the value of which shall be 'in-lock', 'out-of-lock', or 'unknown'.

3.9.2.9 **production-status**

The **production-status** parameter shall specify the current status of RAF production, the value of which shall be 'running', 'halted', or 'interrupted'.

NOTE – See 3.7.2.4 for a description of the **production-status** values.

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3.9.3 EFFECTS

The RAF-STATUS-REPORT operation shall have the following effects:

- a) status information shall be delivered to the user;
- b) the state of the provider shall not change.

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3.10 RAF-GET-PARAMETER

3.10.1 PURPOSE

3.10.1.1 The user shall invoke the RAF-GET-PARAMETER operation to ascertain the value of an RAF service parameter.

3.10.1.2 The provider shall return a report of the outcome of the performance of the RAF-GET-PARAMETER operation to the user.

3.10.1.3 If the operation is successful, the current value of the specified RAF service parameter shall be provided to the user in the return from the operation.

3.10.1.4 RAF-GET-PARAMETER is valid in state 2 ('ready') and state 3 ('active') and shall be invoked only by the user.

3.10.2 INVOCATION, RETURN, AND PARAMETERS

3.10.2.1 General

The parameters of the RAF-GET-PARAMETER operation shall be present in the invocation and return as specified in table 3-10.

Table 3-10: RAF-GET-PARAMETER Parameters

| Parameters | Invocation | Return |
|-----------------------|------------|--------|
| invoker-credentials | M | |
| performer-credentials | | M |
| invoke-ID | M | M |
| raf-parameter | M | C |
| parameter-value | | C |
| result | | M |
| diagnostic | | C |

3.10.2.2 invoker-credentials

The **invoker-credentials** parameter shall provide information that enables the performer to authenticate the RAF-GET-PARAMETER invocation (see 3.1.5).

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3.10.2.3 performer-credentials

The **performer-credentials** parameter shall provide information that enables the invoker to authenticate the return from the performance of RAF-GET-PARAMETER (see 3.1.5).

3.10.2.4 invoke-ID

The performer shall return unchanged the invoker-supplied value of the **invoke-ID** parameter (see 3.1.6).

3.10.2.5 raf-parameter

3.10.2.5.1 The **raf-parameter** parameter shall specify the RAF service parameter whose value is to be returned to the user, and its value shall be one of the values listed in table 3-11.

3.10.2.5.2 The **raf-parameter** parameter is conditionally present in the return based on the **result** parameter:

- a) if the value of **result** is 'positive result', **raf-parameter** shall be present in the return;
- b) if the value of **result** is 'negative result', **raf-parameter** shall not be present in the return.

3.10.2.6 parameter-value

3.10.2.6.1 The **parameter-value** parameter shall contain the value for the parameter specified by **raf-parameter** as described in 3.10.2.5 and table 3-11.

3.10.2.6.2 The **parameter-value** parameter is conditionally present in the return based on the **result** parameter:

- a) if the value of **result** is 'positive result', **parameter-value** shall be present;
- b) if the value of **result** is 'negative result', **parameter-value** shall not be present.

3.10.2.7 result

The **result** parameter shall specify the result of the RAF-GET-PARAMETER operation and shall contain one of the following values:

- a) 'positive result'—the RAF-GET-PARAMETER operation has been performed, and the value of the specified RAF service parameter is provided in the return to the user;

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- b) 'negative result'—the RAF-GET-PARAMETER operation has not been performed for the reason specified in the diagnostic parameter.

Table 3-11: RAF Parameters

| Parameter | Description |
|-----------------------------|---|
| delivery-mode | The delivery mode for this instance of RAF service, which is set by service management (see 3.1.9): its value shall be 'timely online delivery mode', 'complete online delivery mode', or 'offline delivery mode'. |
| latency-limit | The maximum allowable delivery latency time (in seconds) for the online delivery mode, as defined in 3.1.9.1 (i.e., the maximum delay from when the frame is acquired by the provider until the RAF extracted from it is delivered to the user): the value of this parameter shall be 'null' if the delivery mode is offline. |
| minimum-reporting-cycle | The minimum setting (in seconds) of the reporting cycle for status reports that the RAF service user may request in an RAF-SCHEDULE-STATUS-REPORT invocation. |
| permitted-frame-quality-set | The set of frame quality criteria that the RAF service user can choose from to select which frames the RAF service provider shall deliver. The set contains at least one of the following options: 'good frames only', 'erred frames only', or 'all frames'. |
| reporting-cycle | The current setting of the reporting cycle for status reports (see 3.8 and 3.9): the value is 'null' if cyclic reporting is off, otherwise it is the time (in seconds) between successive RAF-STATUS-REPORT invocations (see 3.8). As long as the RAF service user has not yet set this parameter by means of a successful RAF-SCHEDULE-STATUS-REPORT operation, its value shall be 'null'. |
| requested-frame-quality | The frame quality criteria, set by the RAF-START operation, used to determine which frames are selected for delivery. As long as the user has not yet set the value of this parameter by means of a successful RAF-START invocation, its value shall be that of the first element of the permitted-frame-quality-set parameter. |
| return-timeout-period | The maximum time period (in seconds) permitted from when a confirmed RAF operation is invoked until the return is received by the invoker (see 4.1.3). |
| transfer-buffer-size | The size of the transfer buffer: the value of this parameter shall indicate the number of RAF-TRANSFER-DATA and RAF-SYNC-NOTIFY invocations that can be stored in the transfer buffer. The precise specification of the transfer buffer size may be found in 3.1.9. |

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3.10.2.8 diagnostic

3.10.2.8.1 If `result` is 'negative result', the **diagnostic** parameter shall be present in the return, and its value shall be one of the following:

- a) 'duplicate Invoke-ID'—the value of the `invoke-ID` parameter is the same as the `invoke-ID` of a previous, outstanding operation;
- b) 'unknown parameter'—the value of `raf-parameter` does not identify an RAF parameter that is recognized by the service provider;
- c) 'other reason'—the reason for the negative result will have to be found by other means.

3.10.2.8.2 If `result` is 'positive result', the `diagnostic` parameter shall not be present in the return.

3.10.3 EFFECTS

3.10.3.1 If `result` is 'positive result', the value of the RAF parameter specified in the invocation shall be provided to the user in the return.

3.10.3.2 If `result` is 'negative result', no RAF parameter value shall be returned to the user.

3.10.3.3 The state of the provider shall not change.

3.11 RAF-PEER-ABORT

3.11.1 PURPOSE

3.11.1.1 The user or provider shall invoke the RAF-PEER-ABORT operations to notify the peer system that the local application detected an error that requires that the association between them be terminated abnormally.

3.11.1.2 RAF-PEER-REPORT shall be an unconfirmed operation.

3.11.1.3 RAF-PEER-ABORT is valid only in states 2 ('ready') and 3 ('active') and may be invoked by either the user or the provider.

3.11.2 INVOCATION AND PARAMETERS

3.11.2.1 General

The parameters of the RAF-PEER-ABORT operation shall be present in the invocation as specified in table 3-12.

Table 3-12: RAF-PEER-ABORT Parameters

| Parameters | Invocation |
|------------|------------|
| diagnostic | M |

3.11.2.2 diagnostic

The **diagnostic** parameter shall specify why the RAF-PEER-ABORT is being invoked, and its value shall be one of the following:

- 'access denied'—a responder with an identity as presented in the responder-identifier parameter of the RAF-BIND return is not known to the initiator (e.g., the value of the responder-identifier parameter does not match the authorized responder for any service instance known to the initiator);
- 'unexpected responder ID'—the value of the responder-identifier parameter in the RAF-BIND return does not match the identity of the authorized responder for this service instance as specified by service management;
- 'operational requirement'—the local system had to terminate the association to accommodate some other operational need;
- 'protocol error'—the local application detected an error in the sequencing of RAF service operations;

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- e) 'communications failure'—the communications service on the other side of a gateway was disrupted;

NOTE – This diagnostic value is only applicable when the SLE applications are communicating via a gateway.

- f) 'encoding error'—the local application detected an error in the encoding of one or more operation parameters or did not recognize the operation;
- g) 'return timeout'—the local application detected that the return from a confirmed operation was not received within a specified time limit;
- h) 'end of service instance provision period'—the local application detected that the service instance provision period has ended and the initiator has not invoked the RAF-UNBIND operation;
- i) 'unsolicited invoke-ID'—the local application received a return with an `invoke-ID` value that does not match the `invoke-ID` value of any of the operations for which a return is pending;
- j) 'other reason'—the local application detected an unspecified error during the processing of one or more operations.

NOTE – RAF-PEER-ABORT does not carry an `invoker-credentials` parameter. It is conceivable that an intruder may use the RAF-PEER-ABORT operation for a denial-of-service attack. If an intruder has that capability, then a denial-of-service attack can be much more easily accomplished by disrupting communications at a layer lower than the applications layer. Therefore, authentication of RAF-PEER-ABORT would not provide improved protections against such attacks.

3.11.3 EFFECTS

The RAF-PEER-ABORT operation shall have the following effects:

- a) the association shall be aborted, and the user and the provider shall cease to communicate with each other;
- b) the provider shall transition to state 1 ('unbound');
- c) the provider shall discard the contents of the transfer buffer;
- d) statistical information required for the generation of the status report shall be retained throughout the service instance provision period.

4 RAF PROTOCOL

4.1 GENERIC PROTOCOL CHARACTERISTICS

NOTE – This section specifies the handling of invalid SLE-PDUs and other failures affecting the protocol.

4.1.1 UNEXPECTED PROTOCOL DATA UNIT

If the peer application invokes an operation not allowed in the current state of the performer, the performer shall abort the association by invoking the RAF-PEER-ABORT operation with the `diagnostic` parameter set to 'protocol error'.

4.1.2 INVALID PROTOCOL DATA UNIT

If the application receives an invocation or return that contains an unrecognized operation type, contains a parameter of the wrong type, or is otherwise not decodable, the application shall abort the association by invoking the RAF-PEER-ABORT operation with the `diagnostic` parameter set to 'encoding error'.

4.1.3 MISSING RETURN

For confirmed operations, if the invoker does not receive the return from the performer within a timeout period specified by service management, the invoker shall abort the association by invoking the RAF-PEER-ABORT operation with the `diagnostic` parameter set to 'return timeout'.

NOTES

- 1 The timeout period shall be chosen taking into account performance of user and provider applications as well as the delays introduced by the underlying communications service.
- 2 In order to provide responsive service and short timeout periods, the generation of the return from an operation must not depend on any human interaction.
- 3 After invoking the RAF-UNBIND operation, the initiator must not invoke any further operations with the exception of the case addressed in 3.3.1.4 nor send any returns. The responder is not required to send any pending returns after having received the RAF-UNBIND invocation. Therefore, following an RAF-UNBIND invocation, the missing return event may occur.

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4.1.4 UNSOLICITED RETURN

If the application receives a return with an `invoke-ID` parameter value that does not correspond to any invocation for which a return is still pending, the application shall abort the association by invoking the `RAF-PEER-ABORT` operation with the `diagnostic` parameter set to 'unsolicited Invoke-ID'.

4.1.5 COMMUNICATIONS FAILURE

4.1.5.1 Every SLE entity (i.e., every SLE user or provider) that is in an association (bound) with a peer SLE entity shall maintain knowledge of the health of the communications interface with the peer.

4.1.5.2 Every SLE implementation shall provide that, for every association, the two SLE entities in the association maintain a consistent view of the health of the communications interface between them.

4.1.5.3 If an SLE entity determines that communications with the peer SLE entity have been disrupted (e.g., because of a communications service fault), then the SLE entity shall consider that the association with the peer has been aborted.

NOTE – The exact criteria for determining when communications have been disrupted may depend on the characteristics of the underlying communications service and may be specific to a given implementation. However, every RAF user and provider implementation shall provide for monitoring the health of the communications interface and for ensuring that the user and the provider have a consistent view of the health of the communications interface. If the underlying communications service does not intrinsically provide such a capability, the transmission of a periodic 'heartbeat' indicator or equivalent may need to be implemented.

4.1.5.4 Occurrence of the above described communications failure event shall be referred to as a 'protocol abort'.

4.1.5.5 Subsequent to a 'protocol abort' event:

- a) the RAF provider shall transition to state 1 ('unbound');
- b) neither the user nor the provider shall attempt further communications with the peer except that the initiator may attempt to re-establish the association by invoking the `RAF-BIND` operation;
- c) the provider shall discard the contents of the transfer buffer;
- d) the values of RAF service parameters shall return to the initial values set by service management for that service instance; and

- e) statistical information required for the generation of the status report shall be retained throughout the service instance provision period.

4.1.6 ACCESS CONTROL

4.1.6.1 The initiator of an association shall present its own identity in the `initiator-identifier` parameter of the RAF-BIND invocation.

4.1.6.2 If the RAF-BIND operation is invoked with a value of `initiator-identifier` that is not known to the responder, the responder shall not make any attempt to authenticate that invocation. Instead, the responder shall generate an RAF-BIND return with `result` set to 'negative result', `diagnostic` set to 'access denied', and `performer-credentials` set to 'unused'.

4.1.6.3 If the value of `initiator-identifier` is known to the responder, the responder shall attempt to authenticate the RAF-BIND invocation (see 3.1.5) as required for the given initiator. If authentication succeeds but the initiator is not the authorized initiator for the service instance indicated in the `service-instance-identifier` parameter of the RAF-BIND invocation, the responder shall generate an RAF-BIND return with `result` set to 'negative result' and `diagnostic` set to 'service instance not accessible to this initiator'.

NOTE – If authentication fails, the responder shall behave as specified in 4.1.7. If authentication is not required for the given initiator, it shall be as if authentication was successful.

4.1.6.4 If the initiator receives an RAF-BIND return with a `responder-identifier` value that is not known to the initiator, the initiator shall not make any attempt to authenticate this return but shall abort the association by invoking RAF-PEER-ABORT with `diagnostic` set to 'access denied'.

4.1.6.5 If the initiator receives an RAF-BIND return with a `responder-identifier` value that is known to the initiator, the initiator shall attempt to authenticate the RAF-BIND return (see 3.1.5) as required for the given responder. If authentication succeeds but the `responder-identifier` is not the authorized responder for this service instance as specified by service management, the initiator shall abort the association by means of the RAF-PEER-ABORT operation with `diagnostic` set to 'unexpected responder ID'.

NOTE – If authentication fails, the initiator shall behave as specified in 4.1.7. If authentication is not required for the given responder, it shall be as if authentication was successful.

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4.1.7 FAILING AUTHENTICATION

4.1.7.1 An incoming invocation or return shall be ignored if the credentials parameter cannot be authenticated when, by management arrangement, credentials are required.

4.1.7.2 If an invocation is ignored, the operation shall not be performed, and a report of the outcome shall not be returned to the invoker.

4.1.7.3 If a return is ignored, it shall be as if no report of the outcome of the operation has been received.

4.2 RAF SERVICE PROVIDER BEHAVIOR**4.2.1 GENERAL REQUIREMENTS**

4.2.1.1 The behavior of the RAF service provider shall conform to the state transition matrix specified in table 4-1.

4.2.1.2 All actions including state transitions specified for a given state and a given event shall be performed before a subsequent event is considered.

4.2.1.3 SLE-PDUs shall be sent in the sequence specified in table 4-1.

4.2.1.4 Implementations shall ensure that events are not lost while an earlier event is being processed but are buffered in first-in first-out order for processing as soon as processing of the earlier event has completed.

4.2.1.5 The state transition matrix specified in table 4-1 represents one instance of service and thus one association. Once the association is established, if an RAF-BIND invocation for a different association but for the same service instance is received, it shall be rejected with an RAF-BIND return with the `result` parameter set to 'negative result' and the `diagnostic` parameter set to 'already bound'. This event shall not affect the association already in place.

4.2.2 STATE TRANSITION TABLE

NOTES

- 1 The state table specifies operation interactions and state transitions for the service provider in its role as either initiator or responder.
- 2 The leftmost column simply numbers the rows of the table.
- 3 The second column of the state table lists all incoming events. Where these events correspond to the arrival of an incoming SLE-PDU, the ASN.1 type defined for this SLE-PDU in annex A is indicated in parentheses ().

- 4 Where an event is internal to the provider, its description is put in single quotation marks ‘ ’. These events are defined in table 4-2.
- 5 The three columns (one column per state) on the right side of the table specify the behavior the provider will exhibit, which depends on the current state and the incoming event. In some cases, the behavior in addition depends on Boolean conditions, also referred to as predicates. Such conditions are put in double quotation marks “ ”. The predicates are defined in table 4-3. Predicates that are simple Boolean variables set only by that state machine itself are referred to as Boolean flags and specified in table 4-4. The dependency on a predicate is presented in form of an ‘IF <condition> THEN <action> [[ELSEIF <condition> THEN <action>] ELSE <action>] ENDIF’ clause.
- 6 If the action given in the table is simply to send a specific SLE-PDU, that is indicated by the appearance of the name of ASN.1 type of the SLE-PDU to be sent in parentheses (). If that SLE-PDU is a return, the name may be preceded by the plus symbol (+) to indicate that *result* is ‘positive result’ or by the negative symbol (-) to indicate ‘negative result’. Where several actions are to be taken (referred to as a ‘compound action’), the name of the compound action is put in curly braces { }. The individual actions making up each compound action are identified in table 4-5.
- 7 ‘Not applicable’ is stated where the given event can only occur in the given state because of an implementation error on the provider side.
- 8 Where the consequences of an incoming event are not visible to the user because the provider does not send any SLE-PDU in reaction to the given event, the action is put in square brackets [].
- 9 State transitions are indicated by an arrow and the number of the state that will be entered; for example, → 1 indicates the transition to state 1.
- 10 The actions to be taken and the state transition are considered to be one atomic action. The sequence shown in the table is irrelevant except that SLE-PDUs shall be sent in the sequence stated in the table.
- 11 Whenever the provider invokes a confirmed operation with *invoke-ID* set to <n>, it shall start an associated return <n> timer. Should this timer expire before the return <n> is received, the provider shall invoke RAF-PEER-ABORT.

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Table 4-1: Provider Behavior

| No. | Incoming Event | Unbound (State 1) | Ready (State 2) | Active (State 3) |
|-----|--|--|--------------------------------------|--------------------------------------|
| 1 | 'start of service instance provision period' | IF "provider initiated" THEN {invoke bind} ENDIF → 1 | Not applicable | Not applicable |
| 2 | 'return <n> timer expired' | IF "bind pending" THEN {return timeout} IF "provision period" THEN {invoke bind} ENDIF ENDIF → 1 | Not applicable | Not applicable |
| 3 | (-rafBindReturn) | IF "bind pending" THEN set "bind pending" FALSE stop return <n> timer IF "retry permitted" THEN {invoke bind} ELSE {release resources} ENDIF ENDIF → 1 | {peer abort 'protocol error'} → 1 | {peer abort 'protocol error'} → 1 |
| 4 | (+rafBindReturn) | IF "bind pending" THEN set "bind pending" FALSE → 2 stop return <n> timer IF NOT "compatible" THEN {invoke unbind} ENDIF ENDIF | {peer abort 'protocol error'} → 1 | {peer abort 'protocol error'} → 1 |
| 5 | (rafBindInvocation) | IF "provider initiated" THEN {ignore} ELSEIF "positive result" THEN (+rafBindReturn) ELSE (-rafBindReturn) ENDIF → 1 → 2 → 1 | {peer abort 'protocol error'} → 1 | {peer abort 'protocol error'} → 1 |

| No. | Incoming Event | Unbound (State 1) | Ready (State 2) | Active (State 3) |
|-----|---|--------------------|---|---|
| 6 | 'end of service instance provision period' | [ignore] | IF "provider initiated" THEN {invoke unbind} ELSE {peer abort 'end of service instance provision period'} → 1 ENDIF | {peer abort 'end of service instance provision period'} → 1 |
| 7 | (rafUnbindReturn) | [ignore] | IF "unbind pending" THEN {provider unbind} IF "done" THEN {release resources} ENDIF ELSE {peer abort 'protocol error'} → 1 ENDIF | {peer abort 'protocol error'} → 1 |
| 8 | (rafUnbindInvocation) | [ignore] | IF "provider initiated" THEN {peer abort 'protocol error'} → 1 ELSE {user unbind} IF "end" THEN {release resources} ENDIF ENDIF | {peer abort 'protocol error'} → 1 |
| 9 | (rafStartInvocation) | [ignore] | IF "unbind pending" THEN {peer abort 'protocol error'} → 1 ELSEIF "positive result" THEN (+rafStartReturn) initialize transfer buffer ELSE (-rafStartReturn) → 2 ENDIF | {peer abort 'protocol error'} → 1 |
| 10 | (rafStopInvocation) "complete online" or "offline" delivery mode | [ignore] | {peer abort 'protocol error'} → 1 | IF "positive result" THEN IF (NOT "buffer empty") THEN {transmit buffer} (+rafStopReturn) ELSE (+rafStopReturn) ENDIF ELSE (-rafStopReturn) ENDIF → 3 |

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| No. | Incoming Event | Unbound (State 1) | Ready (State 2) | Active (State 3) |
|-----|--|--------------------|--------------------------------------|--|
| 11 | (rafStopInvocation) "timely online" delivery mode | [ignore] | {peer abort 'protocol error'} → 1 | IF "positive result" THEN IF (NOT "buffer empty") THEN {pass buffer contents} (+rafStopReturn) ELSE (+rafStopReturn) ENDIF ELSE (-rafStopReturn) → 3 ENDIF |
| 12 | 'data available', "offline" delivery mode | Not applicable | Not applicable | IF "buffer full" THEN {transmit buffer} {insert annotated frame} ELSE {insert annotated frame} → 3 ENDIF |
| 13 | 'data available', "complete online" delivery mode | Not applicable | Not applicable | IF "buffer full" THEN {transmit buffer} {insert annotated frame} {start release timer} ELSEIF "buffer empty" THEN {insert annotated frame} → 3 {start release timer} ELSE {insert annotated frame} → 3 ENDIF |

| No. | Incoming Event | Unbound (State 1) | Ready (State 2) | Active (State 3) |
|-----|---|--------------------|-----------------|---|
| 14 | 'data available', "timely online" delivery mode | Not applicable | Not applicable | IF "buffer full" THEN {pass buffer contents} → 3 IF "congested" THEN increment buffer size by one {sync notify 'data discarded'} {insert annotated frame} {start release timer} ELSE {insert annotated frame} {start release timer} ENDIF ELSEIF "buffer empty" THEN {insert annotated frame} → 3 {start release timer} ELSE {insert annotated frame} → 3 ENDIF |
| 15 | 'release timer expired', "timely online" delivery mode | Not applicable | Not applicable | {pass buffer contents} → 3 IF "congested" THEN increment buffer size by one {sync notify 'data discarded'} {start release timer} ENDIF |
| 16 | 'release timer expired', "complete online" delivery mode | Not applicable | Not applicable | {transmit buffer} → 3 |

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| No. | Incoming Event | Unbound (State 1) | Ready (State 2) | Active (State 3) |
|-----|---|---------------------|-------------------|--|
| 17 | 'end of data', "timely online" delivery mode | Not applicable | Not applicable | IF "buffer full" THEN {pass buffer contents} → 3 IF "congested" THEN {sync notify 'data discarded'} {sync notify 'end of data'} {transmit buffer} ELSE {sync notify 'end of data'} {transmit buffer} ENDIF ELSE → 3 {sync notify 'end of data'} {transmit buffer} ENDIF |
| 18 | 'end of data', "complete online" delivery mode or "offline" delivery mode | Not applicable | Not applicable | IF "buffer full" THEN {transmit buffer} {sync notify 'end of data'} {transmit buffer} ELSE {sync notify 'end of data'} → 3 {transmit buffer} ENDIF |

| No. | Incoming Event | Unbound (State 1) | Ready (State 2) | Active (State 3) |
|-----|--|---------------------|--|--|
| 19 | 'loss of frame synchronization', "timely online" delivery mode | Not applicable | [ignore] → 2 | IF "buffer full" THEN {pass buffer contents} → 3 IF "congested" THEN {sync notify 'data discarded'} {start release timer} {sync notify 'loss of frame sync'} ELSE {sync notify 'loss of frame sync'} {start release timer} ENDIF ELSEIF "buffer empty" THEN {sync notify 'loss of frame sync'} → 3 {start release timer} ELSE {sync notify 'loss of frame sync'} → 3 ENDIF |
| 20 | 'loss of frame synchronization', "complete online" delivery mode | Not applicable | [ignore] → 2 | IF "buffer full" THEN {transmit buffer} → 3 {sync notify 'loss of frame sync'} {start release timer} ELSEIF "buffer empty" THEN {sync notify 'loss of frame sync'} → 3 {start release timer} ELSE {sync notify 'loss of frame sync'} → 3 ENDIF |
| 21 | 'production status change', "timely online" delivery mode or "complete online" delivery mode | Not applicable | IF NOT "unbind pending" THEN {sync notify 'production status change'} → 2 ENDIF | {sync notify 'production status change'} → 3 |

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| No. | Incoming Event | Unbound (State 1) | Ready (State 2) | Active (State 3) |
|-----|---|--------------------|--|--|
| 22 | (rafScheduleStatusReportInvocation) | [ignore] | IF "positive result" THEN (+rafScheduleStatusReport) → 2 IF "immediately" THEN {immediate report} ELSEIF "periodically" THEN {periodic report} ELSE stop reporting-cycle timer ENDIF ELSE → 2 (-rafScheduleStatusReportReturn) ENDIF | IF "positive result" THEN (+rafScheduleStatusReport) → 3 IF "immediately" THEN {immediate report} ELSEIF "periodically" THEN {periodic report} ELSE stop reporting-cycle timer ENDIF ELSE → 3 (-rafScheduleStatusReportReturn) ENDIF |
| 23 | 'reporting-cycle timer expired' | Not applicable | {periodic report} → 2 | {periodic report} → 3 |
| 24 | (rafGetParameterInvocation) | [ignore] | IF "positive result" THEN (+rafGetParameterReturn) → 2 ELSE (-rafGetParameterReturn) → 2 ENDIF | IF "positive result" THEN (+rafGetParameterReturn) → 3 ELSE (-rafGetParameterReturn) → 3 ENDIF |
| 25 | (rafPeerAbortInvocation) | [ignore] | {clean up} → 1 | {clean up} → 1 |
| 26 | 'invalid protocol data unit' | [ignore] | {peer abort ('encoding error')} → 1 | {peer abort ('encoding error')} → 1 |
| 27 | 'return SLE-PDU with unsolicited Invoke-ID' | [ignore] | {peer abort ('unsolicited Invoke-ID')} → 1 | {peer abort ('unsolicited Invoke-ID')} → 1 |
| 28 | 'protocol abort' | [ignore] | {clean up} → 1 | {clean up} → 1 |
| 29 | 'not authenticated SLE-PDU' | [ignore] → 1 | [ignore] → 2 | [ignore] → 3 |

Table 4-2: Event Description References

| Event | Reference |
|--|---------------------------------|
| 'data available' | 3.1.9.1.2, 3.1.9.2.2, 3.1.9.3.2 |
| 'end of data' | 3.7.2.3 |
| 'end of service instance provision period' | 3.11.2.2 |
| 'invalid protocol data unit' | 4.1.2 |
| 'loss of frame synchronization' | 3.7.2.3 |
| 'not authenticated SLE-PDU' | 4.1.7 |
| 'production status change' | 3.7.2.3 |
| 'release timer expired' | 3.1.9.1.4, 3.1.9.2.6 |
| 'reporting-cycle timer expired' | 3.8.2.6 |
| 'return SLE-PDU with unsolicited Invoke-ID' | 4.1.4 |
| 'return <n> timer expired' | 4.1.3 |
| 'start of service instance provision period' | 1.6.1.7.13 |

Table 4-3: Predicate Descriptions

| Predicate | Evaluates to TRUE if |
|----------------------|---|
| "buffer empty" | There are no RAF SLE-PDUs in the transfer buffer |
| "buffer full" | The transfer buffer cannot accommodate the currently available annotated frame or synchronous notification |
| "compatible" | The version number contained in (+rafBindReturn) is supported by the responder |
| "complete online" | Delivery mode is complete online |
| "done" | The <code>unbind-reason</code> parameter value in the provider-initiated BIND invocation was 'end' |
| "end" | All checks on the UNBIND invocation are passed and the <code>unbind-reason</code> parameter value is 'end' |
| "immediately" | All parameter checks on the RAF-SCHEDULE-STATUS-REPORT are passed and the <code>report-request-type</code> value is 'immediately' |
| "offline" | Delivery mode is offline |
| "online" | Delivery mode is timely online or complete online |
| "periodically" | All parameter checks on the RAF-SCHEDULE-STATUS-REPORT are passed and the <code>report-request-type</code> value is 'periodically' |
| "positive result" | All checks on the invocation are passed |
| "provider initiated" | The RAF-BIND operation is specified to be initiated by the provider for this service instance |
| "provision period" | Current time is inside the service instance provision period |
| "retry permitted" | The <code>diagnostic</code> value contained in the (-rafBindReturn) is 'unable to comply' or 'other', and the service instance provision period is still active |
| "timely online" | Delivery mode is timely online |

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Table 4-4: Boolean Flags

| Flag Name | Initial Value |
|------------------|---------------|
| "bind pending" | FALSE |
| "congested" | FALSE |
| "unbind pending" | FALSE |

Table 4-5: Compound Action Definitions

| Name | Actions Performed |
|--------------------------|---|
| {clean up} | stop release timer stop all return timers stop reporting-cycle timer reinitialize transfer buffer |
| {immediate report} | (rafStatusReportInvocation) stop reporting-cycle timer |
| {insert annotated frame} | annotate the available frame with the parameters of the RAF-TRANSFER-DATA operation insert the annotated frame into the transfer buffer |
| {invoke bind} | (rafBindInvocation) set "bind pending" to TRUE start return <n> timer |
| {invoke unbind} | (rafUnbindInvocation) stop reporting-cycle timer set "unbind pending" to TRUE start return <n> timer |
| {pass buffer contents} | stop release timer submit contents of transfer buffer to underlying communications service IF successful THEN set "congested" to FALSE ELSE set "congested" to TRUE ENDIF reinitialize transfer buffer using the nominal size |
| {peer abort xxxx} | stop release timer stop all return timers stop reporting-cycle timer reinitialize transfer buffer (rafPeerAbortInvocation) with <i>diagnostic</i> set to 'xxxx' |
| {periodic report} | (rafStatusReportInvocation) set reporting-cycle timer to the <i>reporting-cycle</i> value in the most recent SCHEDULE-STATUS-REPORT invocation start reporting-cycle timer |

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| Name | Actions Performed |
|-----------------------|--|
| {provider unbind} | set “unbind pending” to FALSE stop all return timers |
| {release resources} | delete the service instance and release the associated resources if applicable, discard the online frame buffer |
| {return timeout} | (rafPeerAbortInvocation) with <i>diagnostic</i> ‘return timeout’ set “bind pending” to FALSE set “unbind pending” to FALSE |
| {start release timer} | set release timer to latency limit start release timer |
| {sync notify ‘xxxx’} | create an RAF synchronous notification with <i>notification-type</i> set to ‘xxxx’ insert the notification into the transfer buffer |
| {transmit buffer} | stop release timer Submit the contents of transfer buffer to underlying communications service until accepted by that service reinitialize transfer buffer |
| {user unbind} | stop reporting-cycle timer stop all return timers (rafUnbindReturn) |

ANNEX A

DATA TYPE DEFINITIONS

(NORMATIVE)

A1 INTRODUCTION

A1.1 This annex defines the data types that are used by the RAF service. It is intended to provide a clear specification of these data types and to avoid ambiguity. It is not intended to constrain how these data types are implemented or encoded. These definitions are suitable for inclusion in any type of ASN.1 based protocol that implements the RAF service.

A1.2 The data type definitions are presented in seven ASN.1 modules.

A1.3 Subsection A2.1 contains basic types that are common with other SLE Transfer Services. As more services become specified by CCSDS, further types may be added to this module or existing types may be extended. However, that eventuality is not expected to invalidate the module in its present form because it is expected that an implementation compliant with a future extended version of this module will be interoperable with an implementation based on its present version.

A1.4 Subsection A2.2 specifies the SLE-PDUs exchanged between an SLE user and an SLE provider application in order to establish, release or abort an association. They are common among SLE transfer service types.

A1.5 Subsection A2.3 specifies SLE-PDUs related to invocations and returns that are common to SLE transfer service types.

A1.6 Subsection A2.4 specifies the format of the Service Instance Identifiers.

A1.7 Subsection A2.5 specifies data types specific to the RAF service. In part, these specific types are derived from types specified in A2.1 by means of subtyping.

A1.8 Subsection A2.6 specifies all incoming (from a provider point of view) SLE-PDUs. Where applicable, these SLE-PDUs are mapped to the generic SLE-PDUs defined in A2.2 and A2.3.

A1.9 Subsection A2.7 specifies in the same way the outgoing SLE-PDUs.

A1.10 Although subsections A2.2, A2.3, A2.6 and A2.7 define the SLE-PDUs that will be exchanged between the SLE provider and user applications, they shall not be interpreted as requiring that these SLE-PDUs shall be completely mapped to the user data field of the underlying communications protocol. For example, depending on the communications protocol(s) used, part of the SLE-PDUs may be used to determine the appropriate setting of protocol control information.

A2 RAF DATA TYPE SPECIFICATION**A2.1 SLE TRANSFER SERVICE—COMMON TYPES**

CCSDS-SLE-TRANSFER-SERVICE-COMMON-TYPES

```

{ iso identified-organization(3)
  standards-producing-organization(112) ccsds(4)
  space-link-extension(3) sle-transfer-services(1)
  modules(1) common-modules(99) version-five(5) asnl-common-types(1)
}

```

DEFINITIONS

IMPLICIT TAGS

::= BEGIN

```

EXPORTS ConditionalTime
, Credentials
, DeliveryMode
, Diagnostics
, Duration
, ForwardDuStatus
, IntPosLong
, IntPosShort
, IntUnsignedLong
, IntUnsignedShort
, InvokeId
, ParameterName
, SlduStatusNotification
, SpaceLinkDataUnit
, Time
;

```

```

ConditionalTime ::= CHOICE
{ undefined [0] NULL
, known [1] Time
}

```

```

-- If credentials are used, it will be necessary that
-- the internal structure of the octet string is known
-- to both parties. Since the structure will depend on
-- algorithm used, it is not specified here. However,
-- the peer entities may use ASN.1 encoding to make the
-- internal structure visible.

```

```

Credentials ::= CHOICE
{ unused [0] NULL
, used [1] OCTET STRING (SIZE (8 .. 256))
}

```

```

DeliveryMode ::= INTEGER
{ rtnTimelyOnline (0)
, rtnCompleteOnline (1)
, rtnOffline (2)
, fwdOnline (3)
, fwdOffline (4)
}

```

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```

Diagnostics                ::=  INTEGER
{ duplicateInvokeId        (100)
,   otherReason            (127)
}

-- The Duration is expressed in microseconds
Duration                    ::=  IntUnsignedLong

ForwardDuStatus             ::=  INTEGER
{   radiated               (0)
,   expired                (1)
,   interrupted            (2)
,   acknowledged          (3)   -- FSP
,   productionStarted      (4)   -- CLTU: 'radiation started'
,   productionNotStarted   (5)   -- CLTU: 'radiation not started'
,   unsupportedTransmissionMode (6)   -- FSP
}

-- 1 to (2^32)-1
IntPosLong                  ::=  INTEGER (1 .. 4294967295)

-- 1 to (2^16)-1
IntPosShort                 ::=  INTEGER (1 .. 65535)

-- 0 to (2^32)-1
IntUnsignedLong             ::=  INTEGER (0 .. 4294967295)

-- 0 to (2^16)-1
IntUnsignedShort            ::=  INTEGER (0 .. 65535)

InvokeId                   ::=  IntUnsignedShort

```

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```

ParameterName ::= INTEGER
{
  acquisitionSequenceLength (201)
  , apidList (2)
  , bitLockRequired (3)
  , blockingTimeoutPeriod (0)
  , blockingUsage (1)
  , bufferSize (4)
  , clcwGlobalVcId (202)
  , clcwPhysicalChannel (203)
  , copCntrFramesRepetition (300)
  , deliveryMode (6)
  , directiveInvocation (7)
  , directiveInvocationOnline (108)
  , expectedDirectiveIdentification (8)
  , expectedEventInvocationIdentification (9)
  , expectedSlduIdentification (10)
  , fopSlidingWindow (11)
  , fopState (12)
  , latencyLimit (15)
  , mapList (16)
  , mapMuxControl (17)
  , mapMuxScheme (18)
  , maximumFrameLength (19)
  , maximumPacketLength (20)
  , maximumSlduLength (21)
  , minimumDelayTime (204)
  , minReportingCycle (301)
  , modulationFrequency (22)
  , modulationIndex (23)
  , notificationMode (205)
  , permittedControlWordTypeSet (101)
  , permittedFrameQuality (302)
  , permittedGvcidSet (24)
  , permittedTcVcidSet (102)
  , permittedTransmissionMode (107)
  , permittedUpdateModeSet (103)
  , ploplIdleSequenceLength (206)
  , ploplInEffect (25)
  , protocolAbortMode (207)
  , reportingCycle (26)
  , requestedControlWordType (104)
  , requestedFrameQuality (27)
  , requestedGvcid (28)
  , requestedTcVcid (105)
  , requestedUpdateMode (106)
  , returnTimeoutPeriod (29)
  , rfAvailable (30)
  , rfAvailableRequired (31)
  , segmentHeader (32)
  , sequCntrFramesRepetition (303)
  , subcarrierToBitRateRatio (34)
  , throwEventOperation (304)
  , timeoutType (35)
  , timerInitial (36)
  , transmissionLimit (37)
  , transmitterFrameSequenceNumber (38)
  , vcMuxControl (39)
  , vcMuxScheme (40)
  , virtualChannel (41)
}

```


CCSDS RECOMMENDED STANDARD FOR SLE RAF SERVICE

```

SlduStatusNotification ::= INTEGER
{
  produceNotification      (0)
, doNotProduceNotification (1)
}

SpaceLinkDataUnit ::= OCTET STRING (SIZE (1 .. 65536))

Time ::= CHOICE
{
  ccsdsFormat      [0] TimeCCSDS
, ccsdsPicoFormat  [1] TimeCCSDSpico
}

TimeCCSDS ::= OCTET STRING (SIZE(8))
-- P-field is implicit (not present, defaulted to 41 hex
-- T-field:
-- 2 octets: number of days since 1958/01/01 00:00:00
-- 4 octets: number of milliseconds of the day
-- 2 octets: number of microseconds of the millisecond
-- (set to 0 if not used)
-- This definition reflects exactly the format of the CCSDS defined
-- time tag as used in spacelink data units (see reference [7]).

TimeCCSDSpico ::= OCTET STRING (SIZE(10))
-- P-field is implicit (not present, defaulted to 42 hex
-- T-field:
-- 2 octets: number of days since 1958/01/01 00:00:00
-- 4 octets: number of milliseconds of the day
-- 4 octets: number of picoseconds of the millisecond
-- (set to 0 if not used)
-- This definition reflects exactly the format of the CCSDS defined
-- time tag as used in spacelink data units (see reference [7]).

END

```