The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

CROSS SUPPORT TRANSFER SERVICE—FORWARD FRAME SERVICE

RECOMMENDED STANDARD

CCSDS 922.3-B-1

BLUE BOOK

April 2021

The Consultative Committee for Space Data Systems

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Email: secretariat@mailman.ccsds.org

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1 INTRODUCTION

1.1 PURPOSE OF THIS RECOMMENDED STANDARD

This Recommended Standard defines the Forward Frame Cross Support Transfer Service (FF-CSTS). The FF-CSTS is a transfer service that provides the transfer of fixed-length and variable-length Transfer Frames and Channel Access Data Units (CADUs) to a Provider Cross Support Service System (CSSS) Earth-Space Link Terminal (ESLT, e.g., a ground station) to be encoded (as needed) and radiated to a Space User Node (e.g., a mission spacecraft). The supported variable-length Transfer Frames include Telecommand (TC) Transfer Frames defined in reference [7] and variable-length Unified Space Data Link (USLP) Transfer Frames defined in reference [9]. The supported fixed-length Transfer Frames include the Advanced Orbiting System (AOS) Transfer Frames defined in reference [8] and fixed-length USLP Transfer Frames defined in reference [9]. The supported CADU format is defined in reference [10].

NOTES

1 The CADU defined in reference [10] is the CCSDS-standard data unit that carries fixed-length transfer frames into the physical channel and is therefore applicable to AOS Transfer Frames and fixed-length USLP Transfer Frames. As of the publication of this Recommended Standard, the CADU as defined in the current version of reference [10] applies only in the context of telemetry data transmitted on a space-to-ground link. CCSDS is in the process of revising reference [10] to specify which of the coding and synchronization functions and formats that are defined therein will be applicable to the transmission of fixed-length Transfer Frames on the forward link, and to make the CADU a data unit of the forward link.

2 Although the Forward Frame service is defined to support the use of TC, AOS, and USLP Transfer Frames and CADUs on the forward link, the transfer service may be used to handle other space data link and/or channel synchronization data unit formats. The use of the Forward Frame service to support such other data unit formats is outside the normative scope of this Recommended Standard. However, informative annex J presents examples of use cases in which the transfer service can be used beyond the configurations defined in this Recommended Standard.

3 In this Recommended Standard, the term *Space Link Protocol Data Unit* (SL-PDU) refers to either a Transfer Frame or a CADU. It is used in statements that apply to both Transfer Frames and CADUs.

When used to carry Transfer Frames, multiple instances of the Forward Frame service can exist for the same single forward space link physical channel, and each service instance carries the frames from one Virtual Channel (VC) (see references [7], [8], and [9]). Conversely, when used to carry CADUs, the forward space link physical channel is dedicated to a single instance of the Forward Frame service.

When Forward Frame service instances are used to carry individual VCs, those VCs may be multiplexed with VCs from other non-Forward Frame service sources. Such multiplexing is not a function of the Forward Frame service but is a function of the underlying production processing.

1.2 SCOPE

This Recommended Standard defines the FF-CSTS using procedures and operations defined in the *Cross Support Transfer Service Specification Framework* (reference [1]) and in accordance with the *Guidelines for the Specifications of Cross Support Transfer Services* (reference [3]).

1.2.1 Specifically, the Recommended Standard is defined in terms of

a) the CSTS Specification Framework (SFW) procedures that comprise the Forward Frame service. The SFW procedures used in any implementation of this Issue (Issue-1) of this Recommended Standard must conform to the selected procedures as specified in Issue-2 of the SFW as specified in reference [1]. Any future Issues of this Recommended Standard (if any) will reference and conform to the Issue of the SFW that is in effect at that time;

b) the extensions and refinements of the behavior of those CSTS procedures necessary to provide the transfer service;

c) the extensions and refinements of standard CSTS operations associated with each of the procedures;

d) the relationships among the procedures that comprise the service; and

e) the requirements on Forward Frame service production to enable the proper operation of the FF-CSTS.

1.2.2 This Recommended Standard 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 measure the values of Forward Frame service parameters;

d) the methods or technologies required for communication (including methods or technologies to secure communication);

e) methods or technologies employed by users of the Forward Frame service to secure the contents of the data being transferred, including (but not limited to) the use of the CCSDS Space Data Link Security Protocol (reference [L15] and Space Data Link Security Protocol Extended Procedures (reference [L21]) to secure the contents of the transfer frames or CADUs prior to transmitting those frames/CADUs through the FF service; or

f) the management activities necessary to schedule, configure, and control the FF-CSTS.

1.3 APPLICABILITY

The applicability and limits of applicability of CSTSes in general, as described in [1], pertain to the FF-CSTS.

The FF-CSTS is applicable in situations in which there is a need for multiple users to concurrently send data destined for the same space link physical channel to a Space User Node. Each Forward Frame service instance delivers the Transfer Frames from its user to the appropriate underlying production Space Data Link Protocol (SDLP) functions (multiplexing and Only Idle Data frame insertion, as defined in references [7], [8], and [9]), and synchronization and channel coding functions (encoding, randomization, and frame synchronization marking, as defined in reference [11] and in a planned revised version of reference [10]). These underlying production functions are configured by Service Management functions to work cooperatively with Forward Frame transfer service instance(s) to collectively process the user-supplied transfer frames or transmit them to the User Space Node. These underlying production functions may also simultaneously multiplex, encode, etc., frames from other VC sources into the same space link physical channel, although the capability to support such other VC sources is defined by the referenced SDLP and synchronization and channel coding Recommended Standards and is outside the normative scope of this Recommended Standard.

The FF-CSTS is also applicable in situations in which the Earth User Node performs the multiplexing and coding of all fixed length transfer frames to produce all of the user-data-bearing CADUs destined for the same forward space link physical channel. When the FF-CSTS is used to carry CADUs, the underlying production generates Only Idle Data CADUs to maintain the continuous and contiguous flow of CADUs on the forward link, in accordance with the transfer frame formats specified in references [8] and [9] and symbol stream generation requirements specified in a planned revised version of reference [10].

The Forward Frame service operates in one of *two data processing modes*, the *sequence-controlled data processing mode* (see 1.6.1.12.2.1) and the *buffered data processing mode* (see 1.6.1.12.2.2), which allows the service user to trade off between frame-by-frame control of transmission vs. data throughput. Each instance of the Forward Frame service is configured to be in a single data processing mode for the duration of the execution of a Service Package.

1.4 RATIONALE

1.4.1 The rationale for this Recommended Standard is

a) to create a standard for interoperability for the exchange of fixed-length transfer frames, variable-length transfer frames, and CADUs between the cross-support elements of various space agencies and the users of the cross-support services provided by these agencies;

b) to permit Earth User Node sources of VC transfer frames to share the same forward space link physical channel with other VC transfer frame sources, including, but not limited to, other Forward Frame service instances, Delay Tolerant Network (DTN) bundle agents (see annex K), Internet Protocol (IP) routers, and CFDP file delivery agents; and

c) to permit Earth User Nodes to generate and transfer CADUs to be transmitted on a forward space link physical channel.

1.4.2 Four use cases motivate the existence of the Forward Frame service:

a) The ability to transfer TC Transfer Frames (see reference [7]) and variable-length USLP Transfer Frames Transfer Frames (see reference [9]) with sequence and timing enforcement behavior comparable to that provided for CLTUs by the SLE Forward CLTU service (reference [L4]) and for TC Space Packets by the SLE Forward Space Packet service (reference [L14]); this use case is illustrated in annexes I2 and I4.

b) The ability to transfer AOS Transfer Frames (see reference [8]) and USLP fixed-length Transfer Frames (see reference [9]) with maximum throughput and with no sequence or timing enforcement (by the transfer service itself). This use case is illustrated in annexes I3 and I5.

c) The ability to transfer fixed-length CADUs (see reference [10]) with maximum throughput and with no sequence or timing enforcement (by the transfer service itself). This use case provides the fixed-length frame equivalent of the SLE Forward CLTU service (reference [L4]). This use case is illustrated in annex I6.

d) The ability to multiplex data from different sources into a single space link physical channel or master channel including specifically sources that accept DTN bundles or IP datagrams, and process them to create correctly formatted transfer frames for multiplexing. This use case provides services critical to cross supported Solar System Internetworking (SSI) networking configurations (reference [L16]). This use case is illustrated in annex K.

However, the Forward Frame service is not restricted to these four uses cases, and other combinations are possible. For example, variable-length transfer frames could be transferred by a Forward Frame service instance that is configured to operate in the data processing mode that maximizes throughput and performs no sequencing or timing enforcement. Annex J provides several examples of such extended use cases.

1.5 DOCUMENT STRUCTURE

1.5.1 DOCUMENT ORGANIZATION

Section 2 describes the FF-CSTS in terms of

– the functional description of the production and provision of the service;

– the role of Service Management with respect to the FF-CSTS;

– the cross-support view of the FF-CSTS; and

– operational scenarios that illustrate some of the more significant aspects of the service.

Section 3 specifies the top-level composition of the FF-CSTS. The service-type identifier is declared, the procedures that comprise the service are identified, and the CSTS state machine that applies to the FF-CSTS is specified.

Section 4 defines the Sequence Controlled Frame Data Processing (SCFDP) procedure as a derivation of the CSTS SFW Sequence Controlled Data Processing procedure.

Section 5 defines the Buffered Frame Data Processing (BFDP) procedure as a derivation of the CSTS SFW Buffered Data Processing procedure.

Section 6 defines the refinements to the CSTS SFW Throw Event procedure as it is used by the Forward Frame service.

Section 7 specifies how the procedure configuration parameters are to be set for the FF-CSTS.

Section 8 specifies the Forward Frame Service-specific versions of the service-level parameters and events that are required by the CSTS SFW to be present in all CSTSes.

Section 9 defines the refinement of CSTS SFW-defined parameters and events as they apply to the FF-CSTS.

Annex A is the Implementation Conformance Statement (ICS) Proforma for the Forward Frame service.

Annex B is the Abstract Syntax Notation One (ASN.1) module that formally specifies the object identifiers for the Forward Frame transfer service and the FF-CSTS Provider Functional Resource (FR) Type.

Annex C formally specifies the ASN.1 PDUs for the Sequence Controlled Frame Data Processing procedure.

Annex D formally specifies the ASN.1 PDUs for the BFDP procedure.

Annex E formally specifies the ASN.1 PDUs for the Master Throw Event procedure.

Annex F formally specifies the ASN.1 parameters, events, and directives for the Sequence Controlled Frame Data Processing and BFDP procedures.

Annex G identifies the space data link protocol, synchronization and channel coding, and space data link physical channel functions that are performed by the production process that underlies the Forward Frame service and defines the Forward Frame-specific requirements on that production process.

Annex H addresses the security, Space Assigned Numbers Authority (SANA), and patent considerations associated with the FF-CSTS.

Annex I provides examples of the use of the Forward Frame service and the associated production functions to support the transmission of TC frames, AOS frames, variable-length USLP frames, fixed-length frames, and CADUs.

Annex J provides examples of use cases in which the Forward Frame service can be used outside of the use cases for which the service is defined.

Annex K describes how the Forward Frame service enables an ESLT to receive DTN bundles and mission-generated transfer frames and multiplex them into a single forward space link.

Annex L lists the informative references cited in this Recommended Standard.

Annex M lists the abbreviations and acronyms used in this Recommended Standard.

Annex N lists the cross-references to the CSTS SFW (reference [1]).

1.5.2 CROSS SUPPORT TRANSFER SERVICES DOCUMENTATION

The basic organization of the Cross Support Services documentation and the relationship to the CSTS documentation is shown in figure 1-1.

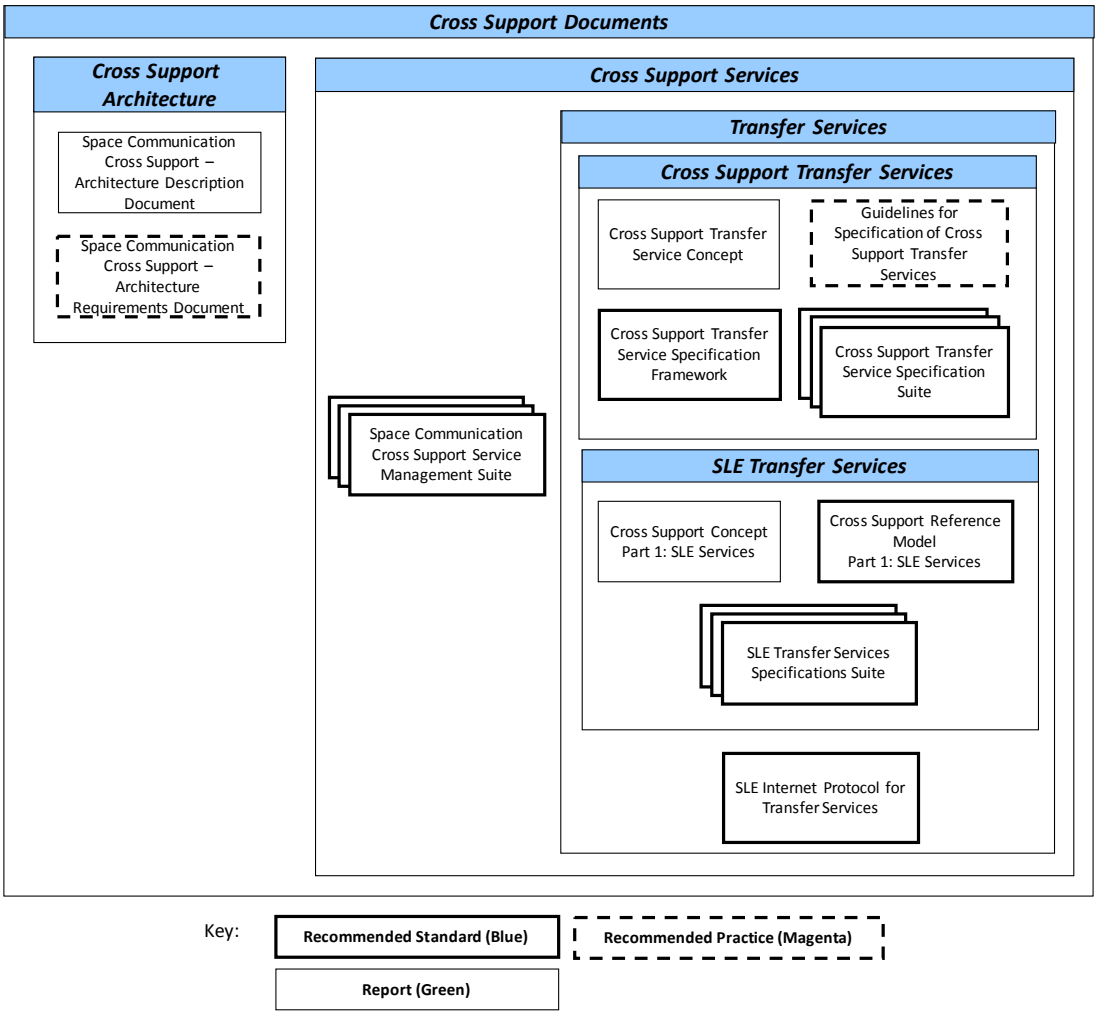


Figure 1-1: Cross Support Services Documentation

The Cross Support Architecture is documented in

a) *Space Communications Cross Support—Architecture Description Document* (reference [L8]): An Informational Report describing an architecture in terms of CCSDS-recommended configurations for secure space communications cross support. This architecture is intended to be used as a common framework when CCSDS Agencies a) provide and use space communications cross support services and b) develop systems that provide interoperable space communications cross support.

b) *Space Communications Cross Support—Architecture Requirements Document* (reference [L16]): A Recommended Practice defining a set of requirements for CCSDS-recommended configurations for secure space communications cross support architectures.

Common to all Cross Support Services

c) *Space Communication Cross Support Service Management suite* (references [L5], [L6], and [L7]). Data format Recommended Standards that specify the Service Management Information Entities that are used to configure and schedule cross support services, which include transfer services.

Common to the Transfer Services, that is, SLE Transfer Services and CSTSes

d) *Space Link Extension—Internet Protocol for Transfer Services* (reference [L2]): A Recommended Standard that defines a protocol for transfer of Protocol Data Units (PDUs) defined in the CSTSes. This Recommended Standard was originally developed to support SLE transfer services (hence the title), but it is also applicable to CSTSes.

The concept, the reference model, and the SLE Transfer Services are documented in

e) *Cross Support Concept—Part 1: Space Link Extension Services* (reference [L1]): A report introducing the concepts of cross support and the SLE services. Many of the concepts for the SLE transfer services have been adopted for the CSTSes (see k) below).

f) *Cross Support Reference Model—Part 1: Space Link Extension Services* (reference [2]): A Recommended Standard that defines the framework and terminology for the specification of SLE services. Much of the framework and terminology of this reference model has been adopted or adapted for CSTSes (see 1.6.3.1 and 2.2 of reference [1]).

g) The *SLE Transfer Services suite*: The SLE Transfer Services are a suite of Cross Support Services that are used to transfer specific TC and TM PDUs. The SLE Transfer Services are closely related to the CSTS suite in that they collectively define the set of operations that are the basis for the CSTS SFW. However, because of their history (the SLE Transfer Services were already specified and implemented prior to development of the CSTS SFW), the SLE Transfer Services are separated from CSTSes.

The documents specific to CSTSes are

h) *Cross Support Transfer Services Specification Framework* (reference [1]): A Recommended Standard that defines the specification of the CSTS procedures;

i) *Guidelines for Specification of Cross Support Transfer Services* (reference [3]): A Recommended Practice that defines the guidelines for construction of a CSTS based on the CSTS SFW;

j) *Cross Support Transfer Services Concept* (reference [L3]): A Report that provides tutorial material on the objectives and concepts of the CSTS specification; and

k) *Cross Support Transfer Services Suite*: The set of specifications for actual CSTSes built from the procedures in the CSTS SFW and in accordance with the CSTS Guidelines. This Recommended Standard is a member of this suite.

1.6 DEFINITIONS

1.6.1 TERMS

1.6.1.1 Terms Defined in *Cross Support Transfer Service—Specification Framework*, Reference [1]

a) Association Control procedure;

b) blocking [operation];

c) Buffered Data Processing procedure;

d) complete [transfer mode];

e) CSTS;

f) functional resource;

g) latency-limit;

h) procedure configuration parameter;

i) ProcessDataInvocation;

j) qualified parameter;

k) Sequence Controlled Data Processing procedure;

l) service instance provision period;

m) service management parameter;

n) timely [transfer mode].

1.6.1.2 Terms Defined in the *Cross Support Reference Model—Part 1: Space Link Extension Services*, Reference [2]

a) Mission User Entity (MUE);

b) Service Package;

c) space link session.

1.6.1.3 Terms Defined in the *Space Communications Cross Support—Architecture Description Document*, Reference [L8]

a) CSSS;

b) ESLT;

c) Earth User CSSS;

d) Earth User Node;

e) Element Management (EM);

f) Provider CSSS;

g) Provision Management (PM);

h) Service Management;

i) Space User Node;

j) Utilization Management (UM).

1.6.1.4 Terms Defined in Abstract Syntax Notation One, Reference [5]

a) ASN.1;

b) Object Identifier.

NOTE – In annexes B, C, D, E, and F of this Recommended Standard, ASN.1 is used for specifying the Object Identifiers and the abstract syntax of the PDUs, parameters, events, and directives of the Forward Frame service.

1.6.1.5 Terms Defined in the TC, AOS, and Unified Space Data Link Protocols, References [7], [8], and [9], Respectively

a) Communications Operation Procedure (COP) (reference [7] only);

b) Global Virtual Channel Identifier (GVCID);

c) Only Idle Data Frame (references [8] and [9] only);

d) Master Channel (MC);

e) Master Channel Identifier (MCID);

f) Spacecraft Identifier (SCID);

g) Transfer Frame (the format is specific to each space data link protocol);

h) Transfer Frame Primary Header;

i) Transfer Frame Version Number (TFVN);

j) VC; and

k) Virtual Channel Identifier (VCID).

1.6.1.6 Terms Defined in the *TM Synchronization and Channel Coding* Recommended Standard, Reference [10]

a) Attached Synchronization Marker (ASM);

b) convolutional coding;

c) Channel Access Data Unit (CADU);

d) Low-Density Parity-Check (LDPC);

e) LDPC coding of a stream of Sync-Marked Transfer Frames;

f) Reed-Solomon;

g) Sync-Marked Transfer Frame (SMTF);

h) Turbo.

1.6.1.7 Terms Defined in this Recommended Standard

1.6.1.7.1 bit masking: As used in this Recommended Standard, bit masking is the method used by Forward Frame services to validate the subfields of the first four octets of the SL-PDU that correspond to the TFVN, SCID, and VCID (which collectively constitute the GVCID) of the Transfer Frame Primary Header of the CCSDS TC, AOS, and USLP Transfer Frames. Because these subfields are of different lengths and appear in different locations within the first four octets of each type of Transfer Frame, a different bit mask exists for each Transfer Frame type. Within each Transfer Frame type's bit mask, the bits of the TFVN, SCID, and VCID subfields are all set to one (1). When a Forward Frame service instance receives an SL-PDU, it ANDs the bit mask with the first four octets of that SL-PDU. If the TFVN, SCID, and VCID subfields of the product of the ANDing are equal to the values of

the TFVN, SCID, and VCID subfields of the four-octet *authorized GVCID* configuration parameter for that Forward Frame service instance.

1.6.1.8 For example, for TC transfer frames, the TFVN appears in bits 0 and 1, the SCID appears in bits 6–15, and the VCID appears in bits 16-21 of the first 4 octets of the Transfer Frame Primary Header. The corresponding GVCID bit mask is

1.6.1.9 11000011 11111111 11111100 00000000 (C3 FF FC 00 Hex)

1.6.1.10 where the spaces between the octet values are for readability.

1.6.1.11 For a Forward Frame service instance configured to process TC transfer frames for the GVCID (TFVN = 0, SCID = 20, VCID = 3), the corresponding authorized GVCID configuration parameter has the value

1.6.1.12 00000000 00010100 00001100 00000000 (00 14 0C 00 Hex)

NOTE – Bit masking is intended for use in Transfer Frame configurations, where multiple Forward Frame service instances for the same space link physical channel are possible and therefore each Forward Frame service instance needs to authenticate transfer frames to ensure that they are of the authorized GVCID. In the CADU configuration there is only a single Forward Frame instance for each physical channel, so the bit mask and authorized GVCID can both be set to all zeroes—that is, 'don't care'—to allow all CADUs to be authenticated regardless of the content of their first four octets (nominally, all or part of the Attached Synchronization Marker).

1.6.1.12.1 CADU configuration: A combination of a single Forward Frame transfer service instance and underlying production functions that are configured by Service Management to support the transfer of CADUs from an Earth User Node to the ESLT performing the Forward Frame service instances. The single Forward Frame service instance provides all of the CADUs for the associated space link physical channel.

1.6.1.12.2 data processing mode: The mode in which a Forward Frame service instance is configured (via Service Management) to process received SL-PDUs. A Forward Frame service instance can be in only one data processing mode for the duration of the execution of a Service Package. The data processing mode has one of two values:

1.6.1.12.2.1 sequence-controlled data processing mode: The sequence-controlled data processing mode allows the service user to place constraints on each SL-PDU regarding (1) the sequence in which the SL-PDU must be received (with respect to the previous SL-PDU) by the Forward Frame service provider and (2) the time window in which the SL-PDU must be submitted to production processing. (See 2.1a) for details.)

NOTE – The sequence-controlled data processing mode of the Forward Frame service is not to be confused with the Sequence-Controlled Service of the TC and Unified Space Data Link Protocols (SDLPs) (references [7] and [9] , respectively). If they are performed, the TC and USLP Sequence-Controlled Services are performed by the MUE of the Earth User Node prior to transfer of the Transfer Frames through the Forward Frame service.

1.6.1.12.2.2 buffered data processing mode: In order to maximize throughput, the buffered data processing mode does not regulate the flow of SL-PDUs to the underlying production process. Increased throughput is also supported by the capability to place multiple SL-PDUs into a single Forward Buffer PDU in order to maximize the efficiency of the underlying communication service. (See 2.1b) for details.)

1.6.1.12.3 functional resource parameter: a functional resource parameter of a CSTS is a parameter that is accessible through the functional resource that represents that CSTS. A functional resource parameter is named using the Functional Resource Type and functional resource parameter Published Identifiers registered in the SANA Functional Resource Registry (reference [4]). A service management parameter (see 1.6.1.1 m)) is a functional resource parameter that is used to configure the CSTS that is represented by its associated CSTS functional resource. In this Recommended Standard, the term 'service management parameter' is used for functional resource parameters that are used to configure the CSTS, and the more-general 'functional resource parameter' is used for read-only (i.e., non-configuration) parameters of the CSTS.

1.6.1.12.4 Only Idle Data CADU: The Only Idle Data CADU is a CADU that is created to preserve the continuity of the transmission stream in the even that there are no valid CADUs available for transmission at release time. Only Idle Data CADUs are generated only when the Forward Frame service is operating in the CADU configuration (see 2.2.2.2 and I6). The generation and injection of Only Idle Data CADUs results in a transmitted waveform that conforms to CCSDS-standard space data link and synchronization and channel coding standard for fixed length frames.

1.6.1.12.5 Only Idle Data SMTF: The Only Idle Data SMTF is a SMTF that is created to preserve the continuity of the transmission stream in the even that there are no valid SMTFs available for transmission at release time. Only Idle Data SMTFs are generated only when the Forward Frame service is used to transfer SMTFs for subsequent encoding through LDPC of a stream of SMTFs (see [10]). Transfer of SMTFs through the Forward Frame service is accomplished through a hybrid of the CADU configuration (see 2.2.2.2 and I6) and LDPC of a stream of SMTFs, as described in J5. The generation and injection of Only Idle Data SMTFs results in a transmitted waveform that conforms to CCSDS-standard space data link and synchronization and channel coding standard for fixed length frames.

1.6.1.12.6 Space Link Protocol Data Unit, SL-PDU: an SL-PDU is either a Transfer Frame or a CADU. The term is used in statements that apply to both Transfer Frames and CADUs.

1.6.1.12.7 Transfer Frame configuration: A combination of Forward Frame transfer service instances and underlying production functions that are configured by Service Management to support the transfer of Transfer Frames from an Earth User Node to the ESLT performing the Forward Frame service instances. Multiple Forward Frame service instances can provide transfer frames for the same space link physical channel in a Transfer Frame configuration, where each Forward Frame service instance nominally carries the frames for a single Virtual Channel.

1.7 NOMENCLATURE

1.7.1 NORMATIVE TEXT

The following conventions apply for the normative specifications in 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.

NOTE – These conventions do not imply constraints on diction in text that is clearly informative in nature.

1.7.2 INFORMATIVE TEXT

In the normative sections of this document, informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

– Overview;
– Background;
– Rationale;
– Discussion.

1.8 CONVENTIONS

This Recommended Standard uses the conventions defined in the CSTS SFW (reference [1]).

1.9 REFERENCES

The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. It is important to note that the edition of the *Cross Support Transfer Service—*

Specification Framework that is named in reference [1] is the only edition that can be used as a source of requirements for this edition of this Cross Support Transfer Service Recommended Standard. All other publications in the list are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the publications (other than the Specification Framework) indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS publications.

[1] *Cross Support Transfer Service—Specification Framework*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 921.1-B-2. Washington, D.C.: CCSDS, February 2021.

[2] *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.

[3] *Guidelines for the Specification of Cross Support Transfer Services*. Issue 1. Recommendation for Space Data System Practices (Magenta Book), CCSDS 921.2-M-1. Washington, D.C.: CCSDS, March 2019.

[4] "Functional Resources." Space Assigned Numbers Authority. http://sanaregistry.org/r/functional_resources/.

[5] *Information Technology—Abstract Syntax Notation One (ASN.1): Specification of Basic Notation*. 5th ed. International Standard, ISO/IEC 8824-1:2015. Geneva: ISO, 2015.

[6] *Information Technology—ASN.1 Encoding Rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)*. 5th ed. International Standard, ISO/IEC 8825-1:2015. Geneva: ISO, 2015.

[7] *TC Space Data Link Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 232.0-B-3. Washington, D.C.: CCSDS, September 2015.

[8] *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.

[9] *Unified Space Data Link Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.1-B-1. Washington, D.C.: CCSDS, October 2018.

[10] *TM Synchronization and Channel Coding*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 131.0-B-3. Washington, D.C.: CCSDS, September 2017.

[11] *TC Synchronization and Channel Coding*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 231.0-B-3. Washington, D.C.: CCSDS, September 2017.

2 OVERVIEW OF THE FORWARD FRAME CROSS SUPPORT TRANSFER SERVICE

2.1 SERVICE SUMMARY

The Forward Frame service is a CCSDS CSTS that provides the user with the capability to transfer SL-PDUs for radiation to a Space User Node (e.g., spacecraft) in one of two data processing modes (as configured via Service Management):

a) **sequence-controlled data processing mode**: The sequence-controlled data processing mode allows the service user to place constraints on each SL-PDU regarding (1) the sequence in which the SL-PDU must be received (with respect to the previous SL-PDU) by the Forward Frame service provider and (2) the time window in which the SL-PDU must be submitted to production processing. When in the sequence-controlled data processing mode, the Forward Frame service provider validates every SL-PDU to ascertain that the SL-PDU is for the virtual channel that is associated with the Forward Frame service instance and that the SL-PDU is of permitted size and reports back to the service user whether the SL-PDU is valid or invalid (and therefore discarded; see 4.5.3 for specification of the frame validation process). For every valid SL-PDU, if the SL-PDU is unable to be processed within the specified time window, the Forward Frame service provider discards the SL-PDU and reports the expiration back to the service user. If the SL-PDU carries the flag to report on completion of data unit processing, the Forward Frame service provider reports back to the service user upon the successful radiation of that SL-PDU;

NOTE – The sequence-controlled data processing mode of the Forward Frame service is not to be confused with the Sequence-Controlled Service of the TC and Unified SDLPs (references [7] and [9], respectively). If they are performed, the TC and USLP Sequence-Controlled Services are performed by the MUE of the Earth User Node prior to transfer of the Transfer Frames through the Forward Frame service.

b) **buffered data processing mode**: In order to maximize throughput, the buffered data processing mode does not regulate the flow of SL-PDUs to the underlying production process. Increased throughput is also supported by the capability to place multiple SL-PDUs into a single Forward Buffer in order to maximize the efficiency of the underlying communication service between the Earth User Node and the ESLT. When in the buffered data processing mode, the Forward Frame service provider validates every SL-PDU to ascertain that the SL-PDU is for the virtual channel that is associated with the Forward Frame service instance and that the SL-PDU is of permitted size but reports back to the service user only if that SL-PDU is found to be invalid (and is therefore discarded; see 5.5.3 for specification of the frame validation process). If the SL-PDU carries the flag to report on completion of data unit processing, the Forward Frame service provider reports back to the service user upon the successful radiation of that SL-PDU.

The Forward Frame service provides the user with the capability to query or receive periodic reports on the cumulative number of SL-PDUs received by the FF provider instance, the cumulative number of SL-PDUs submitted to production processing, and the number of SL-PDUs currently enqueued at the FF provider.

2.2 FUNCTIONAL DESCRIPTION

2.2.1 GENERAL

Forward Frame service is provided and produced in one of two configurations, the Transfer Frame configuration or the CADU configuration. Figure 2-1 illustrates the production and provision of the Forward Frame service in the Transfer Frame configuration. Figure 2-2 illustrates the production and provision of the Forward Frame service in the CADU configuration.

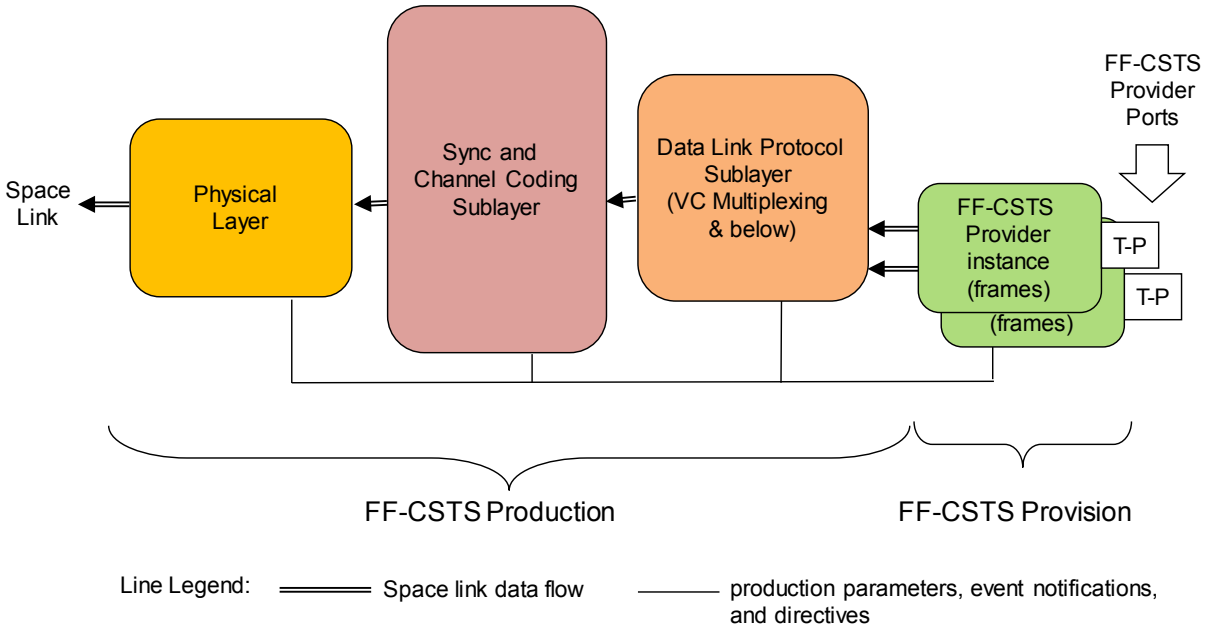


Figure 2-1: Production and Provision of Forward Frame Cross Support Transfer Service—Transfer Frame Configuration

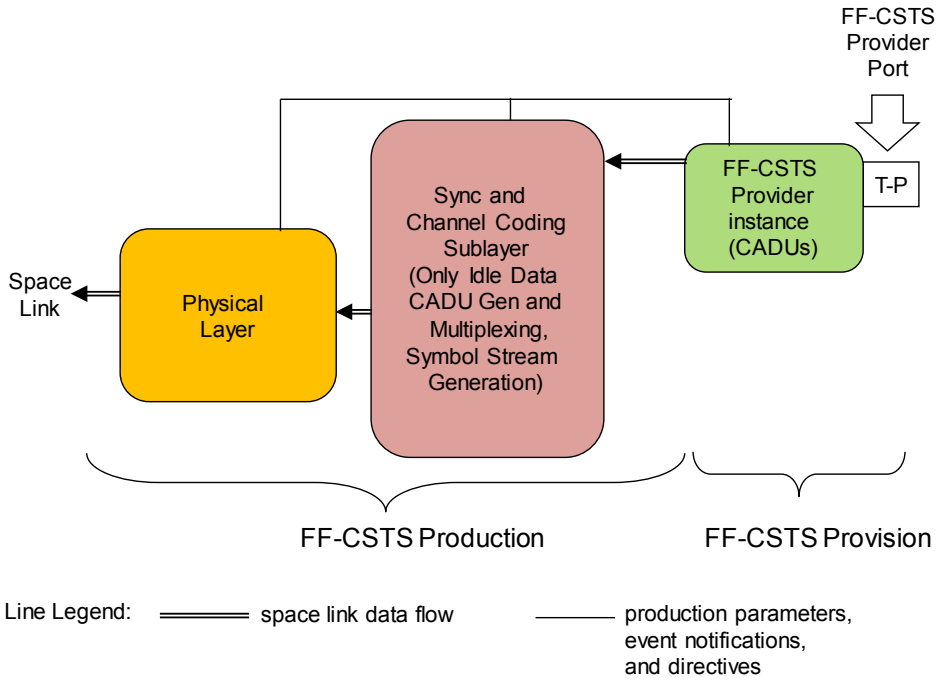


Figure 2-2: Production and Provision of Forward Frame Cross Support Transfer Service—CADU Configuration

NOTE – The colors of the different production components in the figures relate to their specific CCSDS protocol layers and sublayers (see 2.2.2.1). This color-coding scheme is used in the example configurations in annex I.

In the figures, each FF-CSTS Provider icon represents a single instance of the FF service, where each service instance supports a single user of the FF service. In the Transfer Frame configuration (figure 2-1), multiple FF service instances, each carrying frames of a VC dedicated to that service instance, have their frames multiplexed into the same physical channel. In the CADU configuration (figure 2-2), a single FF service instances carries the CADUs of any and all VCs for the physical channel.

NOTE – Figure 2-1 illustrates only the sharing of a physical channel by multiple instances of the FF service because that is the scope of this Recommended Standard. However, one of the main drivers for the FF service is to allow VCs carrying frames from other kinds of VC sources to be multiplexed into the same physical channel with frames carried by instances of the FF service (1.4.1 d)). Sharing of the space link with other non-FF-service data sources is illustrated in annexes I and K.

In figure 2-1, the Data Link Protocol Sublayer icon represents the VC Multiplexing functions and below (e.g., Master Channel Multiplexing) that are defined in the Recommended Standards of the SDLPs whose frames are supported by the FF service: TC SDLP (reference [7]), AOS SDLP (reference [8]), and USLP (reference [9]). When fixed-length AOS or USLP frames are being transferred, the SDLP functions also include the generation of Only Idle Data frames in accordance with the respective Recommended Standards. The

Synchronization and Channel Coding icon represents the synchronization and channel coding functions that are appropriate to the specific SDLP protocol being used: *TC Synchronization and Channel Coding* (reference [11]) for TC and variable-length USLP transfer frames, and *TM Synchronization and Channel Coding* (reference [10]) for AOS and fixed-length USLP transfer frames.

NOTE – In many CCSDS Recommended Standards, "Only Idle Data" is abbreviated using the acronym "OID". However, in this Recommended Standard the "OID" acronym is reserved for "Object Identifier".

In figure 2-2, the Synchronization and Channel Coding Sublayer icon represents two functions: (a) Only Idle Data CADU Generation and Multiplexing and (b) Continuous and Contiguous Symbol Stream Generation. The Only Idle Data CADU Generation and Multiplexing function is specific to the FF service and is normatively specified in G3.2. The Symbol Stream Generation function generates a continuous and contiguous stream of symbols, and for CADUs that contain AOS or USLP transfer frames the function is defined in reference [10].

Both figures show two kinds of lines connecting the different components. The double lines connecting through the bodies of the components represent the flow of space link data from the FF-CSTS Provider to the space link. The role of these components in the processing of space link data is the subject of 2.2.2 and 2.2.3.2. The single lines connecting the components from above or below represent the access to the parameters and event notifications of the production functions that the Forward Frame service provides to the service user. The methods of accessing the parameters and events of these production functions are described in 2.2.3.3, 2.2.3.4, 2.2.3.5, and 2.2.3.6. The parameters and event notifications that must be made available to the Forward Frame service instance by the various production functions are normatively specified in annex G.

The following subsections describe the production and provision of the Forward Frame service, respectively.

2.2.2 SERVICE PRODUCTION

2.2.2.1 Service Production in the Transfer Frame Configuration

As depicted in figure 2-1, FF-CSTS production in the Transfer Frame configuration consists of functions in three layers/sublayers: the Physical Layer, Synchronization and Channel Coding sublayer, and Data Link Protocol sublayer. There are multiple CCSDS Recommended Standards that specify functions in these layers/sublayers that can be combined to support Forward Frame services to user missions. These CCSDS layers are based on the layers of the International Organization for Standardization (ISO) Open System Interconnection seven-layer reference model (reference [L12]). For example, CCSDS Recommended Standards that define functionality in the Physical Layer include Radio Frequency (RF) and modulation standards for Earth stations (reference [L9] and relay satellites (reference [L10]).

The CCSDS Recommended Standards that define functionality in the Physical Layer in the Data Link Protocol sublayer include the AOS (reference [8]), TC (reference [7]), and USLP (reference [9]) protocols. More specifically, the space data link protocol functions that are explicitly performed by FF-CSTS production are the VC Multiplexing (and below) functions of the TC Space Data Link Protocol Sending End functions (reference [7]), AOS Space Data Link Protocol Sending End functions (reference [8]),and the Unified Space Data Link Protocol Sending End functions (reference [9]).

In the Transfer Frame configuration, each FF-CSTS Provider instance transfers the frames of a single VC, and multiple FF-CSTS Provider instances can be used to transfer the frames from various VCs destined for the same physical channel. The multiplexing functions of the SDLP multiplex the Transfer Frames from the Forward Frame service instances that are associated with the same single forward space link physical channel.

When a Forward Frame service is instantiated in a Service Package, it is configured to operate with only one Virtual Channel Multiplexing function which is specific to one SDLP; that is, a Forward Frame service instance can support the frames of only one SDLP during the execution of a Service Package. Because CCSDS SDLPs require that all VCs on the same physical channel use the same SDLP, all FF services instances bound to the same physical channel must be configured to transfer frames of the same SDLP.

NOTE – The multiplexing functions of the CCSDS SDLPs are not limited to multiplexing only VCs carried by Forward Frame service instances. VC Transfer Frames from other sources (e.g., the CCSDS SLE Forward Space Packet service, reference [L14]) can be multiplexed with VC frames carried by one or more Forward Frame service instances into the same single forward space link physical channel. However, such other sources of VC Transfer Frames are outside the scope of this Recommended Standard.

The single multiplexed stream of Transfer Frames is then sent to the appropriate Synchronization and Channel Coding sublayer functions, which encode the Transfer Frames and append channel synchronization symbols that are appropriate for that particular space link.

From the Synchronization and Channel Coding sublayer, the coded symbol stream goes to the Physical Layer functions that modulate the signal onto a carrier for radiation.

The Forward Frame service instances, the multiplexers, the synchronization and channel coding functions, and Physical Layer functions are configured appropriately by Service Management to provide the required combination of services.

Although designed to work with the Data Link Protocol sublayer, Synchronization and Channel Coding sublayer, and Physical Layer functions associated with the TC, AOS, and USLP protocols and *TM Synchronization and Channel Coding*, the Forward Frame service is capable of working with any service production functions that meet the requirements specified in G2.

2.2.2.2 Service Production in the CADU Configuration

In the CADU configuration, a single FF-CSTS Provider transfers all of the CADUs destined for a given forward space link physical channel. With no need to multiplex frames from different sources, the single FF-CSTS Provider sends its CADUs directly to the Synchronization and Channel Coding sublayer functions that have been configured appropriately by Service Management for that space link, as depicted in figure 2-2. The resulting coded symbol stream goes to the Physical Layer functions that modulate the signal onto a carrier for radiation, just as in the case of the Transfer Frames configuration.

Although designed to work with the Synchronization and Channel Coding sublayer and Physical Layer functions associated with the CCSDS CADU processing and transmission as defined in the *TM Synchronization and Channel Coding* Recommended Standard, the Forward Frame service is capable of working with service production functions that meet the requirements specified in G3.

2.2.3 SERVICE PROVISION

2.2.3.1 General

Provision of the Forward Frame service comprises

a) transfer and validation of SL-PDUs (i.e., Transfer Frames or CADUs);

b) cyclic reporting of parameters of the Forward Frame service provider and the underlying production processing functions;

c) query of the current values of parameters of the Forward Frame service provider and the underlying production processing functions;

d) notification of events related to the Forward Frame service provider and the underlying production processing functions; and

e) ability to invoke real-time reconfiguration of underlying production processing functions.

2.2.3.2 Validation and Queuing of SL-PDUs

2.2.3.2.1 General

The behavior of the Forward Frame service depends on the *data processing mode* of the service instance.

2.2.3.2.2 Validation and Queuing of SL-PDUs in the 'Sequence-Controlled' Data Processing Mode

2.2.3.2.2.1 General

When the Forward Frame service instance is configured to operate in the 'sequence-controlled' data processing mode, the prime procedure is the Sequence-Controlled Frame Data Processing procedure, which enforces strict sequencing of the Transfer Frames and provides feedback to the user on the processing status of each SL-PDU.

2.2.3.2.2.2 SL-PDU Validation in the 'Sequence-Controlled' Data Processing Mode

Upon receipt of an SL-PDU, the Forward Frame service provider performs the following validation checks:

a) bit-masking the first four octets of each PDU and comparing the result to a bit pattern that represents the data channel identifier for the data channel that is assigned to that Forward Frame service instance, as specified in 4.5.3.1;

NOTES

1 When the Forward Frame service is used to carry Transfer Frames, the bit-mask corresponds to the header fields that contain the GVCID for the specific space data protocol, and the bit pattern corresponds to the specific GVCID assigned to that service instance. When the Forward Frame service is used to carry CADUs, both the bit-mask and the bit pattern are set to 'all zeroes' (i.e., 'don't care') since the service instance is the only source of SL-PDUs on the forward space link.

2 Use of the bit-mask-and-compare approach to VC identification provides flexibility to allow the Forward Frame service to support both future CCSDS space data link protocols and non-CCSDS space data link protocols, as long as the identification of the 'channel' is contained within the first four octets of the SL-PDU. Both the bit-mask and bit pattern are configured by Service Management for each Forward Frame service instance.

3 Setting the bit mask and bit pattern to 'all zeroes' allows the Forward Frame service (in the CADU configuration) to be used to transfer opaque blocks of octets, for example, in support of non-CCSDS-conformant link PDUs that do not necessarily conform to any CCSDS frame and/or coding standards, or frames for which the header information has been obscured by bulk encryption.

b) checking the size of each Transfer Frame against the allowed size, or range of sizes, (as appropriate to the SDLP) configured for that particular service instance;

c) confirming that the data-unit-id value that accompanies the SL-PDU is one greater than that of the previously received SL-PDU;

d) confirming that time of receipt of the SL-PDU is compatible with the earliest-data-processing-start-time and latest-data-processing-start-time values that accompany the SL-PDU;

e) confirming that the `production-status` is either 'operational' or 'interrupted' at the time of receipt of the SL-PDU; and

f) confirming that the data processing procedure is not in the locked substate.

If the SL-PDU is valid in all of these respects, the Forward Frame service provider accepts the SL-PDU and returns a positive result to the service user. If the SL-PDU fails any of these validity checks, the Forward Frame service provider rejects the SL-PDU and returns a negative result to the service user.

2.2.3.2.2.3 SL-PDU Queuing in the 'Sequence-Controlled' Data Processing Mode

Once an SL-PDU is accepted, it enters the Input Queue of the Forward Frame service instance to await release to the underlying production processing. It may await release for reasons such as interruption of the underlying production processing (or when the service is provided in the Transfer Frame configuration, because the VC carried by the Forward Frame service instance has a low priority relative to other VC sources). If an accepted SL-PDU expires while awaiting release to production processing, the frame is discarded, the service instance is locked, and the service user is notified of the expiration of the data unit. The user must either invoke a reset directive or stop and restart the data processing procedure in order to unlock the procedure and resume transfer of data.

2.2.3.2.3 Validation and Queuing of SL-PDUs in the 'Buffered Data' Data Processing Mode

2.2.3.2.3.1 General

When the Forward Frame service instance is configured to operate in the 'buffered data' data processing mode, the prime procedure is the BFDP procedure. In contrast to the Sequence-Controlled Frame Data Processing procedure, the BFDP procedure imposes no sequencing or absolute processing time window constraints on the SL-PDUs, and it provides feedback to the user regarding the validity of individual SL-PDUs only when SL-PDUs are found to be invalid (and are therefore discarded).

The buffered data processing mode also allows for the aggregation of multiple SL-PDUs into a single Forward Buffer (from which the data processing mode and the associated data processing procedure get their names). Under the proper circumstances, the buffering of multiple SL-PDUs in a single Forward Buffer can be used to optimize throughput through the underlying data communication service that connects the Forward Frame service provider and the service user, and between the underlying communication service and the Forward Frame service provider entity, but otherwise, whether the SL-PDUs are transferred individually or in buffered groups is not perceptible to the service user.

Together, the absence of sequence control, absence of feedback on valid SL-PDUs, and the use of the Forward Buffer allow for increased throughput and thus the use of higher data rates on the forward space link.

In the 'buffered data' data processing mode, the data processing procedure supports two *transfer modes*, 'complete' and 'timely'.

In the 'complete' transfer mode, once the data processing procedure has read an SL-PDU from the underlying terrestrial communication service and validated it, the procedure retains the SL-PDU for as long as necessary to process and submit it to the underlying service production processing, as described in 2.2.3.2.3.3. If there is no capacity within the procedure instance to receive more SL-PDUs, the procedure suspends reading of new SL-PDUs from the underlying terrestrial communication service until such capacity becomes available.

In the 'timely' transfer mode, the data-processing procedure reads and validates every SL-PDU from the underlying terrestrial communication service as soon as it is made available by that service. If the accepted SL-PDUs exceed the available capacity of the procedure instance, the procedure discards the oldest unprocessed SL-PDUs, as described in 2.2.3.2.3.3.

2.2.3.2.3.2 SL-PDU Validation in the 'Buffered Data' Data Processing Mode

Upon reading of an SL-PDU from the underlying terrestrial communication service, the Forward Frame service provider performs the following validation checks:

a) bit-masking the first four octets of each PDU and comparing the result to a bit pattern that represents the data channel identifier for the data channel that is assigned to that Forward Frame service instance, as specified in 5.5.3.1;

NOTES

1 When the Forward Frame service is used to carry Transfer Frames, the bit-mask corresponds to the header fields that contain the GVCID for the specific space data protocol, and the bit pattern corresponds to the specific GVCID assigned to that service instance. When the Forward Frame service is used to carry CADUs, both the bit-mask and the bit pattern are set to 'all zeroes' (i.e., 'don't care') since the service instance is the only source of SL-PDUs on the forward space link.

2 Use of the bit-mask-and-compare approach to VC identification provides flexibility to allow the Forward Frame service to support future CCSDS and non-CCSDS space data link protocols, as long as the identification of the 'channel' is contained within the first four octets of the SL-PDU. Both the bit-mask and bit pattern are configured by Service Management for each Forward Frame service instance.

3 Setting the bit mask and bit pattern to 'all zeroes' allows the Forward Frame service (in the CADU configuration) to be used to transfer opaque blocks of octets, for example, in support of non-CCSDS-conformant link PDUs that do not

necessarily conform to any CCSDS frame and/or coding standards, or frames for which the header information has been obscured by bulk encryption.

b) checking the size of each Transfer Frame against the allowed size, or range of sizes, (as appropriate to the SDLP) configured for that particular service instance.

If the SL-PDU is valid in both these respects, the Forward Frame service provider accepts the SL-PDU. If the SL-PDU fails any of these validity checks, the Forward Frame service provider rejects the SL-PDU and returns a notification to the service user identifying the rejected SL-PDU and the reason for rejection.

2.2.3.2.3.3 SL-PDU Queuing in the 'Buffered Data' Data Processing Mode

Once an SL-PDU is accepted, it enters the Input Queue of the Forward Frame service instance to await release to the underlying production processing.

If the service instance is configured to be in the 'complete' transfer mode, there are no limitations on the time that the SL-PDU may reside in the Input Queue. If the Input Queue becomes full (e.g., because the underlying service production processing is interrupted), the Forward Frame service provider suspends reading incoming new SL-PDUs from the underlying communication service that connects the Forward Frame service provider to the service user and resumes reading when the Input Queue clears enough space to hold additional SL-PDUs.

If the service instance is configured to be in the 'timely' transfer mode, an SL-PDU may be discarded if (a) the SL-PDU has resided in the Input Queue longer than the `processing-latency-limit` specified for that Forward Frame service instance, or (b) the Input Queue is full and new SL-PDUs arrive, forcing the discarding of an equivalent number of the oldest SL-PDUs.

2.2.3.3 Cyclic Reporting

The service user can use the CSTS Framework Cyclic Report procedure of the Forward Frame service to receive periodic reports containing the current values of configuration parameters, counters, and status indicators associated with the Forward Frame service provision and production.

Because the Forward Frame service is intended to be used with multiple production configurations and is also capable of being used with as-yet-undefined production configurations that perform the functions and meet the requirements specified in annex G, the Forward Frame service does not explicitly 'know' about specific configuration parameters, counters, or status indicators of the underlying production processes. Instead, it makes use of the CSTS Cyclic Report procedure's ability to access those parameters by using the standard names that are assigned to them in the SANA Functional Resources registry (reference [4]).

NOTE – The Functional Resources registry groups the various functions of space communication and navigation production processing and transfer service provision into abstract FR types. For each FR type, configuration parameters, monitorable parameters, notifiable events, and directives (i.e., real-time control commands) are specified. The monitor and control parameters, event notifications, and real-time control capabilities of real systems that implement some part of space communication and navigation production processing and transfer service provision functions are expected to map into the standard parameters, events, and directives of the FRs that correspond to those functions. For readers familiar with the Transmission Control Protocol/Internet Protocol (TCP/IP) Simple Network Management Protocol (SNMP) Management Information Base (MIB) (reference [L13]), the SANA Functional Resources registry is analogous to the SNMP MIB.

2.2.3.4 Information Query

The service user can use the CSTS Framework Information Query procedure of the Forward Frame service to query the current values of configuration parameters, counters, and status indicators associated with the Forward Frame service provision and production. As with the Cyclic Report procedure (2.2.3.3), the Forward Frame service makes use of the Information Query procedure's ability to access the parameters of the underlying production processing functions by using the standard parameter names that are assigned to them in the SANA Functional Resources registry.

2.2.3.5 Notifications

The service user can use the CSTS Framework Notification procedure of the Forward Frame service to subscribe to event notifications associated with the Forward Frame service provision and production by using the standard event names that are assigned to them in the SANA Functional Resources registry.

2.2.3.6 Real-time Reconfiguration of Production Processing Functions

Some space link service providers allow limited real-time modification of some of the configuration parameters of production processing, for example, bit rate and modulation index. When space link service providers support such real-time control, the optional Master Throw Event procedure of the Forward Frame service (which is derived from the CSTS Framework Throw Event procedure) is available.

The service user can use the Master Throw Event procedure of the Forward Frame service to invoke directives on production processing functions by using the standard directive names that are assigned to them in the SANA Functional Resources registry. The scope of the Master Throw Event procedure is confined to the production processing functions that are directly supporting the instance of the Forward Frame service that executes that procedure.

When the Forward Service is used in the Transfer Frame configuration, there may be multiple Forward Frame service instances, and therefore potentially multiple users that could invoke real-time reconfigurations through the Master Throw Event procedure, but allowing multiple users to change the shared production functions could wreak havoc. Typically, only one service user would have the authority to invoke real-time reconfigurations of the shared production functions. The limitation on such access is enforced through the `master-throw-event-enabled` configuration parameter of the Master Throw Event procedure. This parameter, which is configured by Service Management, determines whether the user of the service instance is authorized to use the Master Throw Event procedure. Attempts to invoke directives through a Forward Frame service instance for which Master Throw Event is disabled results in the rejection of those directives.

2.3 SERVICE MANAGEMENT

2.3.1 GENERAL

Service Management specifies the set of FF-CSTS Provider instances and supporting production functions to be performed as part of a Service Package, and determines the schedule for the activation and deactivation of those instances and functions.

Service Management is organized around the management of *functional resources* (see annex L of reference [1]). Functional resources are the means by which specific instances of functions (e.g., the instance of a Virtual Channel Multiplexing function that forms Master Channel 1 on the S-Band forward link) are configured by Service Management and monitorable (and in some cases controllable) by Cross Support Transfer Services. Functional resources are logical representations of the functionality, but the specific sets of functions associated with the functional resources do not necessarily coincide one-to-one with specific physical components that implement those functions. This logical representation allows different implementations to be mapped onto the same sets of functional resources for purposes of cross-support configuration, monitoring, and control.

Different sets of functional resources represent the functions of specific service provision entities and the various CCSDS layers that perform the production functions that support those service provision enties, that is, space data link protocols, synchronization and channel coding schemes, and RF modulation standards. For example, there is a set of functional resources that represent the TC Space Data Link Protocol Sending End functions (reference [7]) and a different set of functional resources that represent the Unified Space Data Link Protocol Sending End functions (reference [9]). Both of these functional resource sets perform fuctions that belong to the Data Link Protocol sublayer. The functional resource specifications, which include the identification of the CCSDS protocol, coding, and modulation functions that they represent, are registered in the SANA Functional Resource Registry (reference [4]).

Service Management manages the different provision and production functional resources as separate entities. For example, the FF-CSTS Provider functional resource instances (each of which represents one instance of the FF service) has a set of configuration parameters,

monitored parameters, and notification events that are specifc to the provision of the FF service (i.e, those aspects of the service dealing with the interface to the user of the service). The functional resources that comprise the underlying production of the FF service each have their own sets of configuration parameters, monitored parameters, and notification events. Service Management uses *configuration profiles* (see reference [L7]) to ensure that the FF-CSTS Provider functional resource instances and the supporting production functional resource instances are configured properly to provide the required services.

For clarity and simplicity, the descriptions of the production functions that are performed in conjunction with the Forward Frame service are phrased in terms of the functions as they are defined in the source CCSDS Recommended Standards, without reference to the functional resources that represent those functions. Functional resources are mentioned only when they are pertinent to the discussion.

NOTES

1 A Service Package may include other services in addition to Forward Frame services, and in such cases Service Management specifies and schedules the service instances and production functions related to those services as well. However, discussion of the management of services other than Forward Frame is outside the scope of this Recommended Standard.

2 The means by which Service Management creates the Service Packages is outside the scope of this Recommendation. The CCSDS Space Communication Cross Support Service Management suite ([L5], [L6], and [L7]) defines a standard set of Service Management information entities used in the planning, scheduling, and configuration of Service Packages.

2.3.2 INITIAL CONFIGURATION PARAMETER VALUES

Service Management sets the initial values of the configuration parameters of the Forward Frame service instances and the supporting production functions. Some of the configuration parameters of the Forward Frame service may be subsequently modified by the user of the service instance when the service instance is in the inactive state.

The values of configuration parameters of production functions may be dynamically modified by users of Forward Frame service that are permitted to invoke directives during the execution of the Service Package. The specific configuration parameters that are dynamically modifiable for a particular Provider CSSS are defined by that Provider CSSS.

2.3.3 CONFIGURATION CONSISTENCY

Service Management ensures that the configuration of Forward Frame service instances and underlying production are mutually consistent.

Service Management ensures that the ability to invoke directives on the underlying production functions is enabled for only those Forward Frame service instances for which that capability is authorized.

NOTE – Normally, at most one Forward Frame service instance will be authorized to invoke such directives, but the decision depends on the policies of the missions and the Provider CSSSes. Also, for some Service Packages, the authority to invoke such directives may be restricted to an instance of another type of service, such as SLE Forward Space Packet [L14] or the future Service Control Cross Support Transfer Service (SC-CSTS).

2.3.3.1 For Service Packages that provide Forward Frame services using the Transfer Frame configuration, Service Management ensures that

a) each Forward Frame Service Provider instance is assigned and configured to accept a unique Virtual Channel (as identified by its GVCID) for the forward space link physical channel to which that provider instance will provide its Transfer Frames;

b) each Forward Frame Service Provider instance is configured to be in the data processing mode (sequence-controlled or buffered data) that is appropriate to the forward space link physical channel to which that provider instance will provide its Transfer Frames;

c) each Forward Frame Service Provider instance is configured to accept Transfer Frames in the size, or range of sizes, that is appropriate to the forward space link physical channel to which that provider instance will provide its Transfer Frames;

d) each Forward Frame Service Provider instance is configured to provide its Transfer Frames to the VC multiplexing function that forms the MC that corresponds to that provider instance's GVCID; and

e) the production functions that support the Forward Frame Service Provider instances of the Service Package are properly configured to: multiplex the frames from those Forward Frame Service Provider instances and any other VC sources into the correct MCs for the physical channel(s), insert Only Idle Data Frames as necessary to maintain synchronization (only for fixed-length-frame SDLPs, AOS and USLP), and apply the correct encoding to the frames.

2.3.3.2 For Service Packages that provide Forward Frame services using the CADU configuration, Service Management ensures that

a) the Forward Frame Service Provider instance is configured to ignore the header of the SL-PDUs, as this Forward Frame Service Provider instance is the only one associated with forward space link physical channel and therefore transfers all of the CADUs to that physical channel;

b) the Forward Frame Service Provider instance is configured to be in the data processing mode (sequence-controlled or buffered data) that is appropriate to the forward space link to which that provider instance will provide its SL-PDUs;

c) the Forward Frame Service Provider instance is configured to accept SL-PDUs in the size that is appropriate to the forward space link to which that provider instance will provide its SL-PDUs;

d) the Forward Frame Service Provider instance is configured to provide its Transfer Frames to the synchronization and channel coding functions that form the coded symbol stream for the forward space link; and

e) the synchronization and channel coding functions are configured to produce Only Idle Data CADUs that conform to the format and coding used to generate the CADUs that are being received through the Forward Frame Service Provider instance.

2.4 CROSS SUPPORT VIEW

Figure 2-3 shows an example configuration of an ESLT providing two instances of FF-CSTS to an Earth User CSSS, where the production and provision of the services are in the Transfer Frame configuration. The ESLT is a node of the Provider CSSS.

Prior to the execution of the Service Package, the UM function of the Earth User CSSS and the PM function of the Provider CSSS exchange configuration profiles and schedule request information via Service Management, resulting in a scheduled Service Package. Part of the scheduling of the Service Package is the selection of the ESLT that is to execute the Service Package. PM propagates the Service Package information, which includes the information needed to configure the Forward Frame service instances and associated production functions and makes them available to the mission at the scheduled time, to the EM function of the ESLT assigned to support the Service Package. The EM functions in turn propagate the scheduling and configuration information as needed to the various service production and provision functions that fulfill the Service Package.

During the execution of the Service Package, each FF-CSTS Provider receives Forward Frames from its associated MUE in the Earth User CSSS. Each Forward Frame service provider validates the size and VC of each received frame. Validated frames are input to the appropriate Data Link Protocol sublayer functions, which multiplex the frames from the two Forward Frame service instances. The resultant multiplexed stream of Transfer Frames is then input to the appropriate Sync & Channel Coding sublayer functions. The resultant encoded symbol stream is then modulated onto a carrier signal by the Physical Layer and radiated to the designated Space User Node (e.g., mission spacecraft).

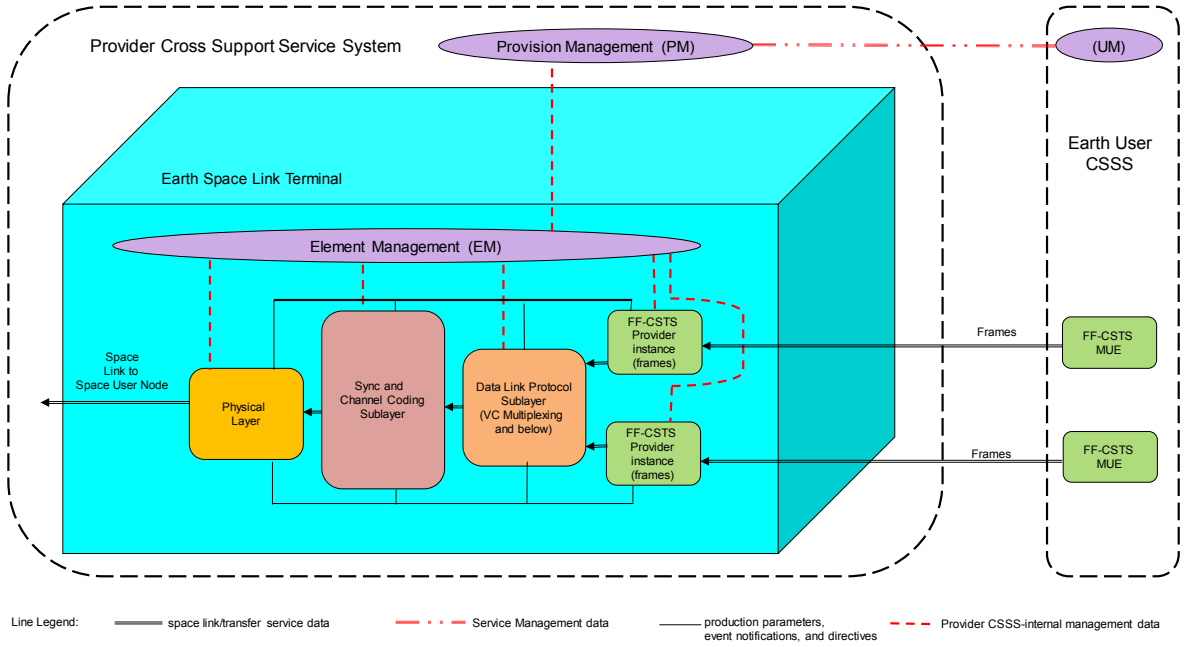


Figure 2-3: Cross Support View of Forward Frame Services—Transfer Frame Configuration

Figure 2-4 shows a similar example configuration of an ESLT providing one instance of FF-CSTS to an Earth User CSSS, but in this case the provision and production of the service are in the CADU configuration.

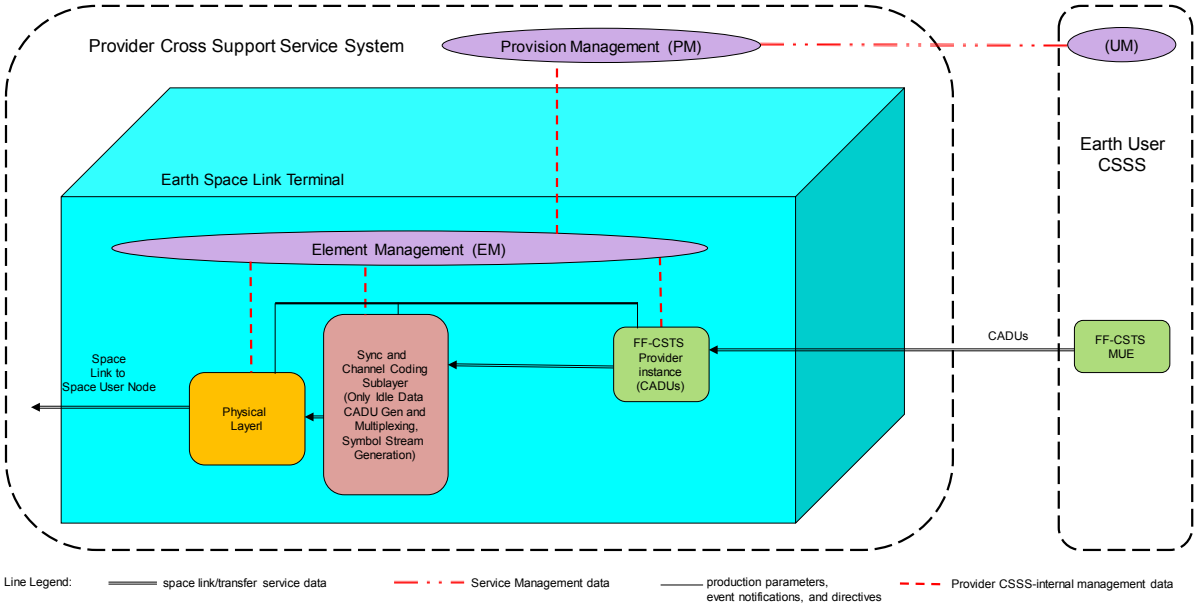


Figure 2-4: Cross Support View of Forward Frame Services—CADU Configuration

As described in 2.2.2.2, in the CADU configuration there is only one Forward Frame service instance per forward space link and no SDLP functions are performed.

2.5 OPERATIONAL SCENARIOS

2.5.1 GENERAL

Three operational scenarios are provided in the following subsections. The first scenario illustrates an example of a configuration in which two Forward Frame service instances carry TC frames. The second scenario illustrates an example of a configuration in which two Forward Frame service instances carry AOS frames. The third scenario illustrates an example of a configuration in which one Forward Frame service instance carries CADUs.

NOTE – For the purposes of these example scenarios, the Physical Layer functions are assumed to be performed in accordance with CCSDS 401 (reference [L9]). The Forward Frame service is essentially independent of the functions performed at the Physical Layer. The example scenarios could also use CCSDS 415 (reference [L10]) at this layer.

2.5.2 TC FRAMES

2.5.2.1 Figure 2-5 depicts the functions of provision and production components used in the Service Package that supports Transfer Frames over a TC link. The figure identifies the TC SDLP, *TC Synchronization and Channel Coding*, and CCSDS 401 RF-and-modulation functions that are performed within the respective CCSDS layers/sublayers.

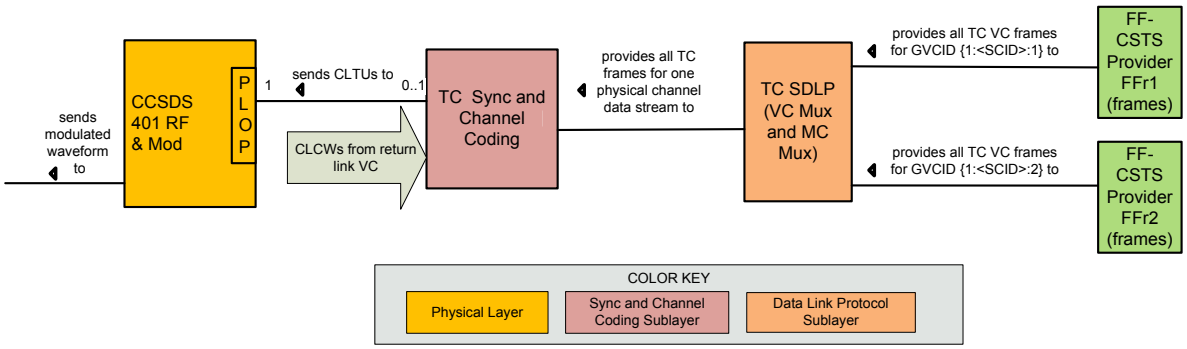


Figure 2-5: Forward Frame Service Scenario—Transfer Frame Configuration—TC Frames

Annex subsection I2 provides a more-detailed description of these functions.

2.5.2.2 Prior to the provision of service, start and stop times for the space link session and the two Forward Frame service instances are negotiated between PM and UM. Configuration and other information needed to enable the service are also agreed upon, established, and verified. In particular, the following configuration items are established:

a) the Forward Frame service instances FFr1 and FFr2 are configured to be in the 'sequence-controlled' data processing mode (3.2), which sets the prime procedure to be the Sequence-Controlled Frame Data Processing procedure;

b) the Forward Frame service instance FFr1 is configured to accept Transfer Frames for TC (that is, version 1) VC 1 for the mission spacecraft with SCID =20; thus the GVCID of VC 1 in this scenario is {1:20:1}.

   Configuring service instance FFr1 to handle this VC consists of

   1) Setting the `gvcid-bit-mask` configuration parameter (table 4-3 and 4.7.2) to the TC frame bit mask

      11000011 11111111 11111100 00000000 (C3 FF FC 00 Hex);

   NOTE – This bit mask corresponds to the presence of the TFVN in bits 0 and 1, the SCID in bits 6–15, and the VCID in bits 16-21 of the first 4 octets of the TC Transfer Frame Primary Header.

   2) Setting the bit pattern in the `authorized-gvcid` configuration parameter (table 4-3 and 4.7.3) to the bit pattern for GVCID {1:20:1}

      00000000 00010100 00000100 00000000 (00 14 04 00 Hex); and

   3) Setting the `minimum-frame-length` and `maximum-frame-length` configuration parameters (table 4-3, 4.7.4 and 4.7.5) to the then maximum and minimum values allowed for VC 1;

c) the Forward Frame service instance FFr2 is configured to accept Transfer Frames for VC 2, where the GVCID of VC 2 in this scenario is {1:20:2};

   1) Setting the `gvcid-bit-mask` configuration parameter (table 4-3 and 4.7.2) to the TC frame bit mask

      11000011 11111111 11111100 00000000 (C3 FF FC 00 Hex);

   2) Setting the bit pattern in the `authorized-gvcid` configuration parameter (table 4-3 and 4.7.3) to the bit pattern for GVCID {1:20:2}

      00000000 00010100 00001000 00000000 (00 14 08 00 Hex); and

   3) Setting the `minimum-frame-length` and `maximum-frame-length` configuration parameters (table 4-3, 4.7.4, and 4.7.5) to the maximum and minimum values allowed for VC 1;

d) the `master-throw-event-enabled` parameter of service instance FFr1 is set to ‘enabled’, allowing the user of that service instance to invoke directives on the underlying service production;

e) the TC SDLP’s VC Multiplexing function is configured to multiplex VCs 1 and 2 using the absolute priority multiplexing scheme (see G2.2.2.2), with VC 1 having the highest priority and VC 2 having the second-highest priority. For both VC 1 and VC 2, the Number of Repetitions for Sequence-Controlled service (type AD) Frames is configured to be 2, and the Number of Repetitions for COP Control Command (type BC) Frames is configured to be 3 (see reference [7]);

f) the TC SDLP's MC Multiplexing function is configured to support the single MC {1:20};

NOTE – Because there is only one MC being used, the MC Multiplexing function does not actually perform any multiplexing; it simply passes along the multiplexed frame stream generated by the VC Multiplexing function.

g) the TC SDLP's All Frames Generation function is configured to add a Frame Error Control Field (FECF) to the trailer of each frame. The Maximum Number of Transfer Frames Given to the Coding Sublayer as a Single Data Unit is configured to be 5, and the Maximum Length of Data Unit Given to the Coding Sublayer is configured to be 3000 (see reference [7]).

h) the *TC Synchronization and Channel Coding* functions are configured to apply frame randomization and Bose–Chaudhuri–Hocquenghem (BCH) encoding of the frame, to perform PLOP-2 (see reference [11]);

i) the functional resource that represents the *TC Synchronization and Channel Coding* functions is configured to use the No RF Available and No Bit Lock flags returned from the spacecraft in the Communications Link Control Word (CLCW) fields of the designated return link VC in the determination of the *resource status* of the functional resource;

NOTES

1 The use of the CLCW No RF Available and No Bit Lock flags in conjunction with the *TC Synchronization and Channel Coding* functions is not part of the behavior of those functions as specified in reference [7]. It is an extended behavior introduced by the SLE Forward CLTU service (see B2.3 of reference [L4]) and the SLE Forward Space Packet service (reference [L14]). The extended behavior is assumed to be performed by the functional resource that represents the *TC Synchronization and Channel Coding* functions to allow the Forward Frame service to operate in a way that is similar to the F-CLTU and FSP services.

2 The `resource-status` parameter is common to all production functional resources, and reports whether the functions that are collectively represented by that functional resource have the status of 'configured', 'operational', 'interrupted', or 'halted' (see annex B of reference [1]). For CSTSes, the resources statuses of the underlying production functional resources are combined to form the *production status* of the CSTS, which in turn affects the state machine of that CSTS.

3 Use of the No RF Available flag and/or the No Bit Lock flag of the CLCW to affect the production status of the functional resource is optional and set by Service Management. If neither is configured for use, production status of the functional resource is unaffected by the values of the CLCW flags.

4 Return link production, which extracts the CLCWs and provides them to the *TC Synchronization and Channel Coding* function, is not illustrated in figure 2-5.

j) the Forward 401 Space Link Transmission function is configured to apply the selected modulation, frequency, etc., to the input symbol stream.

2.5.2.3 At some time before the scheduled start times of the Forward Frame service instances, the details of the Service Package are sent from PM to the EM function of the ESLT. The service instances are created by EM and configured, along with the configuration of the required production functions. Initially, each Forward Frame service provider is in state 1 ('unbound'). At the scheduled start time of the space link session, the ESLT establishes the forward link to the spacecraft and initiates the production processing for the Forward Frame service instances. Typically (but not necessarily), the start times of the service instances 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.

2.5.2.4 The following steps illustrate a typical sequence of operations between the user and the provider of either of the Forward Frame service instances configured to transfer TC frames:

a) The user invokes the BIND operation of the Association Control procedure to establish an association.

b) The user STARTs the Cyclic Report procedure and specifies which parameters of the service instance and underlying production functions to periodically report and the delivery cycle to be used.

c) The user STARTs the Notification procedure and subscribes to the 'tcSyncFwdLinkStatusChange' event of the resource performing the TC Sync and Channel Coding functions.

d) The user STARTs the Sequence-Controlled Frame Data Processing procedure, which causes the Sequence-Controlled Frame Data Processing procedure to transition to the 'active.processing' substate and the Forward Frame service provider to transition to state 'bound.active'.

e) The START invocation identifies the sequence value of the first PROCESS-DATA invocation that will be sent.

NOTES

1 The service user may also use the START invocation to reset the values of certain configuration parameters of the Sequence-Controlled Frame Data Processing procedure, prior to the transfer of Transfer Frames. Activation of the procedure also enables the NOTIFY operation to be invoked when events related specifically to the Sequence-Controlled Frame Data Processing procedure occur.

2 The states of the Sequence-Controlled Frame Data Processing procedure are the same as those of the Framework Sequence-Controlled Data Processing procedure.

f) When production-status changes to ‘operational’ the provider sends a NOTIFY invocation to the user.

g) The user sends a PROCESS-DATA invocation to the provider. The provider verifies that the Transfer Frame contained in the invocation has the correct GVCID, is of the allowed size, and the value of the data-sequence-counter parameter of the PROCESS-DATA invocation matches the value that is expected by the service provider:

   1) if the PROCESS-DATA invocation is invalid for any reason, the PROCESS-DATA invocation is discarded and a negative result is returned;

   2) if the PROCESS-DATA invocation is valid, the service provider returns a positive result and enqueues the frame.

h) Additional frames are sent by the service user and enqueued if valid.

i) When a frame reaches the front of the queue, it is made available to the VC Multiplexing instance that is associated with that Forward Frame service instance when both (1) the time is equal to or later than that specified by the `earliest-data-process-start-time` of the frame and (2) production status is operational. If no earliest start time was specified in the PROCESS-DATA invocation that transferred the frame, the frame is made available to production processing as soon as it reaches the front of the queue or whenever the production status becomes operational, whichever is later.

j) If the frame at the front of the queue does not begin to be processed before the `latest-data-process-start-time` for that frame is reached:

   1) the frame is discarded and a NOTIFY invocation is sent with notification-type ‘expired’;

   2) the Sequence-Controlled Frame Data Processing enters the ‘active.locked’ state, which prevents any further frames in the buffer from being processed and any further PROCESS DATA invocation from being accepted;

   3) upon receipt of the ‘expired’ NOTIFY invocation, the user invokes the EXECUTE-DIRECTIVE operation of the Sequence-Controlled Frame Data Processing procedure to ‘reset’ (that is, clear the buffer and begin accepting frames again). Alternatively, the user can invoke the STOP operation, followed by the START operation, which accomplishes the same thing as the ‘reset’ directive.

k) At some time while the service instance is in the ‘bound.ready’ or ‘bound.active’ state, the user invokes the GET operation of the Information Query procedure to retrieve the current value of one or more parameters of that user’s service instance or an underlying production function.

l) At some time while the Notification procedure is active, the CLCWs received from the spacecraft indicate that the No Bit Lock flag has changed from 0 to 1, indicating a loss of bit lock. This causes the resource status of the functional resource that represents the *TC Synchronization and Channel Coding* functions to change to ‘interrupted’, which in turn causes the production status of the Forward Frame service

instance to transition to ‘interrupted’. This causes the Sequence-Controlled Frame Data Processing procedure to enter the ‘active.locked’ substate, discard any frames in the input queue, inhibit receipt of additional frames, and issue a NOTIFY invocation with event ‘production status change’, with event value ‘interrupted’. Concurrently, the Notification procedure issues a NOTIFY invocation for the event ‘telecommand-synchronization-forward-link-status change’, with event value ‘no bit lock’.

m) Once bit lock is re-acquired, the resource status of the functional resource that represents the *TC Synchronization and Channel Coding* functions changes to ‘operational’, which in turn causes the production status of the Forward Frame service instance to transition to ‘operational’. The Sequence-Controlled Frame Data Processing procedure issues a NOTIFY invocation with event ‘production status change’, with event value ‘operational’. Concurrently, the Notification procedure issues another NOTIFY invocation for the event ‘telecommand-synchronization-forward-link-status change’, this time with event value ‘nominal’.

n) The user of the Forward Frame service invokes the ‘reset’ directive that returns the Forward Frame service instance to the ‘active.processing’ substate and permits the user to resume transferring frames to the service provider.

o) ***For service instance FFr1 only:*** At any time while the service instance is in the ‘bound.ready’ or ‘bound.active’ state, the user may invoke the EXECUTE-DIRECTIVE operation of the Master Throw Event procedure to modify the value of one or more configuration parameters of an underlying production function.

p) The user transfers the last frame to the provider.

q) The provider completes processing of the queued frames.

r) The user invokes the STOP operation for the Sequence-Controlled Frame Data Processing procedure and the provider transitions to state 2, ‘bound.ready’.

s) The user invokes the STOP operation for the Cyclic Report procedure to halt cyclic reporting.

t) The user invokes the STOP operation for the Notification procedure to halt event notifications.

u) The user invokes the UNBIND operation to release the association.

2.5.2.5 During the execution of the Service Package, the production functions perform as follows:

a) The VC Multiplexing function polls the queues of both Forward Frame service instances FFr1 and FFr2, with priority to FFr1, pulls the Transfer Frames from the queues accordingly, and multiplexes them into a single MC with MCID {1:20}.

b) The MC Multiplexing function passes through the multiplexed frames for MC {1:20}.

c) The All Frames Generation function appends an FECF to each frame and forms groups of frames that conform to the constraints imposed by the configuration parameters

Maximum Number of Transfer Frames Given to the Coding Sublayer as a Single Data Unit, and Maximum Length of Data Unit Given to the Coding Sublayer. The resultant groups of frames are submitted to the underlying *TC Synchronization and Channel Coding* functions in such a way that the CLTU that is formed from each group of frames is transmitted, possibly multiple times, in accordance with configuration parameters that specify the Number of Repetitions for Type-A service (AD) Frames and the Number of Repetitions for COP Control Command (BC) Frames for each virtual channel.

d) The *TC Synchronization and Channel Coding* functions randomize and BCH encode the groups of TC frames, and generate CLTUs from them. Each CLTU is subsequently submitted to the PLOP, which appends the appropriate acquisition and idle sequences before and after it.

e) The resulting symbol stream is modulated onto the RF carrier by CCSDS 401 RF-and-modulation functions and radiated to the spacecraft.

2.5.3 AOS FRAMES

2.5.3.1 Figure 2-6 depicts the provision and production components used in the Service Package that supports Transfer Frames over an AOS link. The figure identifies the AOS SDLP, *TM Synchronization and Channel Coding*, and CCSDS 401 RF-and-modulation functions that are performed within the respective layers/sublayers.

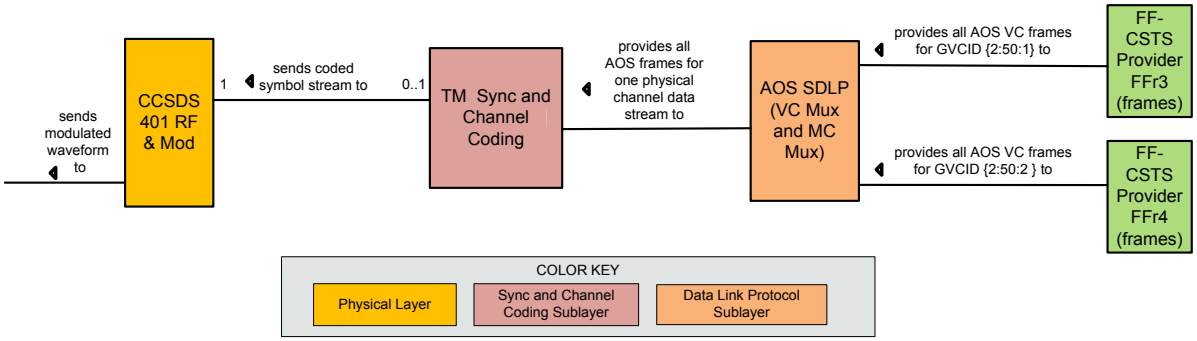


Figure 2-6: Forward Frame Service Scenario—Transfer Frame Configuration—AOS Frames

NOTES

1 As of the publication of this Recommended Standard, the Synchronization and Channel Coding sublayer functions used to support fixed-length frames such as AOS and fixed-length USLP frames on the forward link are planned to be specified in a revised version of reference [10] that will allow it to be used on ground-to-space links.

2 Annex subsection I3 provides a more-detailed description of these functions.

2.5.3.2 Prior to the provision of service, start and stop times for the space link session and the two Forward Frame service instances are negotiated between PM and UM. Configuration and other information needed to enable the service are also agreed upon, established, and verified. In particular, the following configuration items are established:

a) The Forward Frame service instances FFr3 and FFr4 are configured to be in the 'buffered data' data processing mode (which sets the prime procedure to be the BFDP procedure, see 3.2) and in the 'timely' transfer mode (table 5-3 and 5.7.2).

b) The Forward Frame service instance FFr3 is configured to accept Transfer Frames for AOS (that is, version 2) VC 1 for the mission spacecraft with the SCID = 50. Thus the GVCID of VC 1 in this scenario is {2:50:1}.

   Configuring service instance FFr3 to handle this VC consists of

   1) Setting the `gvcid-bit-mask` configuration parameter (table 5-3 and 5.7.3) to the AOS frame bit mask

      11111111 11111111 00000000 00000000 (FF FF 00 00 Hex);

   NOTE – This bit mask corresponds to the presence of the TFVN in bits 0 and 1, the SCID in bits 2–9, and the VCID in bits 10–15 of the first 4 octets of the AOS Transfer Frame Primary Header.

   2) Setting the bit pattern in the `authorized-gvcid` configuration parameter (table 5-3 and 5.7.4) to the bit pattern for GVCID {2:50:1}

      10001100 10000001 00000000 00000000 (8C 81 00 00 Hex); and

   3) Setting both the `minimum-frame-length` and `maximum-frame-length` configuration parameters (table 5-3, 5.7.5, and 5.7.6) to the fixed-length value allowed for VC 1;

c) The Forward Frame service instance FFr4 is configured to accept Transfer Frames for VC 2, where the GVCID of VC 2 in this scenario is {2:50:2};

   Configuring service instance FFr4 to handle this VC consists of:

   1) Setting the `gvcid-bit-mask` configuration parameter (table 5-3 and 5.7.3) to the AOS frame bit mask

      11111111 11111111 00000000 00000000 (FF FF 00 00 Hex);

   2) Setting the bit pattern in the `authorized-gvcid` configuration parameter (table 4-3 and 5.7.4) to the bit pattern for GVCID {2:50:2}

      10001100 10000010 00000000 00000000 (8C 82 00 00 Hex); and

   3) Setting both the `minimum-frame-length` and `maximum-frame-length` configuration parameters (table 5-3, 5.7.5, and 5.7.6) to the fixed-length value allowed for VC 2;

d) The `master-throw-event-enabled` parameter of service instance FFr3 is set to 'enabled', allowing the user of that service instance to invoke directives on the underlying service production.

e) The AOS SDLP's VC Multiplexing function is configured to multiplex VCs 1 and 2 using the absolute priority multiplexing scheme (see G2.2.2.2), with VC 1 having highest priority and VC 2 having the second-highest priority.

f) The AOS SDLP's MC Multiplexing function is configured to support the single MC {2:50}.

g) The AOS SDLP's All Frames Generation function is configured to add an FECF to the trailer of each frame.

NOTE – Because there is only one MC being used, the MC Multiplexing function does not actually perform any multiplexing; it simply passes along the multiplexed frame stream generated by the VC Multiplexing function, and generates Only Idle Data Frames in order to preserve data continuity when there are no valid frames available for transmission.

h) The *TM Synchronization and Channel Coding* functions are configured to perform LDPC encoding, frame randomization, and ASM attachment.

i) The Forward 401 Space Link Transmission function is configured to apply the selected modulation, frequency, etc., to the input symbol stream.

2.5.3.3 At some time before the scheduled start times of the Forward Frame service instances, the details of the Service Package are sent from PM to the EM function of the ESLT. The service instances are created by EM and configured, along with the configuration of the required production functions. Initially, each Forward Frame service provider is in state 1 ('unbound'). At the scheduled start time of the space link session, the ESLT establishes the forward link to the spacecraft and initiates the production processing for the Forward Frame service instances. Typically (but not necessarily) the start times of the service instances will precede by a small margin the start time of the space link session to allow the users to bind to the services before the start of the space link session.

2.5.3.4 The following steps illustrate a typical sequence of operations between the user and the provider of either of the Forward Frame service instances configured to transfer AOS frames.

a) The user invokes the BIND operation of the Association Control procedure to establish an association.

b) The user STARTs the Cyclic Report procedure and specifies which parameters of the service instance and underlying production functions to periodically report and the delivery cycle to be used.

c) The user STARTs the Notification procedure and subscribes to one or more events of underlying production functions.

d) The user STARTs the BFDP procedure, and the provider instance transitions to state 'bound.active'. The service user may use the START invocation to reset the values of certain configuration parameters of the BFDP procedure, prior to the transfer of Transfer Frames. Activation of the procedure also enables the NOTIFY operation to be invoked when events related specifically to the BFDP procedure occur.

NOTE – The states of the BFDP procedure are the same as those of the Framework Buffered Data Processing procedure.

e) When `production-status` changes to 'operational' the provider sends a NOTIFY to the user.

f) The user sends a PROCESS-DATA invocation to the provider. The provider verifies that the Transfer Frame contained in the invocation has the correct GVCID and is of the allowed size:

1) if the Transfer Frame in the PROCESS-DATA invocation is invalid for any reason, the PROCESS-DATA invocation is discarded and a NOTIFY invocation is sent to the user with the appropriate event and event value;

2) if the PROCESS-DATA invocation is valid, the service provider enqueues the frame.

NOTE – The BFDP procedure allows PROCESS-DATA invocations (each of which carries one Transfer Frame) to be transferred individually or in multiples in Forward Buffers. For this scenario, it is assumed that the PROCESS-DATA invocations (and therefore the Transfer Frames) are transferred individually.

g) Additional frames are sent by the service user and enqueued if valid.

h) When a frame reaches the front of the queue, it is made available to the VC Multiplexing instance that is associated with that Forward Frame service instance.

i) At some time during the execution of the Service Package, the production processing of the Transfer Frames is interrupted. The BFDP procedure issues a NOTIFY invocation with event 'production status change' with event value 'interrupted'. The interruption causes production processing to stop accepting PROCESS-DATA invocations from the queue and the queue to fill. Once the queue has filled, the service provider instance ceases accepting PROCESS-DATA invocations from the user.

When the interruption is eventually cleared, production processing is once again able to accept frames from the service instance queue. The BFDP procedure issues a NOTIFY invocation with event 'production status change' with event value 'operational'. Once the queue has been cleared enough to hold additional frames, the service instance resumes accepting new PROCESS-DATA invocations from the service user.

j) At some time while the service instance is in the 'bound.ready' or 'bound.active' state, the user invokes the GET operation of the Information Query procedure to retrieve the current value of one or more parameters of that user's service instance or an underlying production function.

k) ***For service instance FFr3 only***: At any time while the service instance is in the 'bound.ready' or 'bound.active' state, the user may invoke the EXECUTE-DIRECTIVE operation of the Master Throw Event procedure to modify the value of one or more configuration parameters of an underlying production function.

l) The user transfers the last frame to the provider.

m) The provider completes processing of the queued frames.

n) The user invokes the STOP operation for the BFDP procedure and the provider transitions to state 2, 'bound.ready'.

o) The user invokes the STOP operation for the Cyclic Report procedure to halt cyclic reporting.

p) The user invokes the STOP operation for the Notification procedure to halt event notifications.

q) The user invokes the UNBIND operation to release the association.

2.5.3.5 During the execution of the Service Package, the production functions perform as follows:

a) The VC Multiplexing function polls the queues of both Forward Frame service instances FFr3 and FFr4, with priority to FFr3, pulls the Transfer Frames from the queues accordingly, and multiplexes them into a single MC with MCID {2:50}.

b) The MC Multiplexing function passes through the multiplexed frames for MC {2:50}. If no valid frame is available for transmission at a release time, the Only Idle Data Frame subfunction creates an Only Idle Data frame for release in order to preserve the continuity of the transmitted stream.

c) The All Frames Generation function appends an FECF to each frame.

d) The *TM Synchronization and Channel Coding* functions LDPC encodes, randomizes, and attaches an ASM to each frame to generate a CADU. The resulting continuous and contiguous stream of CADUs forms the coded symbol stream.

2.5.4 CADUs

2.5.4.1 Figure 2-7 depicts the provision and production components used in the Service Package that supports CADUs. The figure identifies the *TM Synchronization and Channel Coding* and CCSDS 401 RF-and-modulation functions that are performed within the respective layers/sublayers.

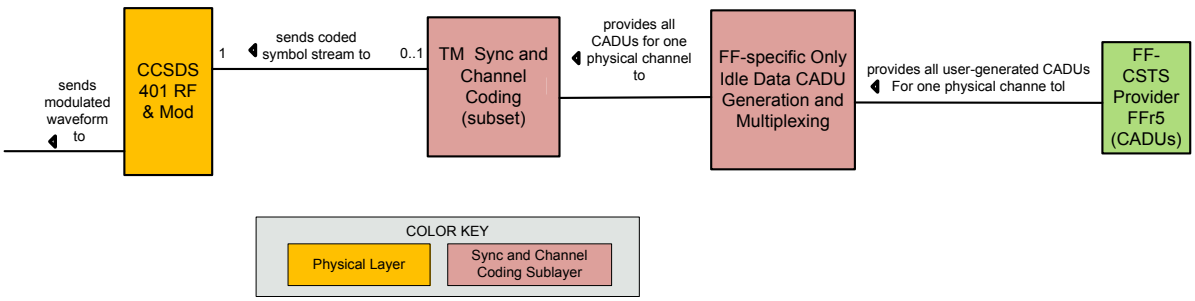


Figure 2-7: Forward Frame Service Scenario—CADU Configuration

2.5.4.2 The configuration also includes an Only Idle Data CADU Generation and Multiplexing function that is not defined as part of any other CCSDS space data link protocol or synchronization and channel coding Recommended Standard. This Only Idle Data CADU Generation and Multiplexing function is a unique production processing requirement of the Forward Frame service, as specified in G3.2.1. This function is necessary to generate Only Idle Data CADUs when there are no valid CADUs available for transmission at release time. The generation and multiplexing of Only Idle Data CADUs results in a transmitted waveform that conforms to CCSDS-standard space data link and synchronization and channel coding standard for fixed-length frames. The Only Idle Data CADU Generation and Multiplexing function is logically categorized as belonging to the Synchronization and Channel Coding sublayer since its only purpose is to maintain continuous and contiguous synchronization on the physical channel.

NOTE – Annex subsection I6 provides a more-detailed description of these functions.

2.5.4.3 Prior to the provision of service, start and stop times for the space link session and the Forward Frame service instance are negotiated between PM and UM. Configuration and other information needed to enable the service are also agreed upon, established, and verified. In particular, the following configuration items are established:

a) The single Forward Frame service instance, FFr5, is configured to be in the ‘buffered data’ data processing mode (which sets the prime procedure to be the BFDP procedure, see 3.2) and in the ‘complete’ transfer mode (table 5-3 and 5.7.2).

b) The Forward Frame service instance FFr5 is configured to accept any SL-PDUs of the specified size for CADUs on the target space data link:

   Configuring service instance FFr5 to handle CADUs consists of

   1) Setting the `gvcid-bit-mask` configuration parameter (table 5-3 and 5.7.3) to the ‘don’t care’ bit mask

      00000000 00000000 00000000 00000000 (00 00 00 00 Hex);

   2) Setting the bit pattern in the `authorized-gvcid` configuration parameter (table 5-3 and 5.7.4) to the ‘don’t care’ bit pattern:

      00000000 00000000 00000000 00000000 (00 00 00 00 Hex); and

3) Setting both the `minimum-frame-length` and `maximum-frame-length` configuration parameters (table 5-3, 5.7.5, and 5.7.6) to the fixed-length value of the CADUs.

c) The Forward Frame service instance does not know or care about the data link protocol or coding schemes that have been applied in the CADUs that are being transferred by the service instance. However, the same cannot be said for the Only Idle Data CADU Generation and Multiplexing function, which must inject Only Idle CADUs into the CADU stream that match the space data link protocol and encoding functions applied to the user-generated CADUs so that the resulting waveform is the same as that which would have been created had the CCSDS-standard Only Idle Data Frame Generation function been used. In this scenario, the CADUs carry fixed-length USLP frames that are LDPC encoded, randomized, and have had their synch markers attached by the user before they are transferred to the ESLT. The Only Idle Data CADU configuration parameter of the Only Idle Data CADU Generation and Multiplexing function must therefore be configured to contain a USLP Only Idle Data Frame that has been LDPC-encoded, randomized, and synchronization-markered.

NOTE – Because the Only Idle Data CADU has static, pre-determined content, the CADU configuration cannot be used to transfer CADUs that result from the Forward Frame service user using LDPC coding of a stream of Sync-Marked Transfer Frames as defined in reference [10] (see 1.6.1.6 e)).

d) Because the Forward Frame service user is transferring CADUs, the frame-level coding, optional randomization, and attachment of the synchronization marker functions of *TM Synchronization and Channel Coding* are not performed by the ESLT as part of the underlying production.

e) The Forward 401 Space Link Transmission function is configured to apply the selected modulation, frequency, etc., to the input symbol stream.

2.5.4.4 At some time before the scheduled start time of the Forward Frame service instance, the details of the Service Package are sent from PM to the EM function of the ESLT. The service instance is created by EM and configured, along with the configuration of the required production functions. Initially, the Forward Frame service provider is in state 1 (‘unbound’). At the scheduled start time of the space link session, the ESLT establishes the forward link to the spacecraft and initiates the production processing for the Forward Frame service instance. Typically (but not necessarily) the start time of the service instance 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.

2.5.4.5 The following steps illustrate a typical sequence of operations between the user and the provider of the Forward Frame service instance configured to transfer CADUs:

a) The user invokes the BIND operation of the Association Control procedure to establish an association.

b) The user STARTs the Cyclic Report procedure and specifies which parameters of her service instance and underlying production functions to periodically report and the delivery cycle to be used.

c) The user STARTs the Notification procedure and subscribes to one or more events of the underlying production functions.

d) The user STARTs the BFDP procedure, and the provider instance transitions to state 'bound.active'. The service user may use the START invocation to reset the values of certain configuration parameters of the BFDP procedure, prior to the transfer of CADUs. Activation of the procedure also enables the NOTIFY operation to be invoked when events related specifically to the BFDP procedure occur.

NOTE – The states of the BFDP procedure are the same as those of the Framework Buffered Data Processing procedure.

e) When `production-status` changes to 'operational' the provider sends a NOTIFY invocation to the user.

f) The user sends a PROCESS-DATA invocation to the provider instance. The provider instance verifies that the CADU contained in the invocation is of the allowed size, and

   1) if the CADU in the PROCESS-DATA invocation is of the wrong size, the PROCESS-DATA invocation is discarded and a NOTIFY invocation is sent to the user with the appropriate event and event value;

   2) if the PROCESS-DATA invocation is valid, the service provider enqueues the CADU.

   NOTE – The BFDP procedure allows PROCESS-DATA invocations (each of which carries one CADU) to be transferred individually or in multiples in Forward Buffers. For this scenario, it is assumed that the PROCESS-DATA invocations (and therefore the CADUs) are transferred individually.

g) Additional CADUs are sent by the service user and enqueued if valid.

h) When a CADU reaches the front of the queue, it is made available to the Only Idle Data CADU Generation and Multiplexing function.

i) At some time during the execution of the Service Package, the production processing of the CADUs is interrupted. The BFDP procedure issues a NOTIFY invocation with event 'production status change' with event value 'interrupted'. The interruption causes production processing to stop accepting PROCESS-DATA invocations from the queue and the queue to fill. Once the queue has filled, the service provider instance ceases accepting PROCESS-DATA invocations from the user.

   When the interruption is eventually cleared, production processing is once again able to accept CADUs from the service instance queue. The BFDP procedure issues a

NOTIFY invocation with event ‘production status change’ with event value ‘operational’. Once the queue has been cleared enough to hold additional CADUs, the service instance resumes accepting new PROCESS-DATA invocations from the service user.

j) At some time while the service instance is in the ‘bound.ready’ or ‘bound.active’ state, the user invokes the GET operation of the Information Query procedure to retrieve the current value of one or more parameters of that user’s service instance or an underlying production function.

k) At any time while the service instance is in the ‘bound.ready’ or ‘bound.active’ state, the user may invoke the EXECUTE-DIRECTIVE operation of the Master Throw Event procedure to modify the value of one or more configuration parameters of an underlying production function.

l) The user transfers the last CADU to the provider.

m) The provider completes processing of the queued CADUs.

n) The user invokes the STOP operation for the BFDP procedure and the provider transitions to state 2, ‘bound.ready’.

o) The user invokes the STOP operation for the Cyclic Report procedure to halt cyclic reporting.

p) The user invokes the STOP operation for the Notification procedure to halt event notifications.

q) The user invokes the UNBIND operation to release the association.

2.5.4.6 During the execution of the Service Package, the production functions perform as follows:

a) The Forward Frame-specific Only Idle Data CADU Generation and Multiplexing function receives the CADUs directly from the FFr5 service provider. If no user-data-bearing CADU is available for transmission at a release time, the Only Idle Data CADU Generation and Multiplexing function generates and injects an Only Idle Data CADU (see 2.5.4.3 c)) into the coded symbol stream.

b) The coded symbol stream is modulated onto the RF carrier by the RF carrier by CCSDS 401 RF-and-modulation functions and radiated to the spacecraft.

3 COMPOSITION OF THE FORWARD FRAME CROSS SUPPORT TRANSFER SERVICE

3.1 DISCUSSION

The Object Identifiers for the Forward Frame service are specified in annex B.

The Forward Frame service can be implemented as defined herein without need for further extension or refinement.

The Forward Frame service is instantiated in one of two *data processing modes*: sequence-controlled data processing mode or buffered data processing mode. Each of these modes has its own prime procedure type. Therefore each of these modes is composed of its own set of procedures. Subsection 3.3 specifies the procedures of the sequence-controlled data processing mode of the FF-CSTS, and 3.4 specifies the procedures of the buffered data processing mode of the FF-CSTS.

NOTE – Normally, CSTSes do not have modes that require different prime procedure types. However, because each Forward Frame service instance must support one of several SDLPs, some that require capabilities provided by the SCFDP procedure and some that require the BFDP procedure, the Forward Frame service must allow the SCFDP procedure to be prime in some service instantiations and the BFDP procedure to be prime in other service instantiations. The approach adopted in this specification is to define two modes, each with its own prime procedure. This approach is not documented in the Guidelines (reference [3]) and is used in this service only because the requirements are outside the provisions of the Guidelines. It should be noted that subsection 1.1 of the Guidelines permits such variances as long as they are necessary to the service and are identified in the service specification as being a variance from the Guidelines.

3.2 DATA PROCESSING MODE SERVICE MANAGEMENT PARAMETER

3.2.1 The data processing mode of the Forward Frame service shall set the prime procedure type for the instance of the service, where the 'sequence-controlled' value of the mode designates the Sequence-Controlled Frame Data Processing procedure to be the prime procedure type, and the 'buffered data' value designates the BFDP procedure to be the prime procedure type.

3.2.2 The data processing mode of the Forward Frame service shall be set by the service management parameter with the classifier `ffDataProcessingMode`.

NOTE – The Object Identifiers associated with the service management parameter classifier `ffDataProcessingMode`, is assigned in the SANA Functional Resources registry (reference [4]) under the {`ffCstsProvider 1`} subtree (see annex B).

3.2.3 The Forward Frame service data processing mode service management parameter shall be of type `FfDataProcessingModeType`, as specified in the SANA Functional Resource registry.

3.3 PROCEDURES OF THE SEQUENCE-CONTROLLED DATA PROCESSING MODE OF THE FORWARD FRAME CROSS SUPPORT TRANSFER SERVICE

3.3.1 GENERAL

3.3.1.1 The sequence-controlled data processing mode of the Forward Frame transfer service shall be composed of the Association Control, Sequence-Controlled Frame Data Processing, Cyclic Report, Notification, Information Query, and Master Throw Event procedures.

3.3.1.2 There shall be one and only one instance of the Association Control procedure.

3.3.1.3 The Association Control procedure shall be adopted directly from reference [1].

3.3.1.4 The version number of the Association Control procedure shall be '2', indicating that the Association Control procedure specified in reference [1] shall be used without substitution of any other version of the Association Control procedure.

3.3.1.5 The Sequence-Controlled Frame Data Processing procedure shall be the prime procedure for the sequence-controlled data processing mode of the Forward Frame transfer service.

3.3.1.6 The Sequence-Controlled Frame Data Processing procedure shall be refined and extended from the Sequence-Controlled Data Processing procedure defined in reference [1].

3.3.1.7 The version number of the Sequence-Controlled Frame Data Processing procedure shall be '1'.

3.3.1.8 There shall be zero secondary instances of the Sequence-Controlled Frame Data Processing procedure.

3.3.1.9 The Cyclic Report procedure shall be adopted directly from reference [1].

3.3.1.10 The version number of the Cyclic Report procedure shall be '1', indicating that the Cyclic Report procedure specified in reference [1] shall be used without substitution of any other version of the Cyclic Report procedure.

3.3.1.11 There shall be zero or more secondary instances of the Cyclic Report procedure.

NOTE – The number of secondary instances of the Cyclic Report procedure is unconstrained by this service specification. However, each real implementation sets the number of instances that will be instantiated.

3.3.1.12 The Information Query procedure shall be adopted directly from reference [1].

3.3.1.13 The version number of the Information Query procedure shall be '1', indicating that the Information Query procedure specified in reference [1] shall be used without substitution of any other version of the Information Query procedure.

3.3.1.14 There shall be zero or one secondary procedure instance of the Information Query procedure.

NOTE – The Information Query procedure is optional; an implementation is not required to include it.

3.3.1.15 The Notification procedure shall be adopted directly from reference [1].

3.3.1.16 The version number of the Notification procedure shall be '2', indicating that the Notification procedure specified in reference [1] shall be used without substitution of any other version of the Notification procedure.

3.3.1.17 There shall be zero or more secondary procedure instances of the Notification procedure.

NOTE – The Notification procedure is optional; an implementation is not required to include it. But if an implementation does include the Notification procedure, it may include one or more instances of it. The number of secondary instances of the Notification procedure is unconstrained by this service specification. However, each real implementation sets the number of instances that will be instantiated.

3.3.1.18 The Master Throw Event procedure shall be refined and extended from the Throw Event procedure defined in reference [1].

3.3.1.19 The version number of the Master Throw Event procedure shall be '1'.

3.3.1.20 There shall be zero or one secondary procedure instances of the Master Throw Event procedure.

NOTE – Table 3-1 summarizes the procedures that constitute the sequence-controlled data processing s mode of the Forward Frame transfer service, where (a) the '[P]' in the *Procedure* row designates Sequence-Controlled Frame Data Processing as the prime procedure; (b) *Version* = 'SFW *v*' indicates that the version number *v* of the service procedure is the same as that of the CSTS SFW procedure for those procedures that are directly adopted from reference [1] (where *v* = 1 for Cyclic Report and Information Query and *v* = 2 for Association Control and Notification), and *Version* = '1' indicates the version of the refined and extended service procedures (Sequence-Controlled Frame Data Processing and Master Throw Event); (c) *No. of Instances* indicates the minimum and maximum number of allowed instances of each procedure type; (d) *Specification Approach* indicates which procedures are directly adopted or refined and extended; and (e) *Source* indicates the CSTS SFW procedure from which the service procedure is adopted or refined and extended.

Table 3-1: Procedures of the Sequence-Controlled Data Processing Mode of the Forward Frame Service

Procedure	Association Control	Sequence-Controlled Frame Data Processing [P]	Cyclic Report	Information Query	Notification	Master Throw Event
Version	SFW 2	1	SFW 1	SFW 1	SFW 2	1
No. of Instances	1..1	1..1	0..*	0..1	0..*	0..1
Specification Approach	adopted	refined-and-extended	adopted	adopted	adopted	refined and extended
Source	Reference [1]: Association Control (4.3)	Reference [1]: Sequence-Controlled Data Processing (4.8)	Reference [1]: Cyclic Report (4.10)	Reference [1]: Information Query (4.9)	Reference [1]: Notification (4.11)	Reference [1]: Throw Event (4.12)

3.3.2 INVOCATION OF THE BUFFERED FRAME DATA PROCESSING PROCEDURE

When the Forward Frame service is configured to be in the Sequence-Controlled data processing mode, the service provider shall

a) respond to a START invocation containing the BFDP procedure-type by rejecting the invocation, returning a START negative result with `diagnostic` 'unsupported option', and continue operating; and

b) respond to any other operation invocation containing the BFDP procedure-type by discarding the invocation and signaling a procedure to association abort with `diagnostic` 'protocol error'.

3.3.3 UNIMPLEMENTED OPTIONAL PROCEDURES

3.3.3.1 Discussion

The Cyclic Report, Information Query, Notification, and Master Throw Event procedures of the sequence-controlled data processing mode are optional, meaning implementations may or may not include these procedures. An implementation that does not support an optional procedure rejects incoming invocations to those procedures but does not abort because of them.

3.3.3.2 Unimplemented Cyclic Report procedure

If the implementation of the Forward Frame service does not include the optional Cyclic Report procedure, the service provider shall:

a) respond to a START invocation containing the Cyclic Report procedure-type by rejecting the invocation, returning a START negative result with `diagnostic` 'unsupported option', and continue operating;

b) respond to any other operation invocation containing the Cyclic Report procedure-type by discarding the invocation and signaling a procedure to association abort with `diagnostic` 'protocol error'.

3.3.3.3 Unimplemented Information Query procedure

If the implementation of the Forward Frame service does not include the optional Implementation Query procedure, the service provider shall respond to a GET invocation containing the Information Query `procedure-type` value by rejecting the invocation, returning a GET negative result with `diagnostic` 'unsupported option', and continuing to operate.

3.3.3.4 Unimplemented Notification procedure

If the implementation of the Forward Frame service does not include the optional Notification procedure, the service provider shall

a) respond to a START invocation containing the Notification procedure-type by rejecting the invocation, returning a START negative result with `diagnostic` 'unsupported option', and continuing to operate; and

b) respond to any other operation invocation containing the Notification procedure-type by discarding the invocation and signaling a procedure to association abort with `diagnostic` 'protocol error'.

3.3.3.5 Unimplemented Master Throw Event procedure

If the implementation of the Forward Frame service does not include the optional Master Throw Event procedure, the service provider shall respond to an EXECUTE-DIRECTIVE invocation containing the Master Throw Event `procedure-type` value by rejecting the invocation, returning an EXECUTE-DIRECTIVE negative acknowledgement with `diagnostic` 'unsupported option', and continuing to operate.

3.4 PROCEDURES OF THE BUFFERED DATA PROCESSING MODE OF THE FORWARD FRAME CROSS SUPPORT TRANSFER SERVICE

3.4.1 GENERAL

3.4.1.1 The buffered data processing mode of the Forward Frame transfer service shall be composed of the Association Control, BFDP, Cyclic Report, Notification, Information Query, and Master Throw Event procedures.

3.4.1.2 There shall be one and only one instance of the Association Control procedure.

3.4.1.3 The Association Control procedure shall be adopted directly from reference [1].

3.4.1.4 The version number of the Association Control procedure shall be '2', indicating that the Association Control procedure specified in reference [1] shall be used without substitution of any other version of the Association Control procedure.

3.4.1.5 The BFDP procedure shall be the prime procedure for the buffered data processing mode of the Forward Frame transfer service.

3.4.1.6 The BFDP procedure shall be refined and extended from the Buffered Data Processing procedure defined in reference [1].

3.4.1.7 The version number of the BFDP procedure shall be '1'.

3.4.1.8 There shall be zero secondary instances of the BFDP procedure.

3.4.1.9 The Cyclic Report procedure shall be adopted directly from reference [1].

3.4.1.10 The version number of the Cyclic Report procedure shall be '1', indicating that the Cyclic Report procedure specified in reference [1] shall be used without substitution of any other version of the Cyclic Report procedure.

3.4.1.11 There shall be zero or more secondary instances of the Cyclic Report procedure.

NOTE – The number of secondary instances of the Cyclic Report procedure is unconstrained by this service specification. However, each real implementation sets the number of instances that will be instantiated.

3.4.1.12 The Information Query procedure shall be adopted directly from reference [1].

3.4.1.13 The version number of the Information Query procedure shall be '1', indicating that the Information Query procedure specified in reference [1] shall be used without substitution of any other version of the Information Query procedure.

3.4.1.14 There shall be zero or one secondary procedure instance of the Information Query procedure.

NOTE – The Information Query procedure is optional; an implementation is not required to include it.

3.4.1.15 The Notification procedure shall be adopted directly from reference [1].

3.4.1.16 The version number of the Notification procedure shall be '2', indicating that the Notification procedure specified in reference [1] shall be used without substitution of any other version of the Notification procedure.

3.4.1.17 There shall be zero or more secondary procedure instances of the Notification procedure.

NOTE – The Notification procedure is optional; an implementation is not required to include it. But if an implementation does include the Notification procedure, it may include one or more instances of it. The number of secondary instances of the Notification procedure is unconstrained by this service specification. However, each real implementation sets the number of instances that will be instantiated.

3.4.1.18 The Master Throw Event procedure shall be refined and extended from the Throw Event procedure defined in reference [1].

3.4.1.19 The version number of the Master Throw Event procedure shall be '1'.

3.4.1.20 There shall be zero or one secondary procedure instances of the Master Throw Event procedure.

NOTE – Table 3-2 summarizes the procedures that constitute the buffered data processing mode of the Forward Frame transfer service, where (a) the '[P]' in the *Procedure* row designates Sequence-Controlled Frame Data Processing as the prime procedure; (b) *Version* = 'SFW *v*' indicates that the version number *v* of the service procedure is the same as that of the CSTS SFW procedure for those procedures that are directly adopted from reference [1] (where *v* = 1 for Cyclic Report and Information Query and *v* = 2 for Association Control and Notification), and *Version* = '1' indicates the version of the refined and extended service procedures (BFDP and Master Throw Event); (c) *No. of Instances* indicates the minimum and maximum number of allowed instances of each procedure type; (d) *Specification Approach* indicates which procedures are directly adopted or refined and extended; and (e) *Source* indicates the CSTS SFW procedure from which the service procedure is adopted or refined and extended.

Table 3-2: Procedures of the Buffered Data Processing Mode of the Forward Frame Service

Procedure	Association Control	Buffered Frame Data Processing [P]	Cyclic Report	Information Query	Notification	Master Throw Event
Version	SFW 2	1	SFW 1	SFW 1	SFW 2	1
No. of Instances	1..1	1..1	0..*	0..1	0..*	0..1
Specification Approach	adopted	refined-and-extended	adopted	adopted	adopted	refined and extended
Source	Reference [1]: Association Control (4.3)	Reference [1]: Buffered Data Processing (4.7)	Reference [1]: Cyclic Report (4.10)	Reference [1]: Information Query (4.9)	Reference [1]: Notification (4.11)	Reference [1]: Throw Event (4.12)

3.4.2 INVOCATION OF THE SEQUENCE-CONTROLLED FRAME DATA PROCESSING PROCEDURE

When the Forward Frame service is configured to be in the buffered data processing mode, the service provider shall

a) respond to a START invocation containing the Sequence-Controlled Frame Data Processing procedure-type by rejecting the invocation, returning a START negative result with `diagnostic` 'unsupported option', and continuing to operate; and

b) respond to any other invocation containing the Sequence-Controlled Frame Data Processing procedure-type by discarding the invocation and signaling a procedure to association abort with `diagnostic` 'protocol error'.

3.4.3 UNIMPLEMENTED OPTIONAL PROCEDURES

3.4.3.1 Discussion

The Cyclic Report, Information Query, Notification, and Master Throw Event procedures of the sequence-controlled data processing mode are optional, meaning implementations may or may not include these procedures. An implementation that does not support an optional procedure rejects incoming invocations to those procedures but does not abort because of them.

3.4.3.2 Unimplemented Cyclic Report Procedure

Subsection 3.3.3.2 specifies the behavior of an implementation of the Forward Frame service that does not include the optional Cyclic Report procedure.

3.4.3.3 Unimplemented Information Query Procedure

Subsection 3.3.3.3 specifies the behavior of an implementation of the Forward Frame service that does not include the optional Information Query procedure.

3.4.3.4 Unimplemented Notification Procedure

Subsection 3.3.3.4 specifies the behavior of an implementation of the Forward Frame service that does not include the optional Notification procedure.

3.4.3.5 Unimplemented Master Throw Event Procedure

Subsection 3.3.3.5 specifies the behavior of an implementation of the Forward Frame service that does not include the optional Master Throw Event procedure.

3.5 FORWARD FRAME CROSS SUPPORT TRANSFER SERVICE STATE MACHINE

The FF-CSTS state machine shall conform to the state machine for a CSTS with a stateful prime procedure instance, as defined in the CSTS Framework (G3 of reference[1]).

4 SEQUENCE-CONTROLLED FRAME DATA PROCESSING PROCEDURE

4.1 DISCUSSION

4.1.1 PURPOSE

The SCFDP procedure of the Forward Frame service is used to transfer SDLP Transfer Frames of one VC from the service user to the service provider.

The principal operational philosophy of the SCFDP procedure is that the sequencing and timing of the transmission of each frame is of critical importance, and that if each frame cannot be transmitted in-sequence and within its permitted time window then the transmission of frames must be suspended until proper sequencing and timing can be restored.

NOTE – The SCFDP procedure is derived from the CSTS SFW Sequence-Controlled Data Processing procedure (4.8 of reference [1]). The SCFDP procedure inherits from that Sequence-Controlled Data Processing procedure the following behavior: (a) data units may be accompanied by earliest and latest processing time parameters; (b) the earliest processing time regulates when the data unit can begin to be processed; (c) if the data unit does not begin to be processed by the latest processing time, that data unit and all data units received after it are discarded; and (d) the procedure does not resume accepting data units until the procedure is reset by the service user. This sequence and timing enforcement by the SCFDP should be taken into account when determining the effects on the behavior of protocol functions that produce the frames being transferred by Forward Frame service instances. For example, the Telecommand space data link protocol (reference [7]) allows frames to be tagged to identify them as frames that bypass the retransmission queue of the COP retransmission protocol. However, the Forward Frame service makes no distinction between the different types of frames. As a result, any expedited TC frames sent via the Forward Frame service in sequence-controlled data processing mode will still be subject to the timing constraints on any frames preceding it, up to and including deletion if one or more of the preceding frames are themselves deleted. Implementations of systems that use the Forward Frame in the sequence-controlled data processing mode should be designed with this behavior in mind.

4.1.2 CONCEPT

The concept of the SCFDP procedure is the same as that of the parent CSTS SFW Sequence-Controlled Data Processing procedure with additional data validation criteria that result in PROCESS-DATA negative result returns, and addition of a START invocation parameter.

Additional `data` validation. In addition to the PROCESS-DATA invocation acceptance criteria described in 4.8.2.2 of reference [1], the SCFDP procedure also validates the length and first four octets of the `data` parameter of the PROCESS-DATA invocation to ensure

that the `data` parameter of the invocation is carrying a valid Transfer Frame for the specific VC and SDLP being supported by the Forward Frame service instance to which the SCFDP procedure instance belongs.

If the length of the frame in the `data` parameter is outside the range of the minimum and maximum permitted lengths, the PROCESS-DATA invocation is rejected.

For the purposes of the SCFDP procedure, the pertinent Transfer Frame identification information comprises the TFVN (which identifies the SDLP), SCID, and VCID fields. Collectively, these three fields comprise the GVCID. The SCFDP procedure is configured to accept the frames with one GVCID. If the GVCID fields of the data parameter do not match their configured values, the PROCESS-DATA invocation is rejected.

NOTE – Assurance that multiple instances of the SCFDP procedure (i.e., that multiple instances of the Forward Frame service) are not configured to permit transfer of frames for the same VC into the same forward space link is the responsibility of Service Management.

Additional Sequence-Controlled Frame Data Processing START invocation parameter. The SCFDP procedure adds the `input-queue-size` parameter to the START invocation to allow the user of the service instance that contains the SCFDP procedure to change the value of the `input-queue-size` configuration parameter of the SCFDP procedure instance as part of activating the procedure instance.

4.2 PROCEDURE TYPE IDENTIFIER

The procedure type identifier `sequenceControlledFrameDataProcessing`, as specified in annex B, shall be used for this procedure.

4.3 REFINEMENT

The Sequence-Controlled Frame Data Processing procedure shall refine the PROCESS-DATA operation of the CSTS SFW Sequence-Controlled Data Processing procedure by setting the type of the `data` parameter to be an octet string.

4.4 EXTENSION

4.4.1 The Sequence-Controlled Frame Data Processing procedure shall extend the PROCESS-DATA negative result of the Framework Sequence-Controlled Data Processing procedure by adding the ‘invalid GVCID’, ‘frame too short’, and ‘frame too long’ diagnostics.

4.4.2 The Sequence-Controlled Frame Data Processing procedure shall extend the START invocation of the Framework Sequence-Controlled Data Processing procedure by adding the `input-queue-size` parameter.

4.4.3 The Sequence-Controlled Frame Data Processing procedure shall extend the behavior of the CSTS SFW Sequence-Controlled Data Processing procedure by modifying the behavior of the procedure to

a) permit the modification of the `input-queue-size` configuration parameter as part of the activation of the procedure instance;

b) reject (in addition to the reasons for rejection inherited from the Sequence-Controlled Data Processing procedure) PROCESS-DATA invocations whose `data` parameter contents (1) do not match the GVCID configured for that Forward Frame service instance, (2) are shorter than the configured minimum length for that Forward Frame service, or (3) are longer than the configured maximum length for that Forward Frame service; and

c) initialize and update parameters that count the number of data units received, the number of data units submitted to processing, and the current size of the Input Queue.

4.5 BEHAVIOR

4.5.1 The Notification of Production Status Changes, Notification of Production Configuration Changes, Locking, Resetting, Stopping, Terminating, and Aborting behaviors of the Sequence-Controlled Frame Data Processing procedure shall be the same as those of the Sequence-Controlled Data Processing procedure specified in subsections 4.8.3.5, 4.8.3.6, 4.8.3.7, 4.8.3.8, 4.8.3.9, 4.8.3.10, and 4.8.3.11, respectively, of reference [1].

4.5.2 The Starting behavior of the Sequence-Controlled Frame Data Processing procedure shall be the same as that of the Sequence-Controlled Data Processing procedure, as specified in 4.8.3.1 of reference [1], with the addition of the following requirement:

> If the value of the `input-queue-size` parameter of the START invocation is 'modify', the value of the `input-queue-size` procedure configuration parameter of the Sequence-Controlled Frame Data Processing procedure shall be set to the value of the `input-queue-size` parameter of the START invocation as part of the activation of the procedure.

4.5.3 The Transfer and Queuing of Data Units behavior of the Sequence-Controlled Frame Data Processing procedure shall be the same as that of the Sequence-Controlled Data Processing procedure, as specified in 4.8.3.2 of reference [1], with the addition of the following requirements:

4.5.3.1 If the result of the ANDing of the first 4 octets of the `data` parameter of the PROCESS-DATA invocation with the `gvcid-bit-mask` configuration parameter does not match the `authorized-gvcid` configuration parameter, the PROCESS-DATA invocation shall be invalid, and the service provider shall issue a PROCESS-DATA negative return with the `diagnostic` 'invalid GVCID'.

a) For Telecommand frames, the value of the `gvcid-bit-mask` configuration parameter shall be
11000011 11111111 11111100 00000000 (C3 FF FC 00 Hex).

b) For Telecommand frames, the bits of the `authorized-gvcid` configuration parameter that correspond to the TFVN, SCID, and VCID fields of the Telecommand Transfer Frame Primary Header shall be set to the GCVID of the permitted virtual channel.

c) For AOS frames, the value of the `gvcid-bit-mask` parameter shall be 11111111 11111111 00000000 00000000 (FF FF 00 00 Hex).

d) For AOS frames, the bits of the `authorized-gvcid` configuration parameter that correspond to the TFVN, SCID, and VCID fields of the AOS Transfer Frame Primary Header shall be set to the GCVID of the permitted virtual channel.

e) For USLP frames, the value of the `gvcid-bit-mask` parameter shall be 11111111 11111111 11111111 11100000 (FF FF FF E0 Hex).

f) For USLP frames, the bits of the `authorized-gvcid` configuration parameter that correspond to the TFVN, SCID, Source or Destination ID, and VCID fields of the USLP Transfer Frame Primary Header shall be set to the GCVID of the permitted virtual channel.

NOTE – Frames transferred by the Forward Frame service contain the SCID of the destination space node. Therefore the Source or Destination ID bit of the authorized-gvcid configuration parameter that corresponds to the Source or Destination ID bit of the USLP Transfer Frame Primary Header (the 21st bit) shall be set to 1 when the Forward Frame service is provided by an ESLT.

4.5.3.2 If the length of the `data` parameter of the PROCESS-DATA invocation is less than that specified by the `minimum-frame-length` configuration parameter, the PROCESS-DATA invocation shall be invalid, and the service provider shall issue a PROCESS-DATA negative return with the `diagnostic` 'frame too short'.

4.5.3.3 If the length of the `data` parameter of the PROCESS-DATA invocation is greater than that specified by the `maximum-frame-length` configuration parameter, the PROCESS-DATA invocation shall be invalid, and the service provider shall issue a PROCESS-DATA negative return with the `diagnostic` 'frame too long'.

4.5.3.4 Upon successful validation of the PROCESS-DATA invocation, the service provider shall

a) increment the value of the `number-of-data-units-received` parameter by 1; and

b) increment the `input-queue-size` parameter by 1.

4.5.3.5 For each PROCESS-DATA invocation that is discarded from the Input Queue without being transferred to production processing, the service provider shall decrement the `input-queue-size` parameter by 1.

4.5.4 The Processing of Data Units behavior of the Sequence-Controlled Frame Data Processing procedure shall be the same as that of the Sequence-Controlled Data Processing procedure, as specified in 4.8.3.3 of reference [1], with the addition of the following requirements: Upon transfer of the data unit from the Input Queue to service production, the service provider shall

a) increment the value of the `number-of-data-units-submitted-to-processing` parameter by 1; and

b) decrement the `input-queue-size` parameter by 1.

4.5.5 The Positive Feedback requirements of the Sequence-Controlled Data Processing procedure, as specified in 4.8.3.4 of reference [1], shall be replaced with the following requirement: Upon the receipt of a 'data unit processing completed' event from service production, the service provider shall

a) increment the value of the `number-of-data-units-processed` parameter by 1; and

b) if the value of the `process-completion-report` parameter (see 4.6.4.1.4 of reference [1]) in the associated PROCESS-DATA invocation was 'produce report', send a NOTIFY invocation with Event Identifier 'data unit processing completed'.

NOTE – The 'data unit processing completed' event is emitted by service production at the detected or estimated time of radiation of the data unit (see G2.3.4).

4.5.6 INITIALIZATION OF DATA UNIT COUNTERS

At the start of the service instance provision period, the service provider shall initialize the values of the `number-of-data-units-received`, `number-of-data-units-submitted-to-processing`, and `number-of-data-units-processed` parameters to 'zero'.

4.6 REQUIRED OPERATIONS

4.6.1 The Sequence-Controlled Frame Data Processing procedure shall use the STOP, NOTIFY, and EXECUTE-DIRECTIVE operations of the Sequence-Controlled Data Processing procedure, as specified in reference [1], without extension or refinement.

4.6.2 The Sequence-Controlled Frame Data Processing procedure shall extend the START operation of the Sequence-Controlled Data Processing procedure, as specified in 4.6.4.

4.6.3 The Sequence-Controlled Frame Data Processing procedure shall extend and refine the PROCESS-DATA operation of the Sequence-Controlled Data Processing procedure, as specified in 4.6.4.

NOTE – Table 4-1 summarizes the operations of the Sequence-Controlled Frame Data Processing procedure of the Forward Frame service.

Table 4-1: Sequence-Controlled Frame Data Processing Procedure Required Operations

Operations	Extended	Refined	Procedure Blocking/Non-Blocking
START	Y	N	Blocking
STOP	N	N	Blocking
PROCESS-DATA	Y	Y	Non-Blocking
NOTIFY	N	N	Non-Blocking
EXECUTE-DIRECTIVE	N	N	Blocking

4.6.4 START (CONFIRMED)

4.6.4.1 Invocation, Return, and Parameters

4.6.4.1.1 General

In addition to the parameters of the START operation of the Sequence-Controlled Data Processing procedure, defined in 4.8 of reference [1], the extension parameter defined in table 4-2 shall be present in the START invocation of the Sequence-Controlled Frame Data Processing procedure.

Table 4-2: START Extension Parameter

Extension Parameter	Invocation	Return
`input-queue-size`	M	

4.6.4.1.2 Extension Parameter Syntax

The type `SequContrFrameDataProcStartInvocExt`, as defined in annex C, shall define the syntax of the extension parameter of the START invocation.

4.6.4.1.3 `input-queue-size`

The input-queue-size parameter shall have one of two values:

a) 'unchanged': The value of the `input-queue-size` configuration parameter of the Sequence-Controlled Frame Data Processing procedure instance is to be unchanged from its current value.

b) 'modify': The value of the `input-queue-size` configuration parameter of the Sequence-Controlled Frame Data Processing procedure instance is to be modified. The 'modify' value contains the value (in number of PROCESS-DATA invocations that can be stored in the queue) to which the `input-queue-size` configuration parameter is to be set.

4.6.4.1.4 The `input-queue-size` configuration parameter shall be present in every START invocation.

4.6.5 PROCESS-DATA (CONFIRMED)

4.6.5.1 Invocation, Return, and Parameters

4.6.5.1.1 `data` Parameter Refinement

The `data` parameter of the PROCESS-DATA invocation shall be formatted as an octet string.

NOTES

1 The `data` parameter of the Framework core PROCESS-DATA invocation has an abstract type that must be resolved by the procedure that uses the PROCESS-DATA operation. The Framework Sequence-Controlled Data Processing procedure defers the resolution of the `data` parameter to the service that uses a procedure that is derived from the Framework Sequence-Controlled Data Processing procedure (reference [1], 4.8.4.2.1, Note).

2 The `data` parameter is expected to contain a Transfer Frame for a support CCSDS space data link protocol. However, the Forward Frame will actually validate any octet string with any format as long as (a) the first four octets of the octet string, when ANDed with the `gvcid-bit-mask` configuration parameter, matches the `authorized-gvcid` configuration parameter; and (b) the length of the octet string is within the configured minimum and maximum lengths.

4.6.5.1.2 Return `diagnostic`

4.6.5.1.2.1 General

The `diagnostic` parameter shall have one of the `diagnostic` values specified in 4.8.4.2.7.1 of reference [1] or one of the following values:

a) 'invalid GVCID'—the header fields corresponding to those of the GVCID do not match the authorized GVCID for this procedure instance (see 4.5.3.1);

b) 'frame too short'—the length of the `data` parameter of the PROCESS-DATA invocation is less than the minimum frame length specified for this procedure instance (see 4.5.3.2);

c) 'frame too long'—the length of the `data` parameter of the PROCESS-DATA invocation is greater than the maximum frame length specified for this procedure instance (see 4.5.3.3).

4.6.5.1.2.2 Return `diagnostic` extension syntax

The type `SequContrFrameDataProcProcDataDiagnosticExt`, as defined in annex C, shall define the syntax of the extension diagnostics for the PROCESS-DATA negative return.

4.7 CONFIGURATION PARAMETERS

4.7.1 The Sequence-Controlled Frame Data Processing procedure configuration parameters that need to be configured in the context of the procedure shall be as defined in table 4-3.

NOTES

1 For each configuration parameter, the table provides the engineering unit (if applicable), provides a cross reference to the use of the parameter in the specification of the procedure, identifies whether the parameter may be read and/or dynamically modified, and also identifies the Parameter Identifier and type to be used in reporting the value of the parameter.

2 Section 1.6.1.7.37 of the reference [1] states, 'Unless explicitly specified otherwise in the Framework definition of a procedure type, the method(s) by which the values of dynamically modifiable procedure configuration parameters are modified is (are) delegated to the service using the procedure or to a derived procedure'. For the Sequence-Controlled Frame Data Processing procedure, the only dynamically modifiable configuration parameter is the `input-queue-size` parameter. For the Forward Frame service, the only method by which the value of this parameter can be modified is through the START invocation as specified in 4.6.4.1.3.

Table 4-3: Sequence-Controlled Frame Data Processing Procedure Configuration Parameters

Parameters	Cross-Reference	Readable	Dynamically modifiable	Configuration Parameter Identifier and Type
`input-queue-size` (in number of PROCESS-DATA invocations the queue will store)	CSTS SFW (reference [1]), 4.6.3.2.3	Yes	Yes	`pDPinputQueueSize PDPinputQueueSizeType` (CSTS SFW F3.16)
`gvcid-bit-mask` (4-octet)	4.5.3.1	Yes	No	`pSCFDPgvcidBitMask PSCFDPgvcidBitMaskType` (annex F)
`authorized-gvcid` (4-octet)	4.5.3.1	Yes	No	`pSCFDPauthorizedGvcid PSCFDPauthorizedGvcidType` (annex F)
`minimum-frame-length` (in octets)	4.5.3.2	Yes	No	`pSCFDPminFrameLen PSCFDPminFrameLenType` (annex F)
`maximum-frame-length` (in octets)	4.5.3.3	Yes	No	`pSCFDPmaxFrameLen PSCFDPmaxFrameLenType` (annex F)

4.7.2 The `gvcid-bit-mask` shall be set to the bit mask pattern for the applicable space data link protocol data unit type (TC, AOS, USLP, CADU, or other) that is specified in the service management parameter with the classifier `ffAuthorizedGvcidAndBitMask`.

4.7.3 The `authorized-gvcid` shall be set to the value that is specified in the service management parameter with the classifier `ffAuthorizedGvcidAndBitMask`.

4.7.4 The `minimum-frame-length` shall be set to the value of the service management parameter with the classifier `ffMinFrameLength`.

4.7.5 The `maximum-frame-length` shall be set to the value of the service management parameter with the classifier `ffMaxFrameLength`.

NOTES

1 The classifier for the `input-queue-size` configuration parameter is specified in 7.3.

2 If the procedure is used to transfer fixed-length frames, the values of the `ffMinFrameLength` and `ffMaxFrameLength` parameters are the same.

3 The Object Identifiers associated with the service management parameter classifiers `ffAuthorizedGvcidAndBitMask`, `ffMinFrameLength`, and `ffMaxFrameLength` are assigned in the SANA Functional Resources registry (reference [4]) under the {`ffCstsProvider 1`} subtree (see annex B).

4.8 READ-ONLY PARAMETERS

4.8.1 The Sequence-Controlled Frame Data Processing procedure read-only parameters shall be as defined in table 4-4.

NOTE – For each read-only parameter, the table provides the engineering unit (if applicable), provides a cross reference to the use of the parameter in the specification of the procedure, the classifier of the parameter, the type to be used in reporting the value of the parameter, and the annex in which that type is specified.

Table 4-4: Sequence-Controlled Frame Data Processing Procedure Read-Only Parameters

Parameters	Cross-Reference	Read-Only Parameter Classifier and Type

`number-of-data-units-received` (in number of PROCESS-DATA invocations)	4.5.3.4 a), 4.5.6	`pSCFDPnumberDataUnitsRcvd`
		`PSCFDPnumberDataUnitsRcvdType`
		(annex F)

`number-of-data-units-submitted-to-processing` (in number of PROCESS-DATA invocations)	4.5.4 a), 4.5.6	`pSCFDPnumberDataUnitsToProcessing`
		`PSCFDPnumberDataUnitsToProcessingType`
		(annex F)

`number-of-data-units-processed` (in number of PROCESS-DATA invocations)	4.5.5 a), 4.5.6	`pSCFDPnumberDataUnitsProcessed`
		`PSCFDPnumberDataUnitsProcessedType`
		(annex F)

4.8.2 When the Sequence Controlled Frame Data Processing Procedure is the prime procedure type, the functional resource parameter (see 1.6.1.12.3) with the classifier `ffNumberDataUnitsRcvd` shall be set to the value of the SCFDP `number-of-data-units-received` parameter.

4.8.3 When the Sequence Controlled Frame Data Processing Procedure is the prime procedure type, the functional resource parameter with the classifier `ffNumberDataUnitsToProcessing` shall be set to the value of the SCFDP `number-of-data-units-submitted-to-processing` parameter.

4.8.4 When the Sequence Controlled Frame Data Processing Procedure is the prime procedure type, the functional resource parameter with the classifier `ffNumberDataUnitsProcessed` shall be set to the value of the SCFDP `number-of-data-units-processed` parameter.

4.9 PROCEDURE STATE TABLE

NOTE – In the following tables, the specifications that are inherited from the parent Sequence-Controlled Data Processing procedure are *italicized*, and additions to the tables that are specific to the Sequence-Controlled Frame Data Processing procedure are in plain text.

Table 4-5: Sequence-Controlled Frame Data Processing Procedure State Table

No.	Incoming Event	State 1 ('inactive')	State 2.1 ('active.processing')	State 2.2 ('active.locked')

1	*(StartInvocation)*	*IF "positive result"*
		THEN
		'change the input queue size'
		(+StartReturn)
		→ 2.1
		ELSE
		(-StartReturn)
		ENDIF
			{procedure to association abort 'protocol error'} → 1	*{procedure to association abort 'protocol error'} → 1*

2	*(StopInvocation)*	*{procedure to association abort 'protocol error'}*	*IF "positive result"*
			THEN
			{initiate stop}
			→ 1
			ELSE
			(-StopReturn)
			ENDIF
				IF "positive result"
				THEN
				{initiate stop}
				→ 1
				ELSE
				(-StopReturn)
				ENDIF

3	*(ProcessDataInvocation)*	*{procedure to association abort 'protocol error'}*	*IF "positive result"*
			THEN
			'queue data unit'
			'increment data units received'
			'increment current input queue'
			(+ProcessDataReturn)
			ELSE
			(-ProcessDataReturn)
			ENDIF
				(-ProcessDataReturn)

4	*'data unit ready'*	*Not applicable*	*IF 'production status = 'interrupted''*
			THEN
			→ 2.2
			ELSE
			'process data unit'
			'increment data units submitted to processing'
			'decrement current input queue'
			ENDIF
				Not applicable

5	*'data unit processing completed'*	*[ignore]*	*IF "report"* *THEN* *'notify 'data processing completed' / 'empty''* *ENDIF*	*Not applicable*
6	*'expired'*	*Not applicable*	*'discard data unit'* 'decrement current input queue' *'notify 'expired' / 'empty''* *→ 2.2*	*Not applicable*

No.	Incoming Event	State 1 ('inactive')	State 2.1 ('active.processing')	State 2.2 ('active.locked')
7	*'production status change to 'interrupted''*	*[ignore]*	*'notify 'production status change' / 'interrupted''* *IF 'processing data unit''* *THEN* *'discard data units in processing'* *→ 2.2* *ENDIF*	*[ignore]*
8	*'production status change to 'halted''*	*[ignore]*	*'discard data units in processing'* *'notify 'production status change' / 'halted''* *→ 2.2*	*'notify 'production status change' / 'halted''*
9	*'production status change to 'operational''*	*[ignore]*	*Not applicable*	*'notify 'production status change' / 'operational''*
10	*'production status change to 'configured''*	*[ignore]*	*Not applicable*	*'notify 'production status change' / 'configured''*
11	*'production configuration change'*	[ignore]	'notify 'production configuration change''	'notify 'production configuration change'/'empty''
12	*'data processing configuration change'*	*[ignore]*	*'notify 'data processing configuration change' / 'procedure configuration parameter values'' (see 4.8.4.3.4.1 of reference [1])*	*'notify 'data processing configuration change' / 'procedure configuration parameter values'' (see 4.8.4.3.4.1 of reference [1])*
13	*'invalid PDU 'xxx''*	*{procedure to association abort 'protocol error'}*	*{procedure to association abort 'xxx'} → 1*	*{procedure to association abort 'xxx'} → 1*
14	*'terminate procedure'*	*'terminate itself'*	*'terminate itself'*	*'terminate itself'*
15	*(ExecuteDirectiveInvocation)*	*{procedure to association abort 'protocol error'}*	*IF directive-identifier = 'reset'* *THEN* *(+ExecuteDirective-Acknowledge)* *{reset}* *(+ExecuteDirectiveReturn)* *ELSE* *{- ExecuteDirective-Acknowledge with diagnostic 'unknown directive'}*	*IF directive-identifier = 'reset'* *THEN* *(+ExecuteDirective-Acknowledge)* *{reset}* *(+ExecuteDirectiveReturn)* *→ 2.1* *ELSE* *{- ExecuteDirective-Acknowledge with diagnostic 'unknown directive'}*

Table 4-6: Procedure State Table Incoming Event Description References

Event	Reference
'expired'	*(4.8.3.3.2.5 and 4.8.4.3.2 of reference [1]). A data unit is available at the head of the Input Queue, but its* `latest-data-process-start-time` *has expired.*
'data unit processing completed'	4.5.5
'data unit ready'	*4.8.3.3.2 of reference [1]* *A data unit is available at the head of the Input Queue, and* `production-status` *is 'operational'; neither* `earliest-data-process-start-time` *nor* `latest-data-process-start-time` *is specified, or the current time is between* `earliest-data-process-start-time` *and* `latest-data-process-start-time`*, and* `production-status` *is 'operational'.*
'terminate procedure'	*4.2.3 of reference [1]*
'production status change to 'xxx'	*B2.5 of reference [1]*
'production configuration change'	*3.11.2.2.3.2 b) of reference [1]*
'data processing configuration change'	*4.6.4.2.3 c) of reference [1]*
'invalid PDU xxx''	*3.2.3.6, 4.2.2.4 of reference [1], where 'xxx' is one of the diagnostic values specified in 4.2.2.5 of reference [1]*

Table 4-7: Procedure State Table Predicate Descriptions

Predicate	Evaluates to TRUE if
"positive result"	*No reason for sending a negative return has been detected; that is, for the START invocation, none of the conditions in (3.7.2.3.1 or 4.6.3.1 a) of reference [1]) apply; for the STOP invocation none of the conditions in 3.3.2.7.1 of reference [1] applies;* and for the PROCESS-DATA invocation none of the conditions in 4.6.5.1.2.1 apply.
"report"	*The* `process-completion-report` *parameter value in the associated (ProcessDataInvocation) PDU is 'produce report' (see 4.6.4.1.4 of reference [1]).*
"processing data unit"	*A data unit has been read from the top of the Input Queue and processing of this data unit has started but not completed*
"production status = 'interrupted'"	*The current value of* `production-status` *is 'interrupted'.*

Table 4-8: Procedure State Table Simple Action References

Name	References
'queue data unit'	4.5.3
'process data unit'	4.5.4
'complete data processing'	*4.6.3.6.2 b) of reference [1]*
'clear the Input Queue'	*(4.6.3.6.2 a) and 4.8.3.8 b) of reference [1]).*
'notify 'xxx' / 'yyy"	*(4.6.3.5.1.1, 4.6.3.5.2, 4.6.3.5.3, 4.6.4.2.3 a), 4.6.4.2.3 b), 4.6.4.2.3 c), and 4.8.4.3.3.1 of reference [1]) (NotifyInvocation) with* `event-name` *set to 'xxx' and* `event-value` *set to 'yyy'. In case a notification does not use an event-value, 'yyy' shall be set to 'empty'.*
'discard data unit'	*4.8.3.3.2.5 of reference [1].*
'discard data units in processing'	*4.6.3.3.6 of reference [1]*
'procedure to association abort 'xxx"	*(4.2.2.3 and 4.2.2.5 of reference [1]) raise 'procedure to association abort 'xxx" event with* `diagnostic` *set to 'xxx' to the Association Control procedure*
'terminate itself'	*4.6.3.7 of reference [1]*
'wait' <event>	*(4.8.3.8 c) and 4.8.3.8 d) of reference [1]), wait until the event <event> occurs*
'set the `data-unit-id` *parameter as per the received* `directive-qualifier` *parameter value'*	*4.8.3.8 e) of reference [1]*
'change the input queue size'	4.5.2
'increment data units received'	4.5.3.4 a)
'increment data units submitted to processing'	4.5.4 a)
'increment current input queue'	4.5.3.4 b)
'decrement current input queue'	4.5.3.5, 4.5.4 b)

Table 4-9: Procedure State Table Compound Action Definitions

Name	Actions Performed
{initiate stop}	*'clear the input queue'* *'complete data processing'* *(+StopReturn)*
{procedure to association abort 'xxx'}	*'clear the input queue'* *'discard data units in processing'* *'procedure to association abort 'xxx''*
{reset}	*'clear the Input Queue'* *'wait 'data unit processing completed''* *'wait 'production status operational''* *'set the* `data-unit-id` *parameter as per the received* `directive-qualifier` *parameter value'*

5 BUFFERED FRAME DATA PROCESSING PROCEDURE

5.1 DISCUSSION

5.1.1 PURPOSE

The BFDP procedure of the Forward Frame service is used to transfer SDLP Transfer Frames of one VC from the service user to the service provider.

The principal operational philosophy of the BFDP procedure is that the sequencing and timing of data contained within the Transfer Frames is ultimately maintained by protocols above the Data Link Layer (that is, above the layer at which the frames exist). Therefore the responsibility of the service performing the BFDP procedure is to allow the frames to flow into the forward link symbol stream with no inhibition on flow other than that possibly resulting from multiplexing with frames of other VCs.

5.1.2 CONCEPT

The concept of the BFDP procedure is the same as that of the parent Buffered Data Processing procedure defined in reference [1], with additional data validation criteria that result in rejection of invalid PROCESS-DATA invocations and rejection notifications, and the addition of START invocation parameters.

`data` validation. The BFDP procedure validates the length and first four octets of the `data` parameter of the PROCESS-DATA invocation to ensure that it is carrying a valid Transfer Frame for the specific VC and SDLP being supported by the Forward Frame service instance to which the BFDP procedure instance belongs.

If the length of the frame in the `data` parameter is outside the range of the minimum and maximum permitted lengths, the PROCESS-DATA invocation is rejected and a NOTIFY invocation is sent to the service user identifying the rejected invocation and the reason for rejection.

For the purposes of the BFDP procedure, the pertinent Transfer Frame identification information comprises the TFVN (which identifies the SDLP), SCID, and VCID fields, which collectively comprise the GVCID. The BFDP procedure is configured to accept the frames with one GVCID. If the GVCID fields of the data parameter do not match their configured values, the PROCESS-DATA invocation is discarded and a NOTIFY invocation is sent to the service user identifying the rejected invocation and the reason for rejection.

NOTE – Assurance that multiple instances of the BFDP procedure (i.e., that multiple instances of the Forward Frame service) are not configured to permit transfer of frames for the same VC into the same forward space link is the responsibility of Service Management.

Additional BFDP START invocation parameters. The BFDP procedure adds the `input-queue-size`, `maximum-forward-buffer-size`, and `processing latency limit` parameters to the START invocation to allow the user of the service instance that contains the BFDP procedure to change the values of the `input-queue-size`, `maximum-forward-buffer-size`, and `processing latency limit` configuration parameters of the BFDP procedure instance, as part of activating the procedure instance.

Service management of transfer mode. Subsection 4.7.2.2 of reference [1] defers to the individual service the specification of the method by which the transfer mode of this procedure is to be determined. This procedure establishes the transfer mode as a procedure configuration parameter, which in turn is set by a service management parameter.

5.2 PROCEDURE TYPE IDENTIFIER

The procedure type identifier `bufferedFrameDataProcessing`, as specified in annex B, shall be used for this procedure.

5.3 REFINEMENT

The BFDP procedure shall refine the PROCESS-DATA operation of the Framework Buffered Data Processing procedure by setting the type of the `data` parameter to be an octet string.

5.4 EXTENSION

5.4.1 The BFDP procedure shall add the `input-queue-size`, `maximum-forward-buffer-size`, and `processing-latency-limit` parameters to the START invocation of the Framework Buffered Data Processing procedure to allow the service user to change the values of the `input-queue-size`, `maximum-forward-buffer-size`, and `processing-latency-limit` dynamically modifiable configuration parameters as part of the activation of the BFDP procedure instance.

5.4.2 The BFDP procedure shall extend the behavior of the Framework Buffered Data Processing procedure by modifying the behavior of the procedure to

a) permit the modification of the `input-queue-size`, `maximum-forward-buffer-size`, and `processing-latency-limit` configuration parameters as part of the activation of the procedure instance;

b) discard PROCESS-DATA invocations whose `data` parameter contents (1) do not match the GVCID configured for that Forward Frame service instance, (2) are shorter than the configured minimum length for that Forward Frame service, or (3) are longer than the configured maximum length for that Forward Frame service; and to send corresponding notifications to the user; and

c) initialize and update parameters that count the number of data units received, the number of data units submitted to processing, and the current size of the Input Queue.

5.5 BEHAVIOR

5.5.1 The Notifications, Stopping, Terminating, and Aborting behaviors of the BFDP procedure shall be the same as those of the Buffered Data Processing procedure specified in 4.7.3.5, 4.7.3.6, 4.7.3.7, and 4.7.3.8, respectively, of reference [1].

5.5.2 The Starting behavior of the BFDP procedure shall be the same as that of the Buffered Data Processing procedure, as specified in 4.7.3.1 of reference [1], with the addition of the following requirements:

5.5.2.1 If the value of the `input-queue-size` parameter of the START invocation is 'modify', the value of the `input-queue-size` procedure configuration parameter of the BFDP procedure shall be set to the value of the `input-queue-size` parameter of the START invocation prior to the activation of the procedure.

5.5.2.2 If the value of the `processing-latency-limit` parameter of the START invocation is 'modify', the value of the `processing-latency-limit` procedure configuration parameter of the BFDP procedure shall be set to the value of the `processing-latency-limit` parameter of the START invocation as part of the activation of the procedure.

5.5.2.3 If the value of the `maximum-forward-buffer-size` parameter of the START invocation is 'modify', the value of the `maximum-forward-buffer-size` procedure configuration parameter of the BFDP procedure shall be set to the value of the `maximum-forward-buffer-size` parameter of the START invocation, as part of the activation of the procedure.

5.5.3 The Transfer and Queuing of PROCESS-DATA Invocations behavior of the BFDP procedure shall be the same as that of the Buffered Data Processing procedure, as specified in 4.7.3.2 of reference [1], with the addition of the following requirements:

5.5.3.1 If the result of the ANDing of the first 4 octets of the `data` parameter of the PROCESS-DATA invocation with the `gvcid-bit-mask` configuration parameter does not match the `authorized-gvcid` configuration parameter, the service provider shall invalidate the PROCESS-DATA invocation and invoke the NOTIFY operation with `event-name` set to 'invalid GVCID' and `event-value` set to the value of the `data-unit-id` parameter of the invalid PROCESS-DATA invocation.

a) For Telecommand frames, the value of the `gvcid-bit-mask` configuration parameter shall be
11000011 11111111 11111100 00000000 (C3 FF FC 00 Hex).

b) For Telecommand frames, the bits of the `authorized-gvcid` configuration parameter that correspond to the TFVN, SCID, and VCID fields of the Telecommand Transfer Frame Primary Header shall be set to the GCVID of the permitted virtual channel.

c) For AOS frames, the value of the `gvcid-bit-mask` parameter shall be 11111111 11111111 00000000 00000000 (FF FF 00 00 Hex).

d) For AOS frames, the bits of the `authorized-gvcid` configuration parameter that correspond to the TFVN, SCID, and VCID fields of the AOS Transfer Frame Primary Header shall be set to the GCVID of the permitted virtual channel.

e) For USLP frames, the value of the `gvcid-bit-mask` parameter shall be 11111111 11111111 11111111 11100000 (FF FF FF E0 Hex).

f) For USLP frames, the bits of the `authorized-gvcid` configuration parameter that correspond to the TFVN, SCID, Source or Destination ID, and VCID fields of the USLP Transfer Frame Primary Header shall be set to the GCVID of the permitted virtual channel.

NOTE – Frames transferred by the Forward Frame service contain the SCID of the destination space node. Therefore the Source or Destination ID bit of the `authorized-gvcid` configuration parameter that corresponds to the Source or Destination ID bit of the USLP Transfer Frame Primary Header (the 21st bit) shall be set to 1 when the Forward Frame service is provided by an ESLT.

5.5.3.2 If the length of the `data` parameter of the PROCESS-DATA invocation is less than that specified by the `minimum-frame-length` configuration parameter, the service provider shall invalidate the PROCESS-DATA invocation and shall invoke the NOTIFY operation with `event-name` set to 'frame too short' and `event-value` set to the value of the `data-unit-id` parameter of the invalid PROCESS-DATA invocation.

5.5.3.3 If the length of the `data` parameter of the PROCESS-DATA invocation is greater than that specified by the `maximum-frame-length` configuration parameter, the service provider shall invalidate the PROCESS-DATA invocation and invoke the NOTIFY operation with `event-name` set to 'frame too long' and `event-value` set to the value of the `data-unit-id` parameter of the invalid PROCESS-DATA invocation.

5.5.3.4 Upon successful validation of the PROCESS-DATA invocation, the service provider shall

a) place the PROCESS-DATA invocation in the Input Queue;

b) increment the value of the `number-of-data-units-received` parameter by 1; and

c) increment the `input-queue-size` parameter by 1.

5.5.3.5 For each PROCESS-DATA invocation that is discarded from the Input Queue without being transferred to production processing, the service provider shall decrement the `input-queue-size` parameter by 1.

5.5.4 The Processing of Data Units behavior of the BFDP procedure shall be the same as that of the Buffered Data Processing procedure, as specified in 4.7.3.3 of reference [1], with the addition of the following requirements:

Upon transfer of the data unit from the Input Queue to production processing, the service provider shall

a) increment the value of the number-of-data-units-submitted-to-processing parameter by 1; and

b) decrement the input-queue-size parameter by 1.

5.5.5 The Positive Feedback requirements of the Buffered Data Processing procedure, as specified in 4.7.3.4 of reference [1], shall be replaced with the following requirement:

Upon the receipt of a 'data unit processing completed' event from service production, the service provider shall

a) increment the value of the number-of-data-units-processed parameter by 1; and

b) if the value of the process-completion-report parameter (see 4.6.4.1.4 of reference [1]) in the associated PROCESS-DATA invocation is 'produce report', send a NOTIFY invocation with Event Identifier 'data unit processing completed'.

NOTE – The 'data unit processing completed' event is emitted by service production at the detected or estimated time of radiation of the data unit (see G2.3.4).

5.5.6 INITIALIZATION OF DATA UNIT COUNTERS

At the start of the service instance provision period, the service provider shall initialize the values of the `number-of-data-units-received`, `number-of-data-units-submitted-to-processing`, and `number-of-data-units-processed` parameters to 'zero'.

5.6 REQUIRED OPERATIONS

5.6.1 The BFDP procedure shall use the STOP operation of the Buffered Data Processing procedure, as specified in reference [1], without extension or refinement.

5.6.2 The BFDP procedure shall extend the START operation of the Buffered Data Processing procedure, as specified in 5.6.5.

5.6.3 The BFDP procedure shall refine the PROCESS-DATA operation of the Buffered Data Processing procedure, as specified in 5.6.6.

5.6.4 The BFDP procedure shall extend the NOTIFY operation of the Buffered Data Processing procedure, as specified in 5.6.7.

NOTE – Table 5-1 summarizes the operations of the BFDP procedure of the Forward Frame service.

Table 5-1: Buffered Frame Data Processing Procedure Required Operations

Operations	Extended	Refined	Procedure Blocking/Non-Blocking
START	Y	N	Blocking
STOP	N	N	Blocking
PROCESS-DATA	N	Y	Non-Blocking
NOTIFY	Y	N	Non-Blocking

5.6.5 START (CONFIRMED)

5.6.5.1 Invocation, Return, and Parameters

5.6.5.1.1 In addition to the parameters of the START operation of the Buffered Data Processing procedure as defined in 4.7.4.1 of reference [1], the extension parameter defined in table 5-2 shall be present in the START invocation of the BFDP procedure.

Table 5-2: START Extension Parameter

Extension Parameter	Invocation	Return
`input-queue-size`	M	
`maximum-forward-buffer-size`	M	
`processing-latency-limit`	M	

5.6.5.1.2 Extension Parameter Syntax

The type `BuffFrameDataProcStartInvocExt`, as defined in annex D, shall define the syntax of the extension parameter of the START invocation.

5.6.5.1.3 `input-queue-size`

The `input-queue-size parameter` shall have one of two values:

a) 'unchanged': The value of the `input-queue-size` configuration parameter of the BFDP procedure instance is to be unchanged from its current value.

b) 'modify': The value of the `input-queue-size` configuration parameter of the BFDP procedure instance is to be modified. The 'modify' value contains the value (in number of PROCESS-DATA invocations that can be stored in the queue) to which the `input-queue-size` configuration parameter is to be set.

5.6.5.1.4 The `input-queue-size` configuration parameter shall be present in every START invocation.

5.6.5.1.5 `maximum-forward-buffer-size`

The `maximum-forward-buffer-size` parameter shall have one of two values:

a) 'unchanged': The value of the `maximum-forward-buffer-size` configuration parameter of the BFDP procedure instance is to be unchanged from its current value.

b) 'modify': The value of the `maximum-forward-buffer-size` configuration parameter of the BFDP procedure instance is to be modified. The 'modify' value contains the value (in number of PROCESS-DATA invocations that can be stored in the forward buffer) to which the `maximum-forward-buffer-size` configuration parameter is to be set.

5.6.5.1.6 The `maximum-forward-buffer-size` configuration parameter shall be present in every START invocation.

5.6.5.1.7 `processing-latency-limit`

The `processing-latency-limit` parameter shall have one of two values:

a) 'unchanged': The value of the `processing-latency-limit` configuration parameter of the BFDP procedure instance is to be unchanged from its current value.

b) 'modify': The value of the `processing-latency-limit` configuration parameter of the BFDP procedure instance is to be modified. The 'modify' value contains the value (in milliseconds) to which the `processing-latency-limit` configuration parameter is to be set.

5.6.5.1.8 The `processing-latency-limit` configuration parameter shall be present in every START invocation.

5.6.6 PROCESS-DATA (UNCONFIRMED)—INVOCATION PARAMETER—`DATA` PARAMETER REFINEMENT

The `data` parameter of the PROCESS-DATA invocation shall be formatted as an octet string.

NOTE – The `data` parameter is expected to contain a fixed-length Transfer Frame for either the AOS or Unified space data link protocol, or a CADU containing a (possibly encoded) CCSDS-standard fixed-length Transfer Frame. However, the Forward Frame service will actually validate any octet string with any format as long as (a) the first four octets of the octet string, when ANDed with the `gvcid-bit-mask` configuration parameter, matches the `authorized-gvcid` configuration parameter; and (b) the length of the octet string is within the configured minimum and maximum lengths. Such a data unit would of course have to have corresponding production processing functions associated with it, and Service Management would have to be able to configure the Forward Frame service instance to operate correctly with those production processing functions.

5.6.7 NOTIFY (UNCONFIRMED)

5.6.7.1 General

The BFDP procedure shall extend the NOTIFY operation of the Buffered Data Processing procedure defined in 4.7.4.2 of reference [1] through the definition of three additional possible events (event names with their event values).

5.6.7.2 Invocation and Parameters

5.6.7.2.1 `event-name` Extension

5.6.7.2.1.1 The value of the `event-name` parameter shall be one of the following:

a) one of the values specified for the NOTIFY operation of the Data Processing procedure in 4.6.4.2.3 of reference [1];

b) 'invalid GVCID' (`event-name`)—in the `data` parameter of a PROCESS-DATA invocation, the header fields corresponding to those of the GVCID do not match the authorized GVCID for this procedure instance (see 4.5.3.1):

   1) the `event-name` of this event shall contain the procedure instance identifier of the BFDP procedure instance triggering the event;

   2) the associated `event-value` shall contain the value of the `data-unit-id` of the failed PROCESS-DATA invocation, where the path specifying the type to be used is defined in 5.6.7.2.1.2;

c) 'frame too short' (`event-name`)—in the `data` parameter of a PROCESS-DATA invocation, the length of the `data` parameter of the PROCESS-DATA invocation is less than the minimum frame length specified for this procedure instance (see 4.5.3.2):

   1) the `event-name` of this event shall contain the procedure instance identifier of the BFDP procedure instance triggering the event;

   2) the associated `event-value` shall contain the value of the `data-unit-id` of the failed PROCESS-DATA invocation, where the path specifying the type to be used is defined in 5.6.7.2.1.2;

d) 'frame too long' (`event-name`)—in the `data` parameter of a PROCESS-DATA invocation, the length of the `data` parameter of the PROCESS-DATA invocation is greater than the maximum frame length specified for this procedure instance (see 4.5.3.3):

   1) the `event-name` of this event shall contain the procedure instance identifier of the BFDP procedure instance triggering the event;

   2) the associated `event-value` shall contain the value of the `data-unit-id` of the failed PROCESS-DATA invocation; the path specifying the type to be used is defined in 5.6.7.2.1.2.

5.6.7.2.1.2 The data type of the `event-value` parameter for the 'invalid GVCID', 'frame too short', and 'frame too long' events uses the following path:

a) the first part of the path is 'NotifyInvocation': 'eventValue': 'EventValue': 'qualifiedValue': 'SequenceOfQualifiedValue': 'SEQUENCE OF QualifiedValue', where this sequence has the length 1;

b) the second part of the path is 'QualifiedValue': 'valid': 'TypeAndValueComplexQualified': 'typeAndValue': 'Embedded': 'EMBEDDED PDV', where the Object Identifier and the type of the `data-unit-id` parameter are `pBFDPdataUnitId` as specified in annex D and `DataUnitId` as specified in F3.3 of reference [1], respectively.

NOTE – All relevant types are defined in F3.3 of reference [1].

5.6.7.2.1.3 The Published Identifier (i.e., Event Identifier) for the event-name of the 'invalid GVCID' event is specified in annex F as `pBFDPinvalidGvcid`.

5.6.7.2.1.4 The Published Identifier (i.e., Event Identifier) for the event-name of the 'frame too short' event is specified in annex F as `pBFDPframeTooShort`.

5.6.7.2.1.5 The Published Identifier (i.e., Event Identifier) for the event-name of the 'frame too long' event is specified in annex F as `pBFDPframeTooLong`.

5.7 CONFIGURATION PARAMETERS

5.7.1 The BFDP procedure configuration parameters that need to be configured in the context of the procedure shall be as defined in table 5-3.

NOTES

1 For each configuration parameter, the table provides the engineering unit (if applicable) a cross reference to the use of the parameter in the specification of the procedure, identifies whether the parameter may be read and/or dynamically modified, and also identifies the Parameter Identifier and type to be used in reporting the value of the parameter.

2 Section 1.6.1.7.37 of reference [1] states, "Unless explicitly specified otherwise in the Framework definition of a procedure type, the method(s) by which the values of dynamically modifiable procedure configuration parameters are modified is (are) delegated to the service using the procedure or to a derived procedure." For the Buffered Frame Data Processing procedure, the only dynamically modifiable configuration parameters are the `input-queue-size`, `maximum-forward-buffer-size`, and `processing-latency-limit` parameters. For the Forward Frame service, the only method by which the values of these parameters can be modified is through the START invocation as specified in 5.6.5.1.3.

Table 5-3: Buffered Frame Data Processing Procedure Configuration Parameters

Parameters	Cross-Reference	Read-able	Dynam-ically modifi-able	Configuration Parameter Identifier and Type
input-queue-size (in number of PROCESS-DATA invocations the queue will store)	CSTS SFW (reference [1]), 4.6.3.2.3	Yes	Yes	pDPinputQueueSize PDPinputQueueSizeType (CSTS SFW F3.16)
maximum-forward-buffer-size (in number of PROCESS-DATA invocations the buffer will store)	CSTS SFW (reference [1]), 4.7.3.2.1.2	Yes	Yes	pBDPmaxForwardBufferSize PBDPmaxForwardBufferSizeType (CSTS SFW F3.16)
processing-latency-limit (in milliseconds)	CSTS SFW (reference [1]), 4.7.3.2.2.7	Yes	Yes	pBDPprocessingLatencyLimit PBDPprocessingLatencyLimitType (CSTS SFW F3.16)
data-transfer-mode (complete, timely)	CSTS SFW (reference [1]), 4.7.3.2.2	Yes	No	pBDPdataTransferMode PBDPdataTransferModeType (CSTS SFW F3.16))
gvcid-bit-mask (4-octet)	5.5.3.1	Yes	No	pBFDPgvcidBitMask PBFDPgvcidBitMaskType (annex F)
authorized-gvcid (4-octet)	5.5.3.1	Yes	No	pBFDPauthorizedGvcid PBFDPauthorizedGvcidType (annex F)
minimum-frame length (in octets)	5.5.3.2	Yes	No	pBFDPminFrameLen PBFDPminFrameLenType (annex F)
maximum-frame length (in octets)	5.5.3.3	Yes	No	pBFDPmaxFrameLen PBFDPmaxFrameLenType (annex F)

5.7.2 The data-transfer-mode shall be set to the value of the bufferedData:dataTransferMode component of the service management parameter with the classifier ffDataProcessingMode.

5.7.3 The gvcid-bit-mask shall be set to the bit mask pattern for the applicable space data link protocol data unit type (TC, AOS, USLP, CADU, or other) that is specified in the service management parameter with the classifier ffAuthorizedGvcidAndBitMask.

5.7.4 The authorized-gvcid shall be set to the value that is specified in the service management parameter with the classifier ffAuthorizedGvcidAndBitMask.

5.7.5 The minimum-frame-length shall be set to the value of the service management parameter with the classifier ffMinFrameLength.

5.7.6 The `maximum-frame-length` shall be set to the value of the service management parameter with the classifier `ffMaxFrameLength`.

NOTES

1 The classifiers for the `input-queue-size`, `maximum-forward-buffer-size`, and `processing-latency-limit` configuration parameters are specified in 7.4.1, 7.4.2, and 7.4.3, respectively.

2 If the procedure is used to transfer fixed-length frames, the values of the `ffMinFrameLength` and `ffMaxFrameLength` parameters are the same.

3 The Object Identifiers associated with the service management parameter classifiers `ffDataTransferMode`, `ffAuthorizedGvcidAndBitMask`, `ffMinFrameLength`, and `ffMaxFrameLength` are assigned in the SANA Functional Resources registry (reference [4]) under the {`ffCstsProvider 1`} subtree (see annex B).

5.8 READ-ONLY PARAMETERS

5.8.1 The BFDP procedure read-only parameters shall be as defined in table 5-4.

NOTE – For each read-only parameter, the table provides the engineering unit (if applicable), a cross reference to the use of the parameter in the specification of the procedure, the classifier of the parameter, the type to be used in reporting the value of the parameter, and the annex in which that type is specified.

Table 5-4: Buffered Frame Data Processing Procedure Read-Only Parameters

Parameters	Cross-Reference	Read-Only Parameter Classifier and Type
number-of-data-units-received (in number of PROCESS-DATA invocations)	5.5.3.4 b), 5.5.6	pBFDPnumberDataUnitsRcvd PBFDPnumberDataUnitsRcvdType (annex F)
number-of-data-units-submitted-to-processing (in number of PROCESS-DATA invocations)	5.5.4 a), 5.5.6	pBFDPnumberDataUnitsToProcessing PBFDPnumberDataUnitsToProcessingType (annex F)
number-of-data-units-processed (in number of PROCESS-DATA invocations)	5.5.5 a), 5.5.6	pBFDPnumberDataUnitsProcessed PBFDPenumberDataUnitsProcessedType (annex F)

5.8.2 When the Buffered Frame Data Processing Procedure is the prime procedure type, the functional resource parameter (see 1.6.1.12.3) with the classifier ffNumberDataUnitsRcvd shall be set to the value of the BFDP number-of-data-units-received parameter.

5.8.3 When the Buffered Frame Data Processing Procedure is the prime procedure type, the functional resource parameter with the classifier ffNumberDataUnitsToProcessing shall be set to the value of the BFDP number-of-data-units-submitted-to-processing parameter.

5.8.4 When the Buffered Frame Data Processing Procedure is the prime procedure type, the functional resource parameter with the classifier ffNumberDataUnitsProcessed shall be set to the value of the BFDP number-of-data-units-processed parameter.

5.9 PROCEDURE STATE TABLE

NOTE – In the following tables, the specifications that are inherited from the parent Buffered Data Processing procedure are *italicized*, and the additions to the tables that are specific to the BFDP procedure are in plain text.

Table 5-5: Buffered Frame Data Processing Procedure State Table

No.	Incoming Event	State 1 ('inactive')	State 2 ('active')

1	*(StartInvocation)*	*IF "positive result"*
		THEN
		{change modifiable parameters}
		set "reading suspended" to FALSE
		(+StartReturn)
		→ 2
		ELSE
		(-StartReturn)
		ENDIF
			{procedure to association abort 'protocol error'}
			⟶1

2	*(StopInvocation)*	*{procedure to association abort 'protocol error'}*	*IF "positive result"*
			THEN
			{initiate stop}
			⟶1
			ELSE
			(-StopReturn)
			ENDIF

3	*(ProcessDataInvocation)*[1]	*{procedure to association abort 'protocol error'}*	IF "valid invocation"
			THEN
			IF "timely mode"
			THEN
			IF "queue overflow"
			THEN
			'discard oldest data units'
			ENDIF
			ENDIF
			'queue data unit'
			'increment data units received'
			'increment current input queue'
			IF "complete mode"
			THEN
			IF "queue full"
			THEN
			'suspend reading'
			set "reading suspended" to TRUE
			ENDIF
			ENDIF
			ELSE
			'notify invalid invocation'
			ENDIF

[1] In terms of Service Provider behavior, handling of an incoming PROCESS-DATA invocation and handling of an incoming forward buffer containing only one PROCESS-DATA invocation are identical.

No.	Incoming Event	State 1 ('inactive')	State 2 ('active')

4	*(ForwardBuffer)*	*{procedure to association abort 'protocol error'}*	FOR_EACH (ProcessDataInvocation)
			IN (ForwardBuffer)
			IF "valid invocation"
			THEN
			IF "timely mode"
			THEN
			IF "queue overflow"
			THEN
			'discard oldest data units'
			ENDIF
			ENDIF
			'queue data unit'
			'increment data units received'
			'increment current input queue'
			IF "complete mode"
			THEN
			IF "queue full"
			THEN
			'suspend reading'
			set "reading suspended" to TRUE
			ENDIF
			ENDIF
			ELSE
			'notify invalid invocation'
			ENDIF
			ENDFOR_EACH

5	*'data unit ready'*	*Not applicable*	*'process data unit'* 'increment data units submitted to processing' 'decrement current input queue'
6	*'data unit processing completed'*	*[ignore]*	*IF "report"* *THEN* *'notify 'data processing completed'/ 'empty"* *ENDIF* *IF "reading suspended"* *THEN* *IF (NOT "queue full")* *THEN* *'resume reading'* *set "reading suspended" to FALSE* *ENDIF* *ENDIF*
7	*'processing latency timer expired'*	*Not applicable*	*'discard data unit'*
8	*'production status change to 'interrupted"*	*[ignore]*	*'discard data units in processing'* *'notify 'production status change' / 'interrupted"*
9	*'production status change to 'halted"*	*[ignore]*	*'discard data units in processing'* *'notify 'production status change' / 'halted"*
10	*'production status change to 'operational"*	*[ignore]*	*'notify 'production status change' / 'operational"*
11	*'production status change to 'configured"*	*[ignore]*	*'notify 'production status change' / 'configured"*
12	*'production configuration change'*	*[ignore]*	*'notify 'production configuration change' / 'empty"*

No.	Incoming Event	State 1 ('inactive')	State 2 ('active')
13	*'data processing configuration change'*	*[ignore]*	*'notify 'data processing configuration change' / 'procedure configuration parameter values" (see 4.7.4.2.2.2 of reference [1])*
14	*'invalid PDU 'xxx"*	*{procedure to association abort 'xxx'}*	*{procedure to association abort 'xxx'}* ⟶*1*
15	*'terminate procedure'*	*'terminate itself'*	*'terminate itself')*

Table 5-6: Procedure State Table Incoming Event Description References

Event	Reference
'data unit processing completed'	5.5.5
'data unit ready'	*4.6.3.3.1 of reference [1]*
'processing latency timer expired'	*4.7.3.2.2.11 of reference [1]*
'terminate procedure'	*4.2.3 of reference [1]*
'production status change to 'xxx"	*B2.5 of reference [1]*
'production configuration change'	*3.11.2.2.3.2 b) of reference [1]*
'data processing configuration change'	*4.7.4.2.2.2 of reference [1]*
'invalid PDU 'xxx"	*(3.2.3.6, 4.2.2.4, 4.7.3.2.1.4 of reference [1]), where 'xxx' is one of the diagnostic values specified in (4.2.2.5 or 4.7.3.2.1.4 of reference [1]).*

Table 5-7: Procedure State Table Predicate Descriptions

Predicate	Evaluates to TRUE if
"queue overflow"	*There is not sufficient space on the Input Queue to store the PROCESS-DATA invocations received (see 4.7.3.2.2.4 of reference [1]): the transfer mode is 'timely'.*
"queue full"	*There is not enough space on the Input Queue to store all PROCESS-DATA invocations that might be contained in a maximum sized forward buffer (see 4.7.3.2.2.3 of reference [1]): the transfer mode is 'complete'.*
"complete mode"	*Complete transfer mode is in effect, based on the setting of the data-*`transfer-mode` *procedure configuration parameter (table* 5-3*).*

Predicate	Evaluates to TRUE if
"timely mode"	*Timely transfer mode is in effect, based on the setting of the data-*`transfer-mode` *procedure configuration parameter (table* 5-3*).*
"positive result"	*No reason for sending a negative return has been detected; that is, for the START invocation, none of the conditions in 3.7.2.3.1 or 4.6.3.1 a) of reference [1] applies, and for the STOP invocation, none of the conditions in 3.3.2.7.1 of reference [1] applies.*
"report"	*The* `process-completion-report` *parameter value in the associated ProcessDataInvocation PDU is 'produce report' (see 4.6.4.1.4 of reference [1]).*
"valid invocation"	*A*ll validity checks specified in 5.5.3.1, 5.5.3.2, and 5.5.3.3 are passed.

Table 5-8: Procedure State Table Boolean Flags

Predicate	Set to TRUE if
"reading suspended"	*In complete transfer mode reading data from the data communications service has been suspended.*

Table 5-9: Procedure State Table Simple Action References

Name	References
'queue data unit'	*4.7.3.2 of reference [1]*
'complete data processing'	*4.6.3.6.2 b) of reference [1]*
'clear the Input Queue'	*4.6.3.6.2 a) of reference [1].*
'suspend reading'	*4.7.3.2 of reference [1]*
'resume reading'	*4.7.3.2 of reference [1]*
'discard oldest data units'	*4.7.3.2 of reference [1]*
'discard data unit'	*(4.7.3.2.2.11 of reference [1]),* 5.5.3.1, 5.5.3.2, 5.5.3.3
'discard data units in processing'	*4.6.3.3.6 of reference [1]*
'notify 'xxx' / 'yyy''	*(NotifyInvocation) with* `event-name` *set to 'xxx' and* `event-value` *set to 'yyy'. (4.6.3.5.1.1, 4.6.3.5.2, 4.6.3.5.3, 4.6.4.2.3 a), 4.6.4.2.3 b), 4.6.4.2.3 c), and 4.7.4.2.2.2 of reference [1])*.
'notify invalid invocation'	Send a (NotifyInvocation) with `event-name` set to the event as defined in 5.5.3.1, 5.5.3.2, or 5.5.3.3 (as appropriate), and event-value set to the value of the `data-unit-id` parameter of the invalid invocation.
'procedure to association abort 'xxx''	*(4.2.2.3 and 4.2.2.5 of reference [1]) raise 'procedure to association abort 'xxx'' event with* `diagnostic` *set to 'xxx' to the Association Control procedure*

Name	References
'terminate itself'	*4.6.3.7 of reference [1]*
'change the input queue size'	5.5.2.1
'change the maximum forward buffer size'	5.5.2.3
'change the processing latency limit'	5.5.2.2
'increment data units received'	5.5.3.4 b)
'increment data units submitted to processing'	5.5.4 a)
'increment current input queue'	5.5.3.4 c)
'decrement current input queue'	5.5.3.5, 5.5.4 b)

Table 5-10: Procedure State Table Compound Action Definitions

Name	Actions Performed
{procedure to association abort 'xxx'}	*'clear the input queue'* *'discard data units in processing'* *'procedure to association abort 'xxx''*
{initiate stop}	*'clear the input queue'* *'complete data processing'* *(+StopReturn)*
{change modifiable parameters}	'change the input queue size' 'change the maximum forward buffer size' 'change the processing latency limit'

6 MASTER THROW EVENT PROCEDURE

6.1 DISCUSSION

6.1.1 PURPOSE

The Master Throw Event procedure of the Forward Frame service is used to allow a service user to reconfigure the values of dynamically modifiable configuration parameters of the FR instances that comprise the production processes that directly support that instance of the Forward Frame service.

6.1.2 CONCEPT

Many Provider CSSSes extend the capability to dynamically modify some configuration parameters (e.g., bit rate, modulation index) of the production processes that support cross transfer services such as the Forward Frame service. The Master Throw Event procedure allows a user of a Forward Frame service instance to be able to change the modifiable configuration parameters of the FR instances that support that specific service instance.

NOTE – The prospective CCSDS SC-CSTS will allow the user of that service to change the modifiable configuration parameters of *all* FR instances in a Service Package. Once the SC-CSTS becomes available, the Master Throw Event procedure of the Forward Frame service is expected to be deprecated.

Because the same set of FR instances can be shared by multiple Forward Frame service instances (as well as other higher-layer protocols, such as those for Space Packets and Space Internetworking), operational policies normally mandate that only one service instance per forward space link be given control over the configuration of those shared resources. This service instance is referred to herein as the *master service instance*, and the user of that service instance is referred to as the *master user*.

To support the enforcement of the operational policy of only one master instance/user per shared forward space link, the Master Throw Event procedure has an `enable-master-throw-event` procedure configuration parameter that controls whether or not the Master Throw Event procedure of a given Forward Frame service can be activated. The `enable-master-throw-event` procedure configuration parameter is in turn configured by a service management parameter.

NOTE – It is ultimately the responsibility of Service Management to enforce the policy by configuring only one instance of Forward Frame service per forward space link to be enabled to use the Master Throw Event procedure.

Procedure enablement validation. The Master Throw Event procedure validates any EXECUTE-DIRECTIVE invocation with procedure type identifier `masterThrowEvent` against the value of the `enable-master-throw-event` procedure configuration parameter for that procedure instance. If the value is ‘enabled’, then the EXECUTE-DIRECTIVE is processed in accordance with the Throw Event procedure specified in reference [1]. If the value is ‘disabled’, the EXECUTE-DIRECTIVE invocation is rejected.

6.2 PROCEDURE TYPE IDENTIFIER

The procedure type identifier `masterThrowEvent`, as specified in annex B, shall be used for this procedure.

6.3 REFINEMENT

The Master Throw Event procedure shall refine the behavior of the Throw Event procedure specified in reference [1] by limiting the valid directives to those of FR instances that are directly associated with the provision or production of the Forward Frame service instance that is executing the Master Throw Event procedure.

NOTE – The default scope of the EXECUTE-DIRECTIVE operation of the Framework Throw Event procedure allows it to transfer directives for (a) the Throw Event procedure instance itself, (b) any instance of other procedure of the service executing the Throw Event procedure and (c) any FR instance that is directly associated with the provision or production of the Forward Frame service instance that is executing the Throw Event procedure (see 3.13.1.1 of reference [1]). There are no directives defined for the Master Throw Event procedure, so case (a) is non-applicable. However, the Forward Frame service does include the Sequence-Controlled Frame Data Processing procedure, for which the 'reset' directive exists; the Master Throw Event procedure explicitly eliminates case (b) to disallow the invocation of the 'reset' directive through the Master Throw Event. Case (c) is the only valid case for the Master Throw Event procedure.

6.4 EXTENSION

6.4.1 The Master Throw Event procedure shall extend the Framework Throw Event procedure by adding the `enable-master-throw-event` procedure configuration parameter to enable the use of the procedure.

6.4.2 The Master Throw Event procedure shall add the 'master throw event disabled' `diagnostic` to the EXECUTE-DIRECTIVE negative result acknowledgement of the Framework Throw Event procedure to indicate that the attempt to use the procedure has been denied.

6.5 BEHAVIOR

6.5.1 The behavior of the Master Throw Event procedure shall be the same as that of the Throw Event procedure (4.12 of reference [1]), with the following requirements:

6.5.2 If the `master-throw-event-enabled` procedure configuration parameter has the value 'disabled', the service provider shall reject every EXECUTE-DIRECTIVE invocation and send a negative acknowledgement with `diagnostic` 'master throw event disabled'.

6.5.3 In order to be valid, the directive must be for a FR instance that is directly associated with the Forward Frame service instance that is executing the Master Throw Event procedure.

6.5.4 If the directive-identifier is for either the Master Throw Event procedure itself or for any instance of any other procedure of the Forward Frame service, the service provider shall reject the EXECUTE-DIRECTIVE invocation and send a negative acknowledgement with `diagnostic` 'unknown directive'.

6.6 REQUIRED OPERATIONS

6.6.1 The Master Throw Event procedure shall extend the EXECUTE-DIRECTIVE operation of the Throw Event procedure, as specified in 6.6.2.

NOTE – Table 6-1 summarizes the operations of the Master Throw Event procedure of the Forward Frame service.

Table 6-1: Master Throw Event Procedure Required Operation

Operations	Extended	Refined	Procedure Blocking/Non-Blocking
EXECUTE-DIRECTIVE	Y	N	Non-Blocking

6.6.2 EXECUTE-DIRECTIVE (CONFIRMED)—INVOCATION, RETURN, AND PARAMETER—ACKNOWLEDGEMENT `DIAGNOSTIC` EXTENSION

6.6.2.1 If an EXECUTE-DIRECTIVE negative acknowledgement is sent, the `diagnostic` parameter shall contain one of the following values:

a) one of the `diagnostic` values specified in 4.12.4.1.3.1 of reference [1]; or

b) 'master throw event disabled'; the Master Throw Event procedure cannot be used by this service instance.

6.6.2.2 The type `MasterTeExecDirNegAckDiagnosticExt`, as defined in annex E, shall specify the additional value of the `diagnostic` parameter of the EXECUTE-DIRECTIVE negative acknowledgement.

6.7 CONFIGURATION PARAMETERS

6.7.1 The Master Throw Event procedure configuration parameters that need to be configured in the context of the procedure shall be as defined in table 6-2.

NOTE – For each configuration parameter, the table provides the engineering unit (if applicable), provides a cross reference to the use of the parameter in the specification of the procedure, identifies whether the parameter may be read and/or dynamically modified, and also identifies the Parameter Identifier and type to be used in reporting the value of the parameter.

Table 6-2: Master Throw Event Procedure Configuration Parameters

Parameters	Cross-Reference	Read-able	Dynam-ically modifi-able	Configuration Parameter Identifier and Type
`master-throw-event-enabled`	6.5.2	Yes	No	`pMTEenableThrowEvent` `PMTEenableThrowEventType` (annex F)

6.7.2 The `master-throw-event-enabled` shall be set to the value of the service management parameter with the classifier `ffMasterThrowEventEnabled`.

NOTE – The Object Identifiers associated with the service management parameter classifier `ffMasterThrowEventEnabled` is assigned in the SANA Functional Resources registry (reference [4]) under the `{ffCstsProvider 1}` subtree (see annex B).

6.8 PROCEDURE STATE TABLE

6.8.1 The Master Throw Event procedure adopts the Throw Event Procedure State Table, Procedure State Table Incoming Event Description References, and Procedure State Table Simple Action References tables (tables 4-71, 4-72, and 4-74, respectively, of reference [1]).

6.8.2 The Master Throw Event procedure modifies the definition of the ‘valid directive’ predicate (Procedure State Table Predicate Definitions, table 4-73 of reference [1]) as follows: the predicate ‘valid directive’ evaluates to TRUE if ‘none of the error conditions identified in 4.12.4.1.3.1 of reference [1]), 6.5.2, or 6.5.4 are true for the EXECUTE-DIRECTIVE invocation.’

7 SETTING OF SERVICE MANAGEMENT AND CONFIGURATION PARAMETERS INHERITED FROM FRAMEWORK OPERATIONS AND PROCEDURES

7.1 GENERAL

The procedures specified in reference [1] define configuration parameters for the Framework procedures, but defer to the derived services the specification of the method by which each of those configuration parameters is to be set. Sections 7.2 through 7.7 specify the method by which each of the Framework procedure configuration parameters is to be set for the FF-CSTS.

For each of the procedure configuration parameters that are specified to be a service management parameter, the classifier for each parameter is also specified. The `parameterId` corresponding to each such classifier is defined in the SANA Functional Resources registry (reference [4]) under the `{ffCstsProvider 1}` subtree (see annex B). The type of each service management parameter is the same as that of the corresponding procedure parameter.

7.2 ASSOCIATION CONTROL PROCEDURE CONFIGURATION PARAMETERS

7.2.1 The `initiator-identifier` configuration parameter (4.3.5 of reference [1]) shall be set by the service management parameter with the classifier `ffInitiatorId`.

7.2.2 The `responder-identifier` configuration parameter (4.3.5 of reference [1]) shall be set by the service management parameter with the classifier `ffResponderId`.

7.2.3 The `service-instance-identifier` parameter (4.3.5 of reference [1]) shall be set by the service management parameter with the classifier `ffSvcInstanceId`.

7.2.4 The `responder-port-identifier` service management parameter (3.4.2.2.4.3 and 4.3.5 of reference [1]) shall be set by the service management parameter with the classifier `ffResponderPortId`.

NOTE – As described in the specification of the `responder-port-identifier` parameter (specified in reference [1]), the contents of the parameter are not used by the Association Control procedure itself, but rather by the underlying communications service that delivers the incoming PDUs to CSTS provider. The purpose of assigning a classifier and `parameterId` to this parameter is to allow its value to be reported or queried.

7.3 SEQUENCE-CONTROLLED FRAME DATA PROCESSING PROCEDURE CONFIGURATION PARAMETERS

The `input-queue-size` configuration parameter (4.8.5 of reference [1]) shall be set by the service management parameter with the classifier `ffInputQueueSize`.

7.4 BUFFERED FRAME DATA PROCESSING PROCEDURE CONFIGURATION PARAMETERS

7.4.1 The `input-queue-size` configuration parameter (4.7.5 of reference [1]) shall be set by the service management parameter with the classifier `ffInputQueueSize`.

7.4.2 The `maximum-forward-buffer-size` configuration parameter (4.7.5 of reference [1]) shall be set by the service management parameter with the classifier `ffMaxFwdBufferSize`.

7.4.3 The `processing-latency-limit` configuration parameter (4.7.5 of reference [1]) shall be set by the service management parameter with the classifier `ffProcedureLatencyLimit`.

7.5 CYCLIC REPORT PROCEDURE CONFIGURATION PARAMETERS

NOTE – The Cyclic Report procedure is optional. If the Cyclic Report procedure is not available in an instance of the Forward Frame service, the values of the procedure configuration parameters associated with the Cyclic Report procedure are undefined.

7.5.1 The set of named Parameter Label Lists that constitutes the `named-label-lists` configuration parameter (4.10.5 of reference [1]) shall be set by the service management parameter with the classifier `ffNamedParamLabelLists`.

7.5.2 The set of named Parameter Label Lists shall be used by all instances of Cyclic Report and Information Query procedures of the FF-CSTS instance.

7.5.3 Service Management shall designate, at most, one list in the set of Parameter Label Lists as the default list of parameters (4.10.5 of reference [1]).

7.5.4 The default list of Parameter Labels shall be used as the default Parameter Label List by all instances of Cyclic Report and Information Query procedures of the FF-CSTS instance.

7.5.5 The `minimum-allowed-delivery-cycle` configuration parameter (4.10.5 of reference [1]) of every instance of the Cyclic Report procedure in the FF-CSTS instance shall be set by the service management parameter with classifier `ffMinAllowedDeliveryCycle`.

7.6 NOTIFICATION PROCEDURE CONFIGURATION PARAMETERS

NOTE – The Notification procedure is optional. If the Notification procedure is not available in an instance of the Forward Frame service, the values of the events associated with the Notification procedure are undefined.

7.6.1 The set of named Event Label Lists that constitutes the `named-label-lists` configuration parameter (4.11.5 of reference [1]) shall be a service management parameter with the classifier `ffNamedEventLabelLists`.

7.6.2 The set of named Event Label Lists shall be available for use by the Notification procedure instance of the Forward Frame transfer service instance.

7.6.3 Service Management shall designate at most one list in the set of Event Label Lists as the default list of events (4.11.5 of reference [1]).

7.6.4 The default list of events shall be used as the default Event Label List by the Notification procedure instance of the FF-CSTS instance.

7.7 INFORMATION QUERY PROCEDURE CONFIGURATION PARAMETERS

NOTE – The Information Query procedure is optional. If the Information Query procedure is not available in an instance of the Forward Frame service, the values of the parameters associated with the Information Query procedure are undefined.

The set of named Parameter Label Lists that constitutes the named label lists configuration parameter (4.9.5 of reference [1]) shall be a service management parameter with the classifier `ffNamedParamLabelLists`.

NOTE – Requirements on the composition of the set of named Parameter Label Lists with the classifier `ffNamedParamLabelLists` are specified in 7.5.2, 7.5.3, and 7.5.4.

7.8 MASTER THROW EVENT PROCEDURE CONFIGURATION PARAMETERS

Service Management specifies the configuration of the set of FR instances that are directly associated with the production of the Forward Frame service instance. The predefined actions and associated directive IDs, directive values, and guard conditions that are defined for that set of associated FR instances collectively form the set of those configuration parameter values that apply to the Forward Frame service instance.

8 FORWARD FRAME SERVICE-LEVEL FUNCTIONAL RESOURCE PARAMETERS AND EVENTS

8.1 GENERAL

The CSTS Specification Framework (reference [1]) specifies that certain service-level parameters and events be specified for the functional resource that represents each CSTS provider. The required functional resource parameters are associated with the `return-timeout` and `production-status` parameters of the CSTS. The required functional resource events notify the occurrence of the 'production status change' and 'production configuration change' events of the CSTS.

8.2 `ffResponseTimeout` FUNCTIONAL RESOURCE PARAMETER

8.2.1 GENERAL

The CSTS Specification Framework specifies that each CSTS define a `response-timeout` functional resource configuration parameter (3.2.1.2 of reference [1]).

NOTE – As described in the specification of the `response-timeout` parameter in reference [1], the parameter is not used by any of the procedures of a CSTS provider unless that CSTS uses one or more provider-invoked procedures. The Forward Frame CSTS does not have any provider-invoked procedures, so the CSTS service provider may use the `response-timeout` parameter value to anticipate how long it (the service provider) has to respond to the invocation of any of the confirmed operations to avoid causing the service user to invoke PEER-ABORT.

8.2.2 The `response-timeout` functional resource configuration parameter (3.2.1.2 of reference [1]) shall be configured and reported by the Forward Frame functional resource parameter with the classifier `ffResponseTimeout`.

8.2.3 The Published Identifier associated with the parameter classifier `ffResponseTimeout` is assigned in the SANA Functional Resources registry (reference [4]) under the `{ffCstsProvider 1}` subtree (see annex B). The `ffResponseTimeout` parameter shall be available to the user of the Forward Frame service through the Cyclic Report (3.3.1.9 and 3.4.1.9) and Information Query (3.3.1.12 and 3.4.1.12) procedures.

8.3 `ffProdStat` FUNCTIONAL RESOURCE PARAMETER

8.3.1 GENERAL

The CSTS Specification Framework specifies that each CSTS provider reports the `production-status` using a parameter of the functional resource that represents that CSTS (see 2.2.2.2) of reference [1]).

8.3.2 The `production-status` of the service shall be reported by the Forward Frame functional resource parameter with the classifier `ffProdStat`.

NOTE – The Published Identifier associated with the parameter classifier `ffProdStat` is assigned in the SANA Functional Resources registry (reference [4]) under the `{ffCstsProvider 1}` subtree (see annex B).

8.3.3 The `ffProdStat` parameter shall have the `ProdStat` data type specified in the SANA Functional Resource registry (reference [4])[1].

8.3.4 The `ffProdStat` parameter shall be available to the user of the Forward Frame service through the Cyclic Report (3.3.1.9 and 3.4.1.9) and Information Query (3.3.1.12 and 3.4.1.12) procedures.

8.4 `ffProdStatChange` EVENT

8.4.1 GENERAL

The CSTS Specification Framework specifies that each CSTS provider notifies 'production status change' events using an event of the functional resource that represents that CSTS, as specified in 3.11.2.2.3.2 a) of reference [1].

8.4.2 The 'production status change' event of the service shall be notified with the Forward Frame functional resource event with the classifier `ffProdStatChange`.

NOTE – The Published Identifier associated with the event classifier `ffProdStatChange` is assigned in the SANA Functional Resources registry (reference [4]) under the `{ffCstsProvider 2}` subtree (see annex B).

8.4.3 The `eventValue` component of the `ffProdStatChange` event shall have the `ProdStat` data type specified in the SANA Functional Resource registry (reference [4])[1].

NOTE – The Published Identifier associated with the event value type for the `ffProdStatChange` event is assigned in the SANA Functional Resources registry (reference [4]) under the `ffProdStatChange` node.

8.4.4 The `ffProdStatChange` event shall be available to the user of the Forward Frame service through the Notification procedure (3.3.1.15 and 3.4.1.15).

8.5 `ffProdConfigurationChange` EVENT

8.5.1 GENERAL

The CSTS Specification Framework specifies that each CSTS provider notifies 'production configuration change' events using an event of the functional resource that represents that CSTS, as specified in 3.11.2.2.3.2 b) of reference [1].

8.5.2 The 'production configuration change' event of the service shall be notified with the Forward Frame functional resource event with the classifier `ffProdConfigurationChange`.

NOTE – The Published Identifier associated with the event classifier `ffProdConfigurationChange` is assigned in the SANA Functional Resources registry (reference [4]) under the `{ffCstsProvider 2}` subtree (see annex B).

8.5.3 The `eventValue` component of the `ffProdConfigurationChange` event shall be set to 'empty', as specified in 3.11.2.2.3.2 b) of reference [1].

8.5.4 The `ffProdConfigurationChange` event shall be available to the user of the Forward Frame service through the Notification procedure (3.3.1.15 and 3.4.1.15).

9 REFINEMENT OF DEFINITIONS OF FRAMEWORK PARAMETERS, EVENTS, DIRECTIVES, AND DIAGNOSTIC VALUES USED BY THE FORWARD FRAME SERVICE

9.1 GENERAL

Except where explicitly refined in this section, the definitions of the parameters, events, directives, and `diagnostic` values of the operations of the Framework procedures that are used by the Forward Frame service shall be the same as their definitions in reference [1].

9.2 'UNSUPPORTED OPTION' `diagnostic` VALUE REFINEMENT

In addition to the definition given in 3.3.2.7.1 c) of reference [1], the 'unsupported option' `diagnostic` value shall also indicate the following error conditions:

a) a START invocation was attempted on an instance of the BFDP procedure when the Forward Frame service is configured in the 'sequence-controlled' data processing mode;

b) a START invocation was attempted on an instance of the Sequence-Controlled Frame Data Processing procedure when the Forward Frame service is configured in the 'buffered' data processing mode;

c) a START invocation was attempted on an instance of the Cyclic Report procedure when the Forward Frame service instance does not implement that procedure;

d) a START invocation was attempted on an instance of the Notification procedure when the Forward Frame service instance does not implement that procedure; and

e) an EXECUTE-DIRECTIVE invocation was attempted on an instance of the Throw Event procedure when the Forward Frame service instance does not implement that procedure.

ANNEX A

IMPLEMENTATION CONFORMANCE STATEMENT PROFORMA

(NORMATIVE)

A1 INTRODUCTION

A1.1 OVERVIEW

This annex provides the ICS Requirements List (RL) for an implementation of the *Cross Support Transfer Services—Forward Frame Service*, CCSDS 922.3-B-1, April 2021. CCSDS 922.3 specifies the requirements on the provider of the FF-CSTS.

As a member of the CSTSes suite of Recommended Standards, implementation conformance is expressed with regard to the protocol on the interface between the user and the provider of the service. Therefore the ICS is a Protocol ICS (PICS), and this annex specifies the PICS proforma RL for the Forward Frame CSTS.

The PICS for an implementation is generated by completing the RL in accordance with the instructions below. An implementation shall satisfy the mandatory conformance requirements referenced in the RL.

The RL support column in this annex is blank. An implementation's completed RL is called the PICS. The PICS states which capabilities and options have been implemented. The following can use the PICS:

a) the implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;

b) a supplier or potential acquirer of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;

c) a user or potential user of the implementation, as a basis for initially checking the possibility of interworking with another implementation (it should be noted that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICSes);

d) a tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A1.2 ABBREVIATIONS AND CONVENTIONS

The RL consists of information in tabular form. The status of features is indicated using the abbreviations and conventions described below.

Item Column

The item column contains a prefix identifying the element the given table is referring to and sequential numbers for items in the table.

Feature Column

The feature column contains a brief descriptive name for a feature. It implicitly means: 'Is this feature supported by the implementation?'

Status Column

The status column uses the following notations:

M	mandatory
O	optional
O<n>	optional, but support of at least one of the group of options labeled by the same numeral <n> is required
C<n>	conditional as defined in corresponding expression below the table
X	prohibited
N/A	not applicable

Support Column Symbols

The support column is to be used by the implementer to state whether a feature is supported by entering Y, N, or N/A, indicating:

Y	yes, supported by the implementation
N	no, not supported by the implementation
N/A	not applicable

The support column should also be used, when appropriate, to enter values supported for a given capability.

Allowed Values Column

All PDU parameter types are specified in annex F of reference [1] using ASN.1. The ASN.1 data type specifications constrain among others the permissible value range, and therefore such constraints are not repeated in the Allowed Values column in the tables contained in

this ICS annex. However, if a parameter is constrained for all instances of the given PDU to a subset of the range or set specified for that parameter in annex F of reference [1], then the subset is identified in the tables that contain PDU parameters.

Allowed Values Column Symbols

If the allowed values are too large to fit in the Allowed Values cell, the Allowed Values column uses the notation 'AV<n>' as an indication that the allowed values are specified below the table.

Supported Values Column

The Supported Values column is to be used by the implementer to state whether the specified range or set of values for the parameter is supported by entering Y or SV<n>, indicating:

Y Yes, the range/set defined in the Recommended Specification is fully supported by the implementation;

SV<n> The range/set defined in the Recommended Specification is not fully supported by the implementation. The supported subset is documented below the table.

A1.3 INSTRUCTIONS FOR COMPLETING THE RL

An implementer shows the extent of compliance to the Recommended Standard by completing the RL; that is, the state of compliance with all mandatory requirements and the options supported are shown. The resulting completed RL is called a PICS. The implementer shall complete the RL by entering appropriate responses in the support or values supported column, using the notation described in A1.2. If a conditional requirement is inapplicable, N/A should be used. If a mandatory requirement is not satisfied, exception information must be supplied by entering a reference X*i*, where *i* is a unique identifier to an accompanying rationale for the noncompliance.

A2 PICS PROFORMA FOR THE FORWARD FRAME CSTS PROTOCOL (CCSDS 922.1-B-1)

A2.1 GENERAL INFORMATION

The PICS for a FF-CSTS implementation shall encompass the filled-in tables A-1 to A-4.

Table A-1: Identification of PICS

Date of Statement (DD/MM/YYYY)	
PICS serial number	
System Conformance statement cross-reference	

Table A-2: Identification of Implementation Under Test

Implementation name	
Implementation version	
Special Configuration	
Other Information	

Table A-3: Identification of Supplier

Supplier	
Contact Point for Queries	
Implementation Name(s) and Versions	
Other information necessary for full identification, for example, name(s) and version(s) for machines and/or operating systems; System Name(s)	

Table A-4: Identification of Specification

CCSDS 922.1-B-1	
Have any exceptions been required? NOTE – A YES answer means that the implementation does not conform to the Recommended Standard. Non-supported mandatory capabilities are to be identified in the PICS, with an explanation of why the implementation is nonconforming.	Yes [ ] No [ ]

A2.2 REQUIREMENTS LIST

This subsection provides the RLs for the elements specified in this Recommended Standard.

Table A-5: Procedures Used by the FF-CSTS Specification

Procedures				
Item	**Description**	**Reference**	**Status**	**Support**
proc-1	Association Control	4.3 of reference [1]	M	
proc-2	Data Processing	4.6 of reference [1]	M	
proc-3	Buffered Data Processing	4.7 of reference [1]	C1	
proc-4	Sequence-Controlled Data Processing	4.8 of reference [1]	C2	
proc-5	Information Query	4.9 of reference [1]	O	
proc-6	Cyclic Report	4.10 of reference [1]	O	
proc-7	Notification	4.11 of reference [1]	O	
proc-8	Throw Event	4.12 of reference [1]	C3	
proc-9	Sequence-Controlled Frame Data Processing	Section 4 of this Recommended Standard	O1	
proc-10	Buffered Frame Data Processing	Section 5 of this Recommended Standard	O1	
proc-11	Master Throw Event	Section 6 of this Recommended Standard	O	

C1 IF proc-10 THEN M ELSE N/A

C2 IF proc-9 THEN M ELSE N/A

C3 IF proc-11 THEN M ELSE N/A

O1 An implementation must support at least one of proc-9 or proc-10, but may support both.

NOTE – If an implementation supports both proc-9 and proc-10, one and only one procedure can be active in any given service instance, as configured by the `ffDataProcessingMode` service management configuration parameter specified in 3.2.

The Data Processing procedure is mandatory in the sense that the Sequence-Controlled Frame Data Processing and BFDP procedures (at least one of which is mandatory) are both derived indirectly from the Data Processing procedure. The Sequence-Controlled Data Delivery procedure is mandatory only when the Sequence-Controlled Frame Data Delivery

procedure is implemented. The Buffered Data Delivery procedure is mandatory only when the Buffered Frame Data Delivery procedure is implemented. In this FF-CSTS ICS, all requirements for the Data Processing procedure are covered by the requirements for both the Sequence-Controlled Frame Data Processing and BFDP procedures, the requirements for the Sequence-Controlled Data Delivery procedure are covered by the requirements for the Sequence-Controlled Frame Data Delivery procedure, and the requirements for the Buffered Data Delivery procedure are covered by the requirements for the Buffered Frame Data Delivery procedure.

The Throw Event procedure is mandatory only when the optional Master Throw Event procedure (which is derived from the Throw Event procedure) is implemented. In this FF-CSTS ICS, all requirements for the Throw Event procedure are covered by the requirements for the Master Throw Event procedure.

Table A-6: Required PDUs

Item	PDU	Reference	Service-Provider-System		Service-User-System	
			Status	Support	Status	Support
pdu-1	BindInvocation	F3.5 of reference [1]	M		M	
pdu-2	BindReturn	F3.5 of reference [1]	M		M	
pdu-3	PeerAbortInvocation	F3.5 of reference [1]	M		M	
pdu-4	UnbindInvocation	F3.5 of reference [1]	M		M	
pdu-5	UnbindReturn	F3.5 of reference [1]	M		M	
pdu-6	ExecuteDirectiveAcknowledge	F3.4 of reference [1]	C4		C4	
pdu-7	ExecuteDirectiveInvocation	F3.4 of reference [1]	C4		C4	
pdu-8	ExecuteDirectiveReturn	F3.4 of reference [1]	C4		C4	
pdu-9	GetInvocation	F3.4 of reference [1]	C5		C5	
pdu-10	GetReturn	F3.4 of reference [1]	C5		C5	
pdu-11	NotifyInvocation	F3.4 of reference [1]	M		M	

Item	PDU	Reference	Service-Provider-System		Service-User-System	
			Status	Support	Status	Support
pdu-12	ProcessDataInvocation	F3.4 of reference [1]	M		M	
pdu-13	ProcessDataReturn	F3.4 of reference [1]	C6		C6	
pdu-14	StartInvocation	F3.4 of reference [1]	M		M	
pdu-15	StartReturn	F3.4 of reference [1]	M		M	
pdu-16	StopInvocation	F3.4 of reference [1]	M		M	
pdu-17	StopReturn	F3.4 of reference [1]	M		M	
pdu-18	TransferDataInvocation	F3.4 of reference [1]	C7		C7	
pdu-19	ForwardBuffer	F3.9 of reference [1]	C8		C8	

C4 IF proc-9 OR proc-11 THEN M ELSE N/A

C5 IF proc-5 THEN M ELSE N/A

C6 IF proc-9 THEN M ELSE N/A

C7 IF proc-6 THEN M ELSE N/A

C8 IF proc-10 THEN M ELSE N/A

Table A-7: BIND Invocation Parameters

Parameters of the BindInvocation PDU						
					Values	
Item	Parameter	Reference	Status	Support	Allowed	Supported
bindInv-1	invokerCredentials	F3.3 of reference [1]	M			
bindInv-2	invokeId	F3.3 of reference [1]	M			
bindInv-3	procedureName	F3.3 of reference [1]	M		AV1	
bindInv-4	initiatorIdentifier	F3.5 of reference [1]	M			
bindInv-5	responderPortIdentifier	F3.5 of reference [1]	M			
bindInv-6	serviceType	F3.5 of reference [1]	M			
bindInv-7	versionNumber	F3.5 of reference [1]	M			
bindInv-8	serviceInstanceIdentifier	F3.5 of reference [1]	M			
bindInv-9	bindInvocationExtension	F3.5 of reference [1]	M		'notUsed'	

AV1 For the BIND invocation the procedureRole element of the parameter bindInv-3 must be set to 'associationControl'.

The parameters bindInv-1, bindInv-2, and bindInv-3 are contained in the complex parameter standardInvocationHeader shown in F3.5 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in F3.3 of reference [1].

Table A-8: BIND Return Parameters

Parameters of the BindReturn PDU						
					Values	
Item	Parameter	Reference	Status	Support	Allowed	Supported
bindRet-1	performerCredentials	F3.3 of reference [1]	M			
bindRet-2	invokeId	F3.3 of reference [1]	M			
bindRet-3	result	F3.3 of reference [1]	M			
bindRet-4	positive	F3.3 of reference [1]	C9		'notUsed'	
bindRet-5	diagnostics	F3.3 of reference [1]	C10		AV2	
bindRet-6	negExtension	F3.3 of reference [1]	C10		'notUsed'	
bindRet-7	responderIdentifier	F3.5 of reference [1]	M			

C9 IF bindRet-3 = 'positive' THEN M ELSE X

C10 IF bindRet-3 = 'negative' THEN M ELSE X

AV2 For the negative BIND return, the parameter bindRet-5 is extended by the type AssocBindDiagnosticExt defined in F3.5 of reference [1]. Therefore the parameter bindRet-5 may have

(a) any value defined for the Diagnostic type in F3.3 of reference [1] except 'diagnosticExtension'; or

(b) any value defined by 'diagnosticExtension': 'acBindDiagExt': 'AssocBindDiagnosticExt' defined in F3.5 of reference [1] except 'assocBindDiagnosticExtExtension'.

All parameters of the BIND return PDU except bindRet-7 are contained in the complex parameter of the type `StandardReturnHeader` that is specified in F3.3 of reference [1]. Specific extensions are, however, specified in F3.5 of that document.

Table A-9: PEER-ABORT Invocation Parameters

Parameters of the PeerAbortInvocation PDU						
Item	Parameter	Reference	Status	Support	Values	
					Allowed	Supported
peerAbortInv-1	diagnostic	F3.5 of reference [1]	M		40..126	

Table A-10: UNBIND Invocation Parameters

Parameters of the UnbindInvocation PDU						
Item	Parameter	Reference	Status	Support	Values	
					Allowed	Supported
unbindInv-1	invokerCredentials	F3.3 of reference [1]	M			
unbindInv-2	invokeId	F3.3 of reference [1]	M			
unbindInv-3	procedureName	F3.3 of reference [1]	M		AV3	
unbindInv-4	unbindInvocationExtension	F3.5 of reference [1]	M		'notUsed'	

AV3 For the UNBIND invocation, the procedureRole element of the parameter unbindInv-3 must be set to 'associationControl'.

The parameters unbindInv-1, unbindInv-2, and unbindInv-3 are contained in the complex parameter standardInvocationHeader shown in F3.5 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in F3.3 of that document.

Table A-11: UNBIND Return Parameters

Parameters of the UnbindReturn PDU						
					Values	
Item	Parameter	Reference	Status	Support	Allowed	Supported
unbindRet-1	performerCredentials	F3.3 of reference [1]	M			
unbindRet-2	invokeId	F3.3 of reference [1]	M			
unbindRet-3	result	F3.3 of reference [1]	M		AV4	

AV4 The value of the parameter unbindRet-3 shall always be set to 'positive': 'notUsed'; that is, the result is always positive and not extended.

All parameters of the UNBIND return PDU are contained the complex parameter of the type `StandardReturnHeader` that is specified in F3.3 of reference [1].

Table A-12: EXECUTE-DIRECTIVE Invocation Parameters

Parameters of the ExecuteDirectiveInvocation PDU						
					Values	
Item	Parameter	Ref.	Status	Support	Allowed	Supported
execDirInv-1	invokerCredentials	F3.3 of reference [1]	M			
execDirInv-2	invokeId	F3.3 of reference [1]	M			
execDirInv-3	procedureName	F3.3 of reference [1]	M		AV5	
execDirInv-4	directiveIdentifier	F3.4 of reference [1]	M		AV6	
execDirInv-5	localProcDirQualifier	F3.4 of reference [1]	C11		AV7	
execDirInv-6	targetProcedureName	F3.4 of reference [1]	X			
execDirInv-7	serviceProcDirQualifierValues	F3.4 of reference [1]	X			
execDirInv-8	functionalResourceInstanceNumber	F3.4 of reference [1]	C12			
execDirInv-9	functionalResourceQualifiers	F3.4 of reference [1]	C12		AV8	
execDirInv-10	directiveQualifierExtension	F3.4 of reference [1]	X			
execDirInv-11	executeDirectiveInvocationExtension	F3.4 of reference [1]	M		'notUsed'	

C11 IF execDirInv-4 is set to the Published Identifier of the ‘reset’ directive (pSCDPresetDirective as defined in F3.16 of reference [1]) THEN M ELSE X

C12 IF execDirInv-4 is set to the Published Identifier of a directive that is registered under a FR type THEN M ELSE X

AV5 If the procedureType element of the parameter execDirInv-3 has the value ‘sequenceControlledFrameDataProcessing’, the value of the procedureRole element of the parameter startInv-3 must be set to ‘prime procedure’; otherwise the value of the procedureRole element of the parameter execDirInv-3 must be set to ‘secondary procedure’.

AV6 The Published Identifier specified in the execDirInv-4 parameter must identify a registered directive.

AV7 The parameter execDirInv-5 will be: ‘directiveQualifier’: ‘localProcDirQualifier’: ‘DirectiveQualifierValues’: ‘parameterlessValues’: ‘TypeAndValue’: Embedded’: ‘EMBEDDED PDV’, where the Object Identifier and the type of the directive-qualifier parameter are pSCDPresetDirectiveDirQual and PSCDPresetDirectiveDirQual, as specified in F3.16 of reference [1].

AV8 The parameter execDirInv-9 will be one of the following:

(a) ‘directiveQualifier’: ‘functResourceDirQualifier’: ‘functionalResourceQualifiers’: ‘DirectiveQualifierValues’: ‘sequenceOfParamIdsAndValues’,

(b) ‘directiveQualifier’: ‘functResourceDirQualifier’: ‘functionalResourceQualifiers’: ‘DirectiveQualifierValues’: ‘parameterlessValues’, or

(c) ‘directiveQualifier’: ‘functResourceDirQualifier’: ‘functionalResourceQualifiers’: ‘DirectiveQualifierValues’: ‘noQualifierValues’.

The parameters execDirInv-1, execDirInv-2, and execDir-3 are contained in the complex parameter standardInvocationHeader in the `ExecuteDirectiveInvocation` type shown in F3.4 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in F3.3 of reference [1].

Table A-13: EXECUTE-DIRECTIVE Acknowledgement Parameters

Parameters of the ExecuteDirectiveAcknowledge PDU						
					Values	
Item	Parameter	Ref.	Status	Support	Allowed	Supported
execDirAck-1	performerCredentials	F3.3 of reference [1]	M			
execDirAck-2	invokeId	F3.3 of reference [1]	M			
execDirAck-3	result	F3.3 of reference [1]	M			
execDirAck-4	positive	F3.3 of reference [1]	C13		'notUsed'	
execDirAck-5	diagnostic	F3.3 of reference [1]	C14		AV9	
execDirAck-6	negExtension	F3.3 of reference [1]	C14		'notUsed'	

C13 IF execDirAck-3 = 'positive' THEN M ELSE X

C14 IF execDirAck-3 = 'negative' THEN M ELSE X

AV9 For the EXECUTE-DIRECTIVE acknowledgement the parameter execDirAck-5 is extended by the type ExecDirNegAckDiagnosticExt defined in F3.4 of reference [1]. Therefore the parameter execDirAck-5 may have

(a) any value defined for the Diagnostic type in F3.3 of reference [1] except 'diagnosticExtension'; or

(b) any value defined by the extension 'diagnosticExtension': 'execDirAckDiagExt': 'ExecDirNegAckDiagnosticExt' in F3.4 of reference [1] except 'execDirNegAckDiagnosticExtExtension'.

All parameters of the EXECUTE-DIRECTIVE acknowledgement PDU are contained the complex parameter of the type `StandardReturnHeader` that is specified in F3.3 of reference [1]. Specific extensions are, however, specified in F3.4 of reference [1].

Table A-14: EXECUTE-DIRECTIVE Return Parameters

Parameters of the ExecuteDirectiveReturn PDU						
Item	Parameter	Ref.	Status	Support	Values	
					Allowed	Supported
execDirRet-1	performerCredentials	F3.3 of reference [1]	M			
execDirRet-2	invokeId	F3.3 of reference [1]	M			
execDirRet-3	result	F3.3 of reference [1]	M			
execDirRet-4	positive	F3.3 of reference [1]	C15		'notUsed'	
execDirRet-5	diagnostic	F3.3 of reference [1]	C16		AV10	
execDirRet-6	negExtension	F3.3 of reference [1]	C16		'notUsed'	

C15 IF execDirRet-3 = 'positive' THEN M ELSE X

C16 IF execDirRet-3 = 'negative' THEN M ELSE X

AV10 For the negative EXECUTE-DIRECTIVE return PDU the parameter execDirRet-5 is extended by the type ExecDirNegReturnDiagnosticExt defined in F3.4 of reference [1]. Therefore the parameter execDirRet-5 may have

(a) any standard value defined for the Diagnostic type in F3.3 of reference [1] except 'diagnosticExtension'; or

(b) any value defined by the extension 'diagnosticExtension': 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt' defined in F3.4 of reference [1] except 'execDirNegReturnDiagnosticExtExtension'. Additional values can be introduced by the further extension 'diagnosticExtension': 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt': 'execDirNegReturnDiagnosticExtExtension'.

If the EXECUTE-DIRECTIVE return PDU is used by the Master Throw Event procedure, that is, the procedureType element of the parameter execDirInv-3 of the associated EXECUTE-DIRECTIVE invocation has the value 'masterThrowEvent', additional values are introduced by the further extension 'diagnosticExtension': 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt': 'execDirNegReturnDiagnosticExtExtension': 'teExecDirDiagExt': 'TeExecDirNegReturnDiagnosticExt' (the type TeExecDirNegReturnDiagnosticExt is specified in F3.14 of reference [1]). Therefore the parameter execDirRet-5 may have, in this case,

(a) any standard value defined for the Diagnostic type in F3.3 of reference [1] except 'diagnosticExtension';

(b) any value defined by the extension 'diagnosticExtension': 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt' defined in F3.4 of reference [1] except 'execDirNegReturnDiagnosticExtExtension'; or

(c) any value defined by the extension 'diagnosticExtension': 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt': 'execDirNegReturnDiagnosticExtExtension': 'teExecDirDiagExt': 'TeExecDirNegReturnDiagnosticExt' (defined in F3.14 of reference [1]) except 'teExecDirNegReturnDiagnosticExtExtension'.

All parameters of the EXECUTE-DIRECTIVE return PDU are contained the complex parameter of the type `StandardReturnHeader` that is specified in F3.3 of reference [1]. Specific extensions are, however, specified in F3.4 and F3.14 of reference [1].

Table A-15: GET Invocation Parameters

Parameters of the GetInvocation PDU						
					Values	
Item	Parameter	Ref.	Status	Support	Allowed	Supported
getInv-1	invokerCredentials	F3.3 of reference [1]	M			
getInv-2	invokeId	F3.3 of reference [1]	M			
getInv-3	procedureName	F3.3 of reference [1]	M		AV11	
getInv-4	listOfParameters	F3.4 of reference [1]	M			
getInv-5	getInvocationExtension	F3.4 of reference [1]	M		'notUsed'	

AV11 The value of the procedureRole element of the parameter getInv-3 is constrained to have the value, 'secondary procedure'.

The parameters getInv-1, getInv-2, and getInv-3 are contained in the complex parameter standardInvocationHeader in the `GetInvocation` type shown in F3.4 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in F3.3 of reference [1].

Table A-16: GET Return Parameters

Parameters of the GetReturn PDU						
					Values	
Item	Parameter	Ref.	Status	Support	Allowed	Supported
getRet-1	performerCredentials	F3.3 of reference [1]	M			
getRet-2	invokeId	F3.3 of reference [1]	M			
getRet-3	result	F3.3 of reference [1]	M			
getRet-4	positive	F3.3 of reference [1]	C17		AV12	
getRet-5	qualifiedParameters	F3.4 of reference [1]	C17		AV13	
getRet-6	getPosReturnExtExtension	F3.4 of reference [1]	C17		'notUsed'	
getRet-7	diagnostic	F3.3 of reference [1]	C18		AV14	
getRet-8	negExtension	F3.3 of reference [1]	C18		'notUsed'	

C17 IF getRet-3 = ‘positive’ THEN M ELSE X

C18 IF getRet-3 = ‘negative’ THEN M ELSE X

AV12 For the positive GET return, the parameter getRet-4 is set to ‘getPosReturnExt’: ‘GetPosReturnExt’ defined in F3.4 of reference [1].

AV13 For the positive GET return, the parameter getRet-5 is specified by ‘qualifiedParameters’: ‘QualifiedParametersSequence’. The type QualifiedParametersSequence is defined in F3.4 of reference [1].

AV14 For the negative GET return, the parameter getRet-7 is extended by the type GetDiagnosticExt defined in F3.4 of reference [1]. Therefore the parameter getRet-7 may have

(a) any standard value defined for the Diagnostic type in F3.3 of reference [1] except ‘diagnosticExtension’; or

(b) any value defined by the extension ‘diagnosticExtension’: ‘getDiagnosticExt’: ‘GetDiagnosticExt’ defined in F3.4 of reference [1] except ‘getDiagnosticExtExtension’.

All parameters of the GET return PDU are contained the complex parameter of the type `StandardReturnHeader` that is specified in F3.3 of reference [1]. Specific extensions are, however, specified in F3.4 of reference [1].

Table A-17: PROCESS-DATA Invocation Parameters

Parameters of the ProcessDataInvocation PDU						
					Values	
Item	Parameter	Ref.	Status	Support	Allowed	Supported
procDataInv-1	invokerCredentials	F3.3 of reference [1]	M			
procDataInv-2	invokeId	F3.3 of reference [1]	M			
procDataInv-3	procedureName	F3.3 of reference [1]	M		AV15	
procDataInv-4	dataUnitId	F3.4 of reference [1]	M			
procDataInv-5	data	F3.4 of reference [1]	M		AV16	
procDataInv-6	processDataInvocationExtension	F3.8 of reference [1]	M		AV17	
procDataInv-7	processCompletionReport	F3.8 of reference [1]	M			
procDataInv-8	dataProcProcDataInvocExtExtension	F3.8 of reference [1]	M		AV18	
procDataInv-9	earliestDataProcessingTime	F3.10 of reference [1]	C19			
procDataInv-10	latestDataProcessingTime	F3.10 of reference [1]	C19			
procDataInv-11	sequContrDataProcProcDataInvocExtExtension	F3.10 of reference [1]	C19		‘notUsed’	

C19 IF procDataInv-8 = (‘scdpProcDataInvocExt’: ‘SequContrDataProcProcDataInvocExt’) THEN M ELSE X

AV15 The value of the procedureRole element of the parameter startInv-3 must be set to ‘prime procedure’.

AV16 The parameter procDataInv-5 is refined to be an octet string.

AV17 The parameter procDataInv-6 shall be set to the value ‘dpProcDataInvocExt’: ‘DataProcProcDataInvocExt’.

AV18 If the PDU is used by the BFDP procedure, that is, the procedureType element of the parameter procDataInv-3 has the value 'BufferedFrameDataProcessing', the value of this parameter shall be set to 'notUsed'.

If the PDU is used by the Sequence-Controlled Frame Data Processing procedure, that is, the procedureType element of the parameter procDataInv-3 has the value 'sequenceControlledFrameDataProcessing', then the parameter procDataInv-8 shall be set to 'scdpProcDataInvocExt': 'SequContrDataProcProcDataInvocExt'.

The parameters procDataInv-1, procDataInv-2, and procDataInv-3 are contained in the complex parameter standardInvocationHeader in the `ProcessDataInvocation` type shown in F3.4 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is in subsection F3.3 of reference [1].

Table A-18: PROCESS-DATA Return Parameters

Parameters of the ProcessDataReturn PDU						
Item	Parameter	Ref.	Status	Support	Values	
					Allowed	Supported
procDataRet-1	performerCredentials	F3.3 of reference [1]	M			
procDataRet-2	invokeId	F3.3 of reference [1]	M			
procDataRet-3	result	F3.3 of reference [1]	M			
procDataRet-4	positive	F3.3 of reference [1]	C20		AV19	
procDataRet-5	dataUnitId	F3.10 of reference [1]	C20			
procDataRet-6	sequContrDataProc ProcDataPosReturn ExtExtension	F3.10 of reference [1]	C20		'notUsed'	
procDataRet-7	diagnostic	F3.3 of reference [1] and annex C of this Recommended Standard	C21		AV20	
procDataRet-8	negExtension	F3.3 of reference [1]	C21		AV21	
procDataRet-9	dataUnitId	F3.10 of reference [1]	C21			
procDataRet-10	sequContrDataProc ProcDataNegReturn ExtExtension	F3.10 of reference [1]	C21		'notUsed'	

C20 IF procDataRet-3 = 'positive' THEN M ELSE X

C21 IF procDataRet-3 = 'negative' THEN M ELSE X

AV19 For the Forward Frame service, this PDU is used only by the Sequence-Controlled Frame Data Processing procedure, that is, the procedureType element of parameter procDataInv-3 in the associated invocation has the value 'sequenceControlledFrameDataProcessing'. Therefore the parameter procDataRet-4 shall be set to 'scdpProcDataPosReturnExt': 'SequContrDataProcProcDataPosReturnExt', defined in F3.10 of reference [1].

AV20 For the PROCESS-DATA return, the parameter procDataRet-7 is extended by the type SequContrDataProcProcDataDiagnosticExt defined in F3.10 of reference [1]. Therefore the parameter procDataRet-7 may have:

(a) any standard value defined for the Diagnostic type in F3.3 of reference [1] except 'diagnosticExtension'; or

(b) any value defined by the extension 'diagnosticExtension': 'scdpProcDataDiagExt': 'SequContrDataProcProcDataDiagnosticExt' defined in F3.10 of reference [1] except 'sequContrDataProcProcDataDiagnosticExtExtension'; or 'SequContrFrameDataProcProcDataDiagnosticExt' defined in annex C except 'scfdpProcDataDiagnosticExtExtension'.

AV21 For the Forward Frame service, this PDU is used only by the Sequence-Controlled Frame Data Processing procedure; that is, the procedureType element of parameter procDataInv-3 in the associated invocation has the value 'sequenceControlledFrameDataProcessing'. Therefore the parameter procDataRet-8 shall be set to 'scdpProcDataNegReturnExt': 'SequContrDataProcProcDataNegReturnExt'. The type SequContrDataProcProcDataNegReturnExt is defined in F3.10 of reference [1].

This PDU is valid only in the case that the PROCESS-DATA operation is used by the Sequence-Controlled Frame Data Processing procedure; that is, the procedureType element of the parameter procDataInv-3 of the associated PROCESS-DATA invocation has the value 'sequenceControlledFrameDataProcessing'. The BFDP procedure uses the unconfirmed variant of the PROCESS-DATA operation.

All parameters of the PROCESS-DATA return PDU are contained the complex parameter of the type `StandardReturnHeader` that is specified in F3.3 of reference [1]. Specific extensions are, however, specified in F3.10 of reference [1] and annex C.

Table A-19: START Invocation Parameters

Parameters of the StartInvocation PDU						
Item	Parameter	Ref.	Status	Support	Values	
					Allowed	Supported
startInv-1	invokerCredentials	F3.3 of reference [1]	M			
startInv-2	invokeId	F3.3 of reference [1]	M			
startInv-3	procedureName	F3.3 of reference [1]	M		AV22	
startInv-4	startInvocationExtension	F3.4 of reference [1]	M		AV23	
startInv-5	firstDataUnitId	F3.10 of reference [1]	C22			
startInv-6	sequContrDataProcStartInvocExtExtension	F3.10 of reference [1]	C22		AV24	
startInv-7	sequContrFrameInputQueueSize	annex C	C22			
startInv-8	sequContrFrameDataProcStartInvocExtExtension	annex C	C22		‘notUsed’	
startInv-9	buffFrameInputQueueSize	annex D	C23			
startInv-10	buffFrameMaximumForwardBufferSize	annex D	C23			
startInv-11	buffFrameprocessingLatencyLimit	annex D	C23			
startInv-12	buffFrameDataProcStartInvocExtExtension	annex D	C23		‘notUsed’	
startInv-13	deliveryCycle	F3.12 of reference [1]	C24			
startInv-14	listOfParameters	F3.12 of reference [1]	C24			
startInv-15	cyclicReportStartInvocExtExtension	F3.12 of reference [1]	C24		‘notUsed’	
startInv-16	listOfEvents	F3.13 of reference [1]	C25			
startInv-17	notificationStartInvocExtExtension	F3.3 of reference [1]	C25		‘notUsed’	

C22 IF startInv-4 = ‘scdpStartInvocExt’: ‘SequContrDataProcStartInvocExt’ THEN M ELSE X

C23 IF startInv-4 = ‘buffFrameDataProcStartInvocExt’: ‘BuffFrameDataProcStartInvocExt’ THEN M ELSE X

C24 IF startInv-4 = ‘crStartInvocExt’: ‘CyclicReportStartInvocExt’ THEN M ELSE X

C25 IF startInv-4 = ‘nStartInvocExt’: ‘NotificationStartInvocExt’ THEN M ELSE X

AV22 If the procedureType element of the parameter startInv-3 has the value ‘sequenceControlledFrameDataProcessing’ or ‘bufferedFrameDataProcessing’, the value of the procedureRole element of the parameter startInv-3 must be set to ‘prime procedure’; otherwise, the value of the procedureRole element of the parameter startInv-3 must be set to ‘secondary procedure’.

AV23 If the procedureType element of the parameter startInv-3 has the value ‘sequenceControlledFrameDataProcessing’, then the parameter startInv-4 shall be set to the value ‘scdpStartInvocExt’: ‘SequContrDataProcStartInvocExt’.

If the procedureType element of the parameter startInv-3 has the value ‘bufferedFrameDataProcessing’, then the parameter startInv-4 shall be set to the value ‘buffFrameDataProcStartInvocExt’: ‘BuffFrameDataProcStartInvocExt’.

If the procedureType element of the parameter startInv-3 has the value ‘cyclicReport’, then the parameter startInv-4 shall be set to the value ‘crStartInvocExt’: ‘CyclicReportStartInvocExt’.

If the procedureType element of the parameter startInv-3 has the value ‘notification’, then the parameter startInv-4 shall be set to the value ‘nStartInvocExt’: ‘NotificationStartInvocExt’.

AV24 The parameter startInv-6 shall be set to the value ‘sequContrFrameDataProcStartInvocExt’: SequContrFrameDataProcStartInvocExt’.

The parameters startInv-1, startInv-2, and startInv-3 are contained in the complex parameter standardInvocationHeader in the `StartInvocation` type shown in F3.4 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in F3.3 of reference [1].

Table A-20: START Return Parameters

Parameters of the StartReturn PDU						
Item	Parameter	Ref.	Status	Support	Values	
					Allowed	Supported
startRet-1	performerCredentials	F3.3 of reference [1]	M			
startRet-2	invokeId	F3.3 of reference [1]	M			
startRet-3	result	F3.3 of reference [1]	M			
startRet-4	positive	F3.3 of reference [1]	C26		‘notUsed’	
startRet-5	diagnostic	F3.3 of reference [1]	C27		AV25	
startRet-6	negExtension	F3.3 of reference [1]	C27		‘notUsed’	

C26 IF startRet-3 = ‘positive’ THEN M ELSE X

C27 IF startRet-3 = ‘negative’ THEN M ELSE X

AV25 If the procedureType element of the parameter startInv-3 of the associated START invocation has the value of either ‘sequenceControlledFrameDataProcessing’ or ‘BufferedFrameDataProcessing’, then parameter startRet-5 is extended only by the type StartDiagnosticExt defined in F3.4 of reference [1]. Therefore the parameter startRet-5 may have

(a) any standard value defined for the Diagnostic type in F3.3 of reference [1] except ‘diagnosticExtension’; or

(b) any value defined by the extension ‘diagnosticExtension’: ‘startDiagnosticExt’: ‘StartDiagnosticExt’ in F3.3 of reference [1] except ‘startDiagnosticExtExtension’.

If the procedureType element of the parameter startInv-3 of the associated START invocation has the value ‘cyclicReport’, then parameter startRet-5 is extended by the type CyclicReportStartDiagnosticExt defined in F3.12 of reference [1]. Therefore the parameter startRet-5 may have in this case

(a) any standard value defined for the Diagnostic type in F3.3 of reference [1] except ‘diagnosticExtension’;

b) any value defined by the extension ‘diagnosticExtension’: ‘startDiagnosticExt’: ‘StartDiagnosticExt’ in subsection F3.4 of reference [1] except ‘startDiagnosticExtExtension’; or

(c) any value defined by the extension ‘diagnosticExtension’: ‘startDiagnosticExt’: ‘StartDiagnosticExt’: ‘startDiagnosticExtExtension’: crStartDiagExt’: ‘CyclicReportStartDiagnosticExt’ defined in F3.12 of reference [1] except ‘cyclicReportStartDiagnosticExtExtension’.

If the procedureType element of the parameter startInv-3 of the associated START invocation has the value ‘notification’, then parameter startRet-5 is extended by the type NotificationStartDiagnosticExt defined in F3.13 of reference [1]. Therefore the parameter startRet-5 may have in this case

(a) any standard value defined for the Diagnostic type in subsection F3.3 of reference [1] except ‘diagnosticExtension’;

(b) any value defined by the extension ‘diagnosticExtension’: ‘startDiagnosticExt’: ‘StartDiagnosticExt’ in F3.4 of reference [1] except ‘startDiagnosticExtExtension’; or

(c) any value defined by the extension ‘diagnosticExtension’: ‘startDiagnosticExt’: ‘StartDiagnosticExt’: ‘startDiagnosticExtExtension’: ‘nStartDiagExt’: ‘NotificationStartDiagnosticExt’ defined in F3.3 of reference [1] except ‘notificationStartDiagnosticExtExtension’.

Table A-21: STOP Invocation Parameters

Parameters of the StopInvocation PDU						
Item	Parameter	Ref.	Status	Support	Values	
					Allowed	Supported
stopInv-1	invokerCredentials	F3.3 of reference [1]	M			
stopInv-2	invokeId	F3.3 of reference [1]	M			
stopInv-3	procedureName	F3.3 of reference [1]	M		AV26	
stopInv-4	stopInvocationExtension	F3.4 of reference [1]	M		'notUsed'	

AV26 If the procedureType element of the parameter stopInv-3 has the value 'sequenceControlledFrameDataProcessing' or 'bufferedFrameDataProcessing', the value of the procedureRole element of the parameter stopInv-3 must be set to 'prime procedure'; otherwise, the value of the procedureRole element of the parameter startInv-3 must be set to 'secondary procedure'.

The parameters stopInv-1, stopInv-2, and stopInv-3 are contained in the complex parameter standardInvocationHeader in the `StopInvocation` type shown in F3.4 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in F3.3 of reference [1].

Table A-22: STOP Return Parameters

Parameters of the StopReturn PDU						
Item	Parameter	Ref.	Status	Support	Values	
					Allowed	Supported
stopRet-1	performerCredentials	F3.3 of reference [1]	M			
stopRet-2	invokeId	F3.3 of reference [1]	M			
stopRet-3	result	F3.3 of reference [1]	M			
stopRet-4	positive	F3.3 of reference [1]	C28		'notUsed'	
stopRet-5	diagnostic	F3.3 of reference [1]	C29		AV27	
stopRet-6	negExtension	F3.3 of reference [1]	C29		'notUsed'	

C28 IF stopRet-3 = 'positive' THEN M ELSE X

C29 IF stopRet-3 = 'negative' THEN M ELSE X

AV27 The parameter stopRet-5 may have any standard value defined for the Diagnostic type in F3.3 of reference [1] except 'diagnosticExtension'.

All parameters of the STOP return PDU are contained the complex parameter of the type `StandardReturnHeader` that is specified in F3.3 of reference [1].

Table A-23: NOTIFY Invocation Parameters

Parameters of the NotifyInvocation PDU						
					Values	
Item	Parameter	Ref.	Status	Support	Allowed	Supported
notifyInv-1	invokerCredentials	F3.3 of reference [1]	M			
notifyInv-2	invokeId	F3.3 of reference [1]	M			
notifyInv-3	procedureName	F3.3 of reference [1]	M		AV28	
notifyInv-4	eventTime	F3.4 of reference [1]	M			
notifyInv-5	eventName	F3.4 of reference [1]	M			
notifyInv-6	eventValue	F3.4 of reference [1]	M		AV29	
notifyInv-7	notifyInvocationExtension	F3.4 of reference [1]	M		AV30	
notifyInv-8	dataUnitIdLastProcessed	F3.8 of reference [1]	C30			
notifyInv-9	dataProcessingStatus	F3.8 of reference [1]	C31		AV31	
notifyInv-10	dataProcessingStartTime	F3.8 of reference [1]	C31			
notifyInv-11	dataUnitIdLastOk	F3.8 of reference [1]	C30			
notifyInv-12	dataProcessingStopTime	F3.8 of reference [1]	C32			
notifyInv-13	productionStatus	F3.8 of reference [1]	C30		AV32	
notifyInv-14	dataProcNotifyInvocExtExtension	F3.8 of reference [1]	C30		‘notUsed’	

C30 IF notifyInv-7 = ‘dpNotifyInvocExt’: ‘DataProcNotifyInvocExt’ THEN M ELSE X

C31 IF (notifyInv-7 = ‘dpNotifyInvocExt’: ‘DataProcNotifyInvocExt’) AND (notifyInv-8 is not ‘noDataProcessed’) THEN M ELSE X

C32 IF (notifyInv-7 = ‘dpNotifyInvocExt’: ‘DataProcNotifyInvocExt’) AND (notifyInv-11 is not ‘noSuccessfulProcessing’) THEN M ELSE X

AV28 If the procedureType element of the parameter notifyInv-3 has the value ‘sequenceControlledFrameDataProcessing’ or ‘bufferedFrameDataProcessing’, the value of the procedureRole element of the parameter stopInv-3 must be set to ‘prime procedure’; otherwise, the value of the procedureRole element of the parameter notifyInv-3 must be set to ‘secondary procedure’.

AV29 If the procedureType element of the parameter notifyInv-3 has the value ‘notification’, the value of the notifyInv-6 parameter can be a value that can be expressed using the type SequenceOfQualifiedValue specified in F3.3 of reference [1] or ‘empty’, but must not be set to ‘eventValueExtension’ (see EventValue defined in F3.3 of reference [1]).

If the procedureType element of the parameter notifyInv-3 has the value ‘sequenceControlledFrameDataProcessing’, the value of the notifyInv-6 parameter can be any of the event values that are specified for the events specified in (4.6.4.2.3, 4.8.4.3.3 or 4.8.4.3.4 of reference [1]).

If the procedureType element of the parameter notifyInv-3 has the value ‘bufferedFrameDataProcessing’, the value of the notifyInv-6 parameter can be any of the event values that are specified for the events defined in (4.6.4.2.3 or 4.7.4.2.2 of reference [1]) or 5.6.7.2.1 of this Recommended Standard.

AV30 If the procedureType element of the parameter notifyInv-3 has the value ‘bufferedFrameDataProcessing’ or ‘sequenceControlledFrameDataProcessing’, then the parameter notifyInv-7 shall be set to the value ‘dpNotifyInvocExt’: ‘DataProcNotifyInvocExt’.

In all other cases, this parameter shall be set to ‘notUsed’.

AV31 If the procedureType element of the parameter notifyInv-3 has the value ‘sequenceControlledFrameDataProcessing’, the parameter notifyInv-9 can take on

(a) any value specified for the dataProcessingStatus element of the DataProcNotifyInvocExt type defined in F3.8 of reference [1] except dataProcessingStatusExtension; or

(b) any value specified by the SequContrDataProcStatus type defined in F3.8 of reference [1] except sequContrDataProcStatusExtension.

If the procedureType element of the parameter notifyInv-3 has the value ‘bufferedFrameDataProcessing’, the parameter notifyInv-9 can take on any value specified for the dataProcessingStatus element of the DataProcNotifyInvocExt type defined in F3.8 of reference [1] except dataProcessingStatusExtension.

AV32 If the parameter notifyInv-5 has the value ‘productionStatusChange’, the parameter notifyInv-13 shall be set to ‘productionStatusChange’: ‘NULL’; that is, it is absent. For all other values of the parameter notifyInv-5, it shall be set to ‘anyOtherEvent’: ‘ProductionStatus’.

The parameters notifyInv-1, notifyInv-2, and notifyInv-3 are contained in the complex parameter standardInvocationHeader in the `NotifyInvocation` type shown in F3.4 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in F3.3 of reference [1].

Table A-24: TRANSFER-DATA Invocation Parameters

Parameters of the TransferDataInvocation PDU						
					Values	
Item	Parameter	Ref.	Status	Support	Allowed	Supported
transferDataInv-1	invokerCredentials	F3.3 of reference [1]	M			
transferDataInv-2	invokeId	F3.3 of reference [1]	M			
transferDataInv-3	procedureName	F3.3 of reference [1]	M		AV33	
transferDataInv-4	generationTime	F3.4 of reference [1]	M			
transferDataInv-5	sequenceCounter	F3.4 of reference [1]	M			
transferDataInv-6	data	F3.4 of reference [1]	M		AV34	
transferDataInv-7	qualifiedParameters	F3.12 of reference [1]	M			
transferDataInv-8	cyclicReportTransferDataInvocDataRefExtension	F3.12 of reference [1]	M		'notUsed'	
transferDataInv-9	transferDataInvocationExtension	F3.4 of reference [1]	M		'notUsed'	

AV33 The value of the procedureRole element of the parameter transferDataInv-3 shall be set to 'secondary procedure'.

AV34 The parameter transferDataInv-6 shall be set to the value 'extendedData': 'crTransferDataInvocDataRef': 'CyclicReportTransferDataInvocDataRef'. The type CyclicReportTransferDataInvocDataRef is defined in F3.12 of reference [1].

The parameters transferDataInv-1, transferDataInv-2, and transferDataInv-3 are contained in the complex parameter standardInvocationHeader in the `TransferDataInvocation` type shown in F3.4 of reference [1]. This parameter is of the type `StandardInvocationHeader` that is specified in subsection F3.3 of reference [1].

ANNEX B

SERVICE OBJECT IDENTIFIERS

(NORMATIVE)

B1 FORWARD FRAME OBJECT IDENTIFIERS ASN.1 MODULE

```
CCSDS-FORWARD-FRAME-OBJECT-IDENTIFIERS
{  iso(1) identified-organization(3) standards-producing-organization(112)
ccsds(4) css(4) csts(1) services(2) forwardFrame(3)
forwardFrameServiceModules(4) object-identifiers(1) version (1)
}

DEFINITIONS
IMPLICIT TAGS
::= BEGIN

EXPORTS  bfdpDirectivesId
,        bfdpEventsId
,        bfdpExtendedOpsParam
,        bfdpExtendedProcParam
,        forwardFrameDerivedServices
,        forwardFrameExtendedServiceParameters
,        forwardFrameServiceProcedures
,        masterThrowEventDirectivesId
,        masterThrowEventEventsId
,        masterThrowEventExtendedOpsParam
,        masterThrowEventExtendedProcParam
,        scfdpExtendedOpsParam
,        scfdpExtendedProcParam
,        scfdpEventsId
,        scfdpDirectivesId
;

IMPORTS  crossSupportFunctionalities
,        services
         FROM CCSDS-CSTS-OBJECT-IDENTIFIERS

         BufferSize
,        IntUnsigned
         FROM CCSDS-CSTS-COMMON-TYPES
;

-- ******************************************************

-- Root Object Identifiers of the Service

forwardFrame   OBJECT IDENTIFIER ::=   {services 3}
forwardFrameDerivedServices   OBJECT IDENTIFIER ::= {forwardFrame 1}
forwardFrameExtendedServiceParameters  OBJECT IDENTIFIER    ::=
                                       {forwardFrame 2}
forwardFrameServiceProcedures OBJECT IDENTIFIER ::=
{forwardFrame 3}
forwardFrameServiceModules    OBJECT IDENTIFIER ::= {forwardFrame 4}
```

```
-- ********************************************************
-- Procedure Type Identifiers
sequenceControlledFrameDataProcessing  OBJECT IDENTIFIER
                                    ::= {forwardFrameServiceProcedures 1}
scfdpExtendedOpsParam                  OBJECT IDENTIFIER
                                ::= {sequenceControlledFrameDataProcessing 1}
scfdpExtendedProcParam                 OBJECT IDENTIFIER
                                ::= {sequenceControlledFrameDataProcessing 2}
scfdpEventsId                        OBJECT IDENTIFIER
                                ::= {sequenceControlledFrameDataProcessing 3}
scfdpDirectivesId                   OBJECT IDENTIFIER
                                ::= {sequenceControlledFrameDataProcessing 4}

bufferedFrameDataProcessing   OBJECT IDENTIFIER
                                   ::= {forwardFrameServiceProcedures 2}
bfdpExtendedOpsParam                  OBJECT IDENTIFIER
                           ::= {bufferedFrameDataProcessing 1}
bfdpExtendedProcParam                 OBJECT IDENTIFIER
                           ::= {bufferedFrameDataProcessing 2}
bfdpEventsId                        OBJECT IDENTIFIER
                           ::= {bufferedFrameDataProcessing 3}
bfdpDirectivesId                    OBJECT IDENTIFIER
                           ::= {bufferedFrameDataProcessing 4}

masterThrowEvent  OBJECT IDENTIFIER
                             ::= {forwardFrameServiceProcedures 3}
masterThrowEventExtendedOpsParam                OBJECT IDENTIFIER
                           ::= {masterThrowEvent 1}
masterThrowEventExtendedProcParam               OBJECT IDENTIFIER
                           ::= {masterThrowEvent 2}
masterThrowEventEventsId                    OBJECT IDENTIFIER
                           ::= {masterThrowEvent 3}
masterThrowEventDirectivesId                  OBJECT IDENTIFIER
                           ::= {masterThrowEvent 4}


-- ********************************************************
-- Object Identifiers and Data Types of the FF-CSTS Provider
-- FR type

-- The Object Identifiers of the FF-CSTS Provider FR type
-- are specified and registered in the SANA Functional Resources registry
-- (reference [4]) under the crossSupportFunctionalities subtree.
-- The root of the FF-CSTS Provider FR type OID has the
-- classifier ffCstsProvider.
-- All parameters of the FF-CSTS Provider FR shall be
-- registered under the node of the ffCstsProvider subtree that has the
-- Object Identifier {ffCstsProvider  1}.These include,but are not limited
-- to, the service management parameters and read-only functional resource
-- parameters specified in 4.8 and 5.8:
-- All events of the FF-CSTS Provider FR shall be
-- registered under the node of the ffCstsProvider subtree that has the
-- Object Identifier {ffCstsProvider  2}.
-- All directives of the FF-CSTS Provider FR shall be
-- registered under the node of the ffCstsProvider subtree that has the
-- Object Identifier {ffCstsProvider  3}.


END
```

B2 TRANSFER SYNTAX

There are no data types specified in this module.

ANNEX C

PROCEDURE—SEQUENCE-CONTROLLED FRAME DATA PROCESSING PDUS

(NORMATIVE)

C1 SEQUENCE-CONTROLLED FRAME DATA PROCESSING PDUS ASN.1 MODULE

```
CCSDS-SEQUENCE-CONTROLLED-FRAME-DATA-PROCESSING-PDUS
{  iso(1) identified-organization(3) standards-producing-organization(112)
ccsds(4) css(4) csts(1) services(2) forwardFrame(3)
forwardFrameServiceModules(4) extensions(2)
sequenceControlledFrameDataProcessingPdus(1) version (1)
}

DEFINITIONS
IMPLICIT TAGS
::=   BEGIN

EXPORTS  SequContrFrameDataProcProcDataDiagnosticExt
,        SequContrFrameDataProcStartInvocExt
,        SequenceControlledFrameDataProcessingPdu
;

IMPORTS  AdditionalText
,        Embedded
,        Extended
,        IntUnsigned
         FROM CCSDS-CSTS-COMMON-TYPES

-- CCSDS-CSTS-COMMON-TYPES is defined in F3.3 of the
-- CSTS SFW (reference [1]).

         SequContrDataProcessingPdu
         FROM CCSDS-CSTS-SEQUENCE-CONTROLLED-DATA-PROCESSING-PDUS

-- CCSDS-CSTS-SEQUENCE-CONTROLLED-DATA-PROCESSING-PDUS is defined in F3.10
-- of the CSTS SFW (reference [1]).

         scfdpExtendedOpsParam
         FROM CCSDS-FORWARD-FRAME-OBJECT-IDENTIFIERS
;

-- The Sequence-Controlled Frame Data Processing procedure is derived from
-- the CSTS SFW Sequence-Controlled Data Processing procedure, which
-- in turn is derived from the Data Processing procedure. Its PDU
-- is cast as the type of the PDU defined in the Sequence-Controlled Frame
Data Processing procedure:
-- SequContrDataProcessingPdu type defined in the
-- CCSDS-CSTS-SEQUENCE-CONTROLLED-DATA-PROCESSING-PDUS module
-- (F3.10) of the CSTS SFW (reference [1]).
```

```
SequenceControlledFrameDataProcessingPdu ::= SequContrDataProcessingPdu

-- *****
-- START Invocation
-- The parent Sequence-Controlled Data Processing procedure START
-- invocation is extended with the sequContrFrameInputQueueSize parameter
-- from the 'SequContrFrameDataProcStartInvocExt extension type.
-- This extension is defined by 'StartInvocation':
-- 'startInvocationExtension': 'scdpStartInvocExt':
-- 'SequContrDataProcStartInvocExt':
-- 'sequContrDataProcStartInvocExtExtension':
-- 'SequContrFrameDataProcStartInvocExt'.

-- 'StartInvocation': 'startInvocationExtension': 'scdpStartInvocExt':
-- 'SequContrDataProcStartInvocExt':
-- 'sequContrDataProcStartInvocExtExtension':
-- 'SequContrFrameDataProcStartInvocExt':
-- 'sequContrFrameDataProcStartInvocExtExtension' shall be set to
-- 'notUsed'.

SequContrFrameDataProcStartInvocExt ::=      SEQUENCE
   {  sequContrFrameInputQueueSize        CHOICE
      {  unchanged      [0]         NULL
      ,  modify         [1]         IntUnsigned
      }
   ,  sequContrFrameDataProcStartInvocExtExtension    Extended
   }

sequContrFrameDataProcStartInvocExt
               OBJECT IDENTIFIER ::=   {scfdpExtendedOpsParam     1}

-- START return
-- The START positive return does not extend StartReturn; that is,
-- 'StartReturn': 'StandardReturnHeader': 'result': 'positive' shall be set
-- to 'notUsed'.

-- The START negative return does not extend StartReturn; that is,
-- 'StartReturn': 'StandardReturnHeader': 'result': 'negative':
-- 'negExtension' shall be set to 'notUsed'.

-- The START negative return makes use of: (a) one of the common
-- diagnostics of 'StandardReturnHeader': 'result': 'negative':
-- 'diagnostic': 'Diagnostic' (see 3.3.2.7 and F3.3 of reference [1])
-- except 'diagnosticExtension'; or (b) one of the additional values
-- specified by 'StartReturn': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'startDiagnosticExt': 'StartDiagnosticExt' in F3.4 of reference [1]
-- except 'startDiagnosticExtExtension'.

-- *****
-- STOP Invocation
-- The STOP invocation is not extended; that is, 'StopInvocation':
-- 'stopInvocationExtension' shall be set to 'notUsed'.

-- STOP return
-- The STOP positive return does not extend StopReturn; that is,
'StopReturn':
-- 'StandardReturnHeader': 'result': 'positive' shall be set to 'notUsed'.
```

```
-- The STOP negative return does not extend StopReturn; that is,
'StopReturn':
-- 'StandardReturnHeader': 'result': 'negative': 'negExtension' shall be
-- set to 'notUsed'.

-- The STOP negative return makes use of one of the common diagnostics
-- of 'StandardReturnHeader': 'result': 'negative': 'diagnostic':
-- 'Diagnostic' (see 3.3.2.7 and F3.3 of reference [1]) except
-- 'diagnosticExtension'.

-- *****
-- PROCESS-DATA Invocation
-- The parent Sequence-Controlled Frame Data Processing PROCESS-DATA
-- invocation is extended with the additional parameters from the
-- DataProcProcDataInvocExt and SequContrDataProcProcDataInvocExt extension
-- types. No further parameters are added by the Sequence-Controlled Frame
-- Data Processing procedure; that is, 'ProcessDataInvocation':
-- 'processDataInvocationExtension': 'dpProcDataInvovExt':
-- 'DataProcProcDataInvocExt': 'dataProcProcDataInvocExtExtension':
-- 'scdpProcDataInvocExt': 'SequContrDataProcProcDataInvocExt':
-- 'sequContrDataProcDataInvocExtExtension' shall be set to 'notUsed'.

-- PROCESS-DATA positive return
-- The parent Sequence-Controlled Data Processing PROCESS-DATA
-- positive return is extended with additional parameters from
-- the SequContrDataProcProcDataPosReturnExt extension type.
-- No further parameters are added by the Sequence-Controlled Frame
-- Data Processing procedure; that is, 'ProcessDataReturn':
-- 'StandardReturnHeader': 'result': 'positive':
-- 'scdpProcDataPosReturnExt': 'SequContrDataProcProcDataPosReturnExt':
-- 'sequContrDataProcProcDataPosReturnExtExtension' shall be set to
-- 'notUsed'.

-- PROCESS-DATA negative return parameters
-- The parent Sequence-Controlled Data Processing PROCESS-DATA
-- negative return is extended with additional parameters from the
-- SequContrDataProcProcDataNegReturnExt extension type.
-- No further parameters are added to the ProcessDataReturn by the
-- Sequence-Controlled Frame Data Processing procedure; that is,
-- 'ProcessDataReturn': 'StandardReturnHeader': 'result': 'negative':
-- 'negExtension': 'scdpProcDataNegReturnExt':
-- 'SequContrDataProcProcDataNegReturnExt':
-- 'sequContrDataProcProcDataNegReturnExtExtension'shall be set to
-- 'notUsed'.
```

```
-- PROCESS-DATA negative return diagnostics
-- The parent Sequence-Controlled Data Processing PROCESS-DATA
-- negative return is extended with additional diagnostics from the
-- SequContrDataProcProcDataDiagnosticExt extension type. Additional
-- diagnostics are added to the ProcessDataReturn by the
-- Sequence-Controlled Frame Data Processing procedure; that is, the
-- PROCESS-DATA negative return makes use of:
-- (a) one of the common diagnostics of 'StandardReturnHeader' : 'result':
-- 'negative': 'diagnostic': 'Diagnostic' (see 3.3.2.7 and F3.3 of
-- reference [1]) except 'diagnosticExtension';
-- (b) one of the additional diagnostics defined by 'ProcessDataReturn':
-- 'StandardReturnHeader': 'result': 'negative': 'diagnostic':
-- 'Diagnostic': 'diagnosticExtension': 'scdpProcDataDiagExt':
-- 'SequContrDataProcProcDataDiagnosticExt' (see F3.10 of reference [1])
-- except 'sequContrDataProcProcDataDiagnosticExtExtension';
-- (c) 'ProcessDataReturn': 'StandardReturnHeader': 'result': 'negative':
-- 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'scdpProcDataDiagExt': 'SequContrDataProcProcDataDiagnosticExt':
-- 'sequContrDataProcProcDataDiagnosticExtExtension':
-- 'SequContrFrameDataProcProcDataDiagnosticExt' except
-- 'scfdpProcDataDiagnosticExtExtension'.

SequContrFrameDataProcProcDataDiagnosticExt     ::=         CHOICE
   {  invalidGvcid                                      [1]   AdditionalText
   ,  frameTooShort                                     [2]   AdditionalText
   ,  frameTooLong                                      [3]   AdditionalText
   ,  scfdpProcDataDiagnosticExtExtension               [100] Embedded
   }

sequContrFrameDataProcProcDataDiagnosticExt
               OBJECT IDENTIFIER ::=   {scfdpExtendedOpsParam     2}

------
-- NOTIFY invocation
-- The parent Sequence-Controlled Data Processing NOTIFY invocation
-- is extended with additional parameters from the DataProcNotifyInvocExt
-- extension type. No further parameters are added by the Sequence-
-- Controlled Frame Data Processing; that is, 'NotifyInvocation':
-- 'notifyInvocationExtension': 'dpNotifyInvocExt':
-- 'DataProcNotifyInvocExt': 'dataProcNotifyInvocExtExtension' shall be set
-- to IotUsed'.
-- The parent Sequence-Controlled Data Processing NOTIFY invocation
-- extends the processing-status parameter through the
-- SequContrDataProcStatus extension type. No further processing-status
-- values are added by the Sequence-Controlled Frame Data Processing; that
-- is,'NotifyInvocation': 'notifyInvocationExtension': 'dpNotifyInvocExt':
-- 'DataProcNotifyInvocExt': 'dataUnitIdLastProcessed':
-- 'dataUnitLastProcessed': 'dataProcessingStatus':
-- 'dataProcessingStatusExtension': 'scdpNotifyProcStatusExt':
-- 'SequContrDataProcStatus' must not be set to
-- 'sequContrDataProcStatusExtension'.

-- *****
-- EXECUTE-DIRECTIVE invocation
-- The Sequence-Controlled Frame Data Processing EXECUTE-DIRECTIVE
-- invocation does not add any directive-identifiers to those already used
-- by the parent Sequence-Controlled Data Processing EXECUTE-DIRECTIVE
-- (reference [1], 4.8 and F3.10).
```

```
-- The EXECUTE-DIRECTIVE invocation is not extended; that is,
-- 'ExecuteDirectiveInvocation': 'execute DirectiveInvocationExtension'
-- shall be set to 'notUsed'.

-- EXECUTE-DIRECTIVE acknowledgement
-- The EXECUTE-DIRECTIVE positive acknowledgement is not extended; that is,
-- 'ExecuteDirectiveAcknowledge': 'StandardAcknowledgeHeader':
-- 'StandardReturnHeader': 'result': 'positive' shall be set to 'notUsed'.
-- The EXECUTE-DIRECTIVE negative acknowledgement is not extended; that is,
-- 'ExecuteDirectiveAcknowledge': 'StandardAcknowledgeHeader':
-- 'StandardReturnHeader': 'result': 'negative': 'negExtension' shall be
-- set to 'notUsed'.

-- The EXECUTE-DIRECTIVE negative acknowledgement makes use of: (a) one of
-- the common diagnostics of 'StandardReturnHeader': 'result': 'negative':
-- 'diagnostic': 'Diagnostic' (see 3.3.2.7 of reference
-- [1]); or (b) one of
-- the additional diagnostics defined by 'ExecuteDirectiveAcknowledge':
-- 'StandardAcknowledgeHeader': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirAckDiagExt': 'ExecDirNegAckDiagnosticExt'. No further
-- diagnostics are specified; that is, 'ExecuteDirectiveAcknowledge':
-- 'StandardAcknowledgeHeader': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirAckDiagExt': 'ExecDirNegAckDiagnosticExt' must not be set to
-- 'execDirNegAckDiagnosticExtExtension'.

-- EXECUTE-DIRECTIVE return
-- The EXECUTE-DIRECTIVE positive return is not extended; that is,
-- 'ExecuteDirectiveReturn': 'StandardReturnHeader': 'result': 'positive'
-- shall be set to 'notUsed'.

-- The EXECUTE-DIRECTIVE negative return is not extended; that is,
-- 'ExecuteDirectiveReturn': 'StandardReturnHeader': 'result': 'negative':
-- 'negExtension' shall be set to 'notUsed'.

-- The EXECUTE-DIRECTIVE negative return makes use of: (a) one of the
-- common diagnostics of 'StandardReturnHeader': 'result': 'negative':
-- 'diagnostic': 'Diagnostic' (see 3.3.2.7 and F3.3 of reference [1])
-- except 'diagnosticExtension'; or (b) one of the additional diagnostics
-- defined by 'ExecuteDirectiveReturn': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt'in F3.4
-- of reference [1] except 'execDirNegReturnDiagnosticExtExtension'.

END
```

C2 TRANSFER SYNTAX

The `SequContrFrameDataProcStartInvocExt` and `SequContrFrameDataProcProcDataDiagnosticExt` types specified in this module shall be encoded for transfer using the Basic Encoding Rules specified in reference [6].

ANNEX D

PROCEDURE—BUFFERED FRAME DATA PROCESSING PDUS

(NORMATIVE)

D1 BUFFERED FRAME DATA PROCESSING PDUS ASN.1 MODULE

```
CCSDS-BUFFERED-FRAME-DATA-PROCESSING-PDUS
{  iso(1) identified-organization(3) standards-producing-organization(112)
ccsds(4) css(4) csts(1) services(2) forwardFrame(3)
forwardFrameServiceModules(4) extensions(2)
bufferedFrameDataProcessingPdus(2) version (1)
}

DEFINITIONS
IMPLICIT TAGS
::=   BEGIN

EXPORTS  BufferedFrameDataProcessingPdu
;

IMPORTS  Extended
,        IntUnsigned
         FROM CCSDS-CSTS-COMMON-TYPES

-- CCSDS-CSTS-COMMON-TYPES is defined in F3.3 of the
-- CSTS SFW (reference [1]).

         BufferedDataProcessingPdu
         FROM CCSDS-CSTS-BUFFERED-DATA-PROCESSING-PDUS

-- CCSDS-CSTS-BUFFERED-DATA-PROCESSING-PDUS is defined in F3.9
-- of the CSTS SFW (reference [1]).

         bfdpExtendedOpsParam
,        bfdpEventsId
         FROM CCSDS-FORWARD-FRAME-OBJECT-IDENTIFIERS

;

-- The BFDP procedure is derived from the CSTS
-- SFW Buffered Data Processing procedure, which in turn is derived from
-- the Data Processing procedure. Its PDU is cast as the type of the PDU
-- defined in the
-- BFDP procedure: BufferedDataProcessingPdu type
-- defined in the CCSDS-CSTS-BUFFERED-DATA-PROCESSING-PDUS module (F3.9) of
-- the CSTS SFW (reference [1]).

BufferedFrameDataProcessingPdu ::=  BufferedDataProcessingPdu
```

```
-- *****
-- START Invocation
-- The parent Buffered Data Processing procedure START invocation is
-- extended with the buffFrameInputQueueSize,
-- buffFrameMaximumForwardBufferSize, and buffFrameProcessingLatencyLimit
-- parameters from the 'BuffFrameDataProcStartInvocExt extension type.
-- This extension is defined by 'StartInvocation':
-- 'startInvocationExtension': 'buffFrameDataProcStartInvocExt':
-- 'BuffFrameDataProcStartInvocExt':
-- 'StartInvocation': 'startInvocationExtension':
-- 'buffFrameDataProcStartInvocExt ':
-- 'BuffFrameDataProcStartInvocExt':
-- 'buffFrameDataProcStartInvocExtExtension' shall be set to 'notUsed'.

BuffFrameDataProcStartInvocExt   ::=      SEQUENCE
{  buffFrameInputQueueSize          CHOICE
   {  unchanged      [0]      NULL
   ,  modify         [1]      IntUnsigned
   }
,  buffFrameMaximumForwardBufferSize   CHOICE
   {  unchanged      [0]      NULL
   ,  modify         [1]      IntUnsigned
   }
,  buffFrameProcessingLatencyLimit     CHOICE
   {  unchanged      [0]      NULL
   ,  modify         [1]      IntUnsigned
   }
,  buffFrameDataProcStartInvocExtExtension   Extended
}

buffFrameDataProcStartInvocExt
               OBJECT IDENTIFIER ::=   {bfdpExtendedOpsParam1}

-- START return
-- The START positive return does not extend StartReturn; that is,
-- 'StartReturn': 'StandardReturnHeader': 'result': 'positive' shall be set
-- to 'notUsed'.

-- The START negative return does not extend StartReturn; that is,
-- 'StartReturn': 'StandardReturnHeader': 'result': 'negative':
-- 'negExtension' shall be set to 'notUsed'.

-- The START negative return makes use of: (a) one of the common
-- diagnostics of 'StandardReturnHeader': 'result': 'negative':
-- 'diagnostic': 'Diagnostic' (see 3.3.2.7 and F3.3 of reference [1])
-- except 'diagnosticExtension'; or (b) one of the additional values
-- specified by 'StartReturn': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
--'startDiagnosticExt': 'StartDiagnosticExt' in F3.4 of reference [1]
-- except 'startDiagnosticExtExtension'.

-- *****
-- STOP Invocation
-- The STOP invocation is not extended; that is, 'StopInvocation':
-- 'stopInvocationExtension' shall be set to 'notUsed'.
```

```
-- STOP return
-- The STOP positive return does not extend StopReturn; that is,
-- 'StopReturn':'StandardReturnHeader': 'result': 'positive' shall be set
-- to 'notUsed'.

-- The STOP negative return does not extend StopReturn; that is,
-- 'StopReturn':'StandardReturnHeader': 'result': 'negative':
-- 'negExtension' shall be set to 'notUsed'.

-- The STOP negative return makes use of one of the common diagnostics
-- of 'StandardReturnHeader': 'result': 'negative': 'diagnostic':
-- 'Diagnostic' (see 3.3.2.7 and F3.3 of reference [1]) except
-- 'diagnosticExtension'.

-- *****
-- PROCESS-DATA Invocation
-- The parent Buffered Data Processing procedure PROCESS-DATA invocation is
-- extended with the additional parameter from the DataProcProcDataInvocExt
-- extension type. No further parameters are added by the Buffered Frame
-- Data Processing procedure; that is, 'ProcessDataInvocation':
-- 'processDataInvocationExtension': 'dpProcDataInvocExt':
-- 'DataProcProcDataInvocExt': 'dataProcProcDataInvocExtExtension' shall be
-- set to 'notUsed'.

pBFDPdataUnitId OBJECT IDENTIFIER ::= { bfdpEventsId  1}

------
-- NOTIFY invocation
-- The parent Buffered Data Processing NOTIFY invocation is extended with
-- an additional parameter from the DataProcNotifyInvocExt extension type.
-- No further parameters are added by the BFDP;
-- that is, 'NotifyInvocation': 'notifyInvocationExtension':
-- 'dpNotifyInvocExt': 'DataProcNotifyInvocExt':
-- 'dataProcNotifyInvocExtExtension' shall be set to 'notUsed'.

-- The parent Buffered Data Processing NOTIFY invocation does not extend
-- the data-processing-status parameter, and no further
-- data-processing-status values are added by the Buffered Frame Data
-- Processing procedure; that is, 'NotifyInvocation':
-- 'notifyInvocationExtension': 'dpNotifyInvocExt':
-- 'DataProcNotifyInvocExt': 'dataUnitIdLastProcessed':
-- 'dataUnitLastProcessed': 'dataProcessingStatus' must not be set to
-- 'dataProcStatusExtension'.

-- NOTIFY event-name extension
-- This procedure defines the additional eventName values 'invalid GVCID',
-- 'frame length too short', and 'frame length too long'. The associated
-- Published Identifiers are pBFDPinvalidGvcid, pBFPDframeTooShort, and
-- pBFDPframeTooLong, respectively, as defined in annex F.

-- *****

END
```

D2 TRANSFER SYNTAX

The `BuffFrameDataProcStartInvocExt` type specified in this module shall be encoded for transfer using the Basic Encoding Rules specified in reference [6].

ANNEX E

PROCEDURE—MASTER THROW EVENT PDUS

(NORMATIVE)

E1 MASTER THROW EVENT PDUS ASN.1 MODULE

```
CCSDS-MASTER-THROW-EVENT-PDUS
{  iso(1) identified-organization(3) standards-producing-organization(112)
ccsds(4) css(4) csts(1) services(2) forwardFrame(3)
forwardFrameServiceModules(4) extensions(2) masterThrowEventPdus(3) version
(1)
}

DEFINITIONS
IMPLICIT TAGS
::=   BEGIN

EXPORTS  MasterThrowEventPdu
;

IMPORTS  AdditionalText
,        Embedded
,        Extended
         FROM CCSDS-CSTS-COMMON-TYPES

-- CCSDS-CSTS-COMMON-TYPES is defined in F3.3 of the
-- CSTS SFW (reference [1]).

         ThrowEventPdu
         FROM CCSDS-CSTS-THROW-EVENT-PDUS

-- FROM CCSDS-CSTS-THROW-EVENT-PDUS is defined in F3.14 of the
-- CSTS SFW (reference [1]).

         masterThrowEventExtendedOpsParam
         FROM CCSDS-FORWARD-FRAME-OBJECT-IDENTIFIERS
;

-- The Master Throw Event procedure is derived from the CSTS SFW Throw
-- Event procedure. Its PDU is cast as the type of the PDU defined in the
-- Throw Event procedure: ThrowEventPdu type is defined in the
-- CCSDS-CSTS-THROW-EVENT-PDUS module (F3.14) of the CSTS Specification
-- Framework (reference [1]).

MasterThrowEventPdu ::= ThrowEventPdu

-- *****
-- EXECUTE-DIRECTIVE invocation
-- The EXECUTE-DIRECTIVE invocation is not extended; that is,
-- 'ExecuteDirectiveInvocation': 'executeDirectiveInvocationExtension'
-- shall be set to 'notUsed'.
```

```
-- EXECUTE-DIRECTIVE acknowledgement
-- The EXECUTE-DIRECTIVE positive acknowledgement is not extended, i.e.,
-- 'ExecuteDirectiveAcknowledge': 'StandardAcknowledgeHeader':
-- 'StandardReturnHeader': 'result': 'positive' shall be set to 'notUsed'.

-- The EXECUTE-DIRECTIVE negative acknowledgement is not extended, i.e.,
-- 'ExecuteDirectiveAcknowledge': 'StandardAcknowledgeHeader':
-- 'StandardReturnHeader': 'result': 'negative': 'negExtension' shall be
-- set to 'notUsed'.

-- The EXECUTE-DIRECTIVE negative acknowledgement diagnostics are extended
-- by the addition of the masterThroweEventDisabled diagnostic. The
-- EXECUTE-DIRECTIVE negative acknowledgement makes use of:
-- (a) one of the common diagnostics of 'StandardReturnHeader': 'result':
-- 'negative':'diagnostic': 'Diagnostic' (see 3.3.2.7 of reference [1]); or
-- (b) one of the additional diagnostics defined by
-- 'ExecuteDirectiveAcknowledge': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirAckAckDiagExt':'ExecDirNegAckDiagnosticExt' (see F3.4 of
-- reference [1]); or
-- (c) one of the additional diagnostics defined by
-- 'ExecuteDirectiveAcknowledge': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirAckAckDiagExt':'ExecDirNegAckDiagnosticExt':
-- 'execDirNegAckDiagnosticExtExtension': 'masterTeExecDirDiagExt':
-- 'MasterTeExecDirNegAckDiagnosticExt'.
-- No further diagnostics are specified, i.e.,
-- 'ExecuteDirectiveAcknowledge': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirAckAckDiagExt': 'ExecDirNegAckDiagnosticExt':
-- 'execDirNegAckDiagnosticExtExtension': 'masterTeExecDirDiagExt':
-- 'MasterTeExecDirNegAckDiagnosticExt' must not be set to
-- 'masterTeExecDirNegAckDiagnosticExtExtension'.

MasterTeExecDirNegAckDiagnosticExt ::= CHOICE
   {  masterThrowEventDisabled                        [0]   AdditionalText
   ,  masterTeExecDirNegAckDiagnosticExtExtension     [100] Embedded
   }
masterTeExecDirDiagExt OBJECT IDENTIFIER ::=
                           { masterThrowEventExtendedOpsParam 1}

-- EXECUTE-DIRECTIVE return
-- The EXECUTE-DIRECTIVE positive return is not extended, i.e.,
-- 'ExecuteDirectiveReturn': 'StandardReturnHeader': 'result': 'positive'
-- shall be set to 'notUsed'.

-- The EXECUTE-DIRECTIVE negative return is not extended, i.e.,
-- 'ExecuteDirectiveReturn': 'StandardReturnHeader': 'result': 'negative':
-- 'negExtension' shall be set to 'notUsed'.
```

```
-- The EXECUTE-DIRECTIVE negative return makes use of:
-- (a) one of the common diagnostics of 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic' (see (3.3.2.7 and F3.3 of
-- reference [1])) except 'diagnosticExtension'; or
-- (b) one of the additional diagnostics defined by
-- 'ExecuteDirectiveReturn': 'StandardReturnHeader': 'result':
-- 'negative': 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt' in F3.4
-- of reference [1] except 'execDirNegReturnDiagnosticExtExtension'; or
-- (c) one of the additional diagnostics defined by
-- 'ExecuteDirectiveReturn': 'StandardReturnHeader': 'result': 'negative':
-- 'diagnostic': 'Diagnostic': 'diagnosticExtension':
-- 'execDirNegReturnDiagnosticExt': 'ExecDirNegReturnDiagnosticExt':
-- 'execDirNegReturnDiagnosticExtExtension': 'teExecDirDiagExt':
-- 'TeExecDirNegReturnDiagnosticExt' in F3.14 of reference [1] except
-- 'teExecDirNegReturnDiagnosticExtExtension'.
-- *****

END
```

E2 TRANSFER SYNTAX

The `MasterTeExecDirNegAckDiagnosticExt` type specified in this module shall be encoded for transfer using the Basic Encoding Rules specified in reference [6].

ANNEX F

FORWARD FRAME SERVICE PROCEDURE PARAMETERS, EVENTS, AND DIRECTIVES

(NORMATIVE)

F1 FORWARD FRAME SERVICE PROCEDURE PARAMETERS, EVENTS, AND DIRECTIVES ASN.1 MODULE

```
CCSDS-FORWARD-FRAME-SERVICE-PROCEDURE-PARAMETERS-EVENTS-DIRECTIVES
{  iso(1) identified-organization(3) standards-producing-organization(112)
ccsds(4) css(4) csts(1) services(2) forwardFrameService(3) modules (4)
procedureParamEventDirective(3) version (1)
}

DEFINITIONS
IMPLICIT TAGS
::=   BEGIN

EXPORTS  PFDPauthorizedGvcidType
,        PFDPgvcidBitMaskType
,        PFDPmaxFrameLenType
,        PFDPminFrameLenType
,        PFDPnumberDataUnitsProcessedType
,        PFDPnumberDataUnitsRcvdType
,        PFDPnumberDataUnitsToProcessingType
,        PBFDPauthorizedGvcidType
,        PBFDPgvcidBitMaskType
,        PBFDPmaxFrameLenType
,        PBFDPminFrameLenType
,        PFDPnumberDataUnitsProcessedType
,        PBFDPnumberDataUnitsRcvdType
,        PBFDPnumberDataUnitsToProcessingType
,        PSCFDPauthorizedGvcidType
,        PSCFDPgvcidBitMaskType
,        PSCFDPmaxFrameLenType
,        PSCFDPminFrameLenType
,        PSCFDPnumberDataUnitsProcessedType
,        PSCFDPnumberDataUnitsRcvdType
,        PSCFDPnumberDataUnitsToProcessingType
,        PMTEenableThrowEventType
;
```

```
IMPORTS  bfdpDirectivesId
,        bfdpEventsId
,        bfdpExtendedOpsParam
,        bfdpExtendedProcParam
,        masterThrowEventDirectivesId
,        masterThrowEventEventsId
,        masterThrowEventExtendedOpsParam
,        masterThrowEventExtendedProcParam
,        scfdpDirectivesId
,        scfdpEventsId
,        scfdpExtendedOpsParam
,        scfdpExtendedProcParam
         FROM CCSDS-FORWARD-FRAME-OBJECT-IDENTIFIERS

         BufferSize
,        IntPos
,        IntUnsigned
         FROM CCSDS-CSTS-COMMON-TYPES
;

-- CCSDS-CSTS-COMMON-TYPES is defined in F3.3 of the
-- CSTS Specification Framework (reference [1]).

-- ============================================================
-- Data types common to both Forward Frame Prime Procedure types
PFDPauthorizedGvcidType             ::=   OCTET STRING (SIZE (4))
PFDPgvcidBitMaskType                ::=   OCTET STRING (SIZE (4))
PFDPmaxFrameLenType                 ::=   IntPos
PFDPminFrameLenType                 ::=   IntPos
PFDPnumberDataUnitsRcvdType            ::=   IntUnsigned
PFDPnumberDataUnitsToProcessingType ::=   IntUnsigned
PFDPnumberDataUnitsProcessedType    ::=   IntUnsigned

-- SEQUENCE-CONTROLLED FRAME DATA PROCESSING derivations of the common data
-- types

pSCFDPauthorizedGvcid               OBJECT IDENTIFIER
                                    ::= {scfdpExtendedProcParam 1}
PSCFDPauthorizedGvcidType              ::=   PFDPauthorizedGvcidType

pSCFDPgvcidBitMask                  OBJECT IDENTIFIER
                                    ::= {scfdpExtendedProcParam 2}
PSCFDPgvcidBitMaskType                 ::=   PFDPgvcidBitMaskType

pSCFDPmaxFrameLen                   OBJECT IDENTIFIER
                                    ::= {scfdpExtendedProcParam 3}
PSCFDPmaxFrameLenType                  ::=   PFDPmaxFrameLenType

pSCFDPminFrameLen                   OBJECT IDENTIFIER
                                    ::= {scfdpExtendedProcParam 4}
PSCFDPminFrameLenType                  ::=   PFDPminFrameLenType

pSCFDPnumberDataUnitsRcvd           OBJECT IDENTIFIER
                                    ::= {scfdpExtendedProcParam 5}
PSCFDPnumberDataUnitsRcvdType ::= PFDPnumberDataUnitsRcvdType
```

```
pSCFDPnumberDataUnitsToProcessing   OBJECT IDENTIFIER
                                    ::= {scfdpExtendedProcParam 6}
PSCFDPnumberDataUnitsToProcessingType  ::=
                           PFDPnumberDataUnitsToProcessingType

pSCFDPnumberDataUnitsProcessed      OBJECT IDENTIFIER
                                    ::= {scfdpExtendedProcParam 7}
PSCFDPnumberDataUnitsProcessedType     ::=
                             PFDPnumberDataUnitsProcessedType


-- BUFFERED FRAME DATA PROCESSING derivations of the common data types

pBFDPauthorizedGvcid             OBJECT IDENTIFIER
                                    ::= {bfdpExtendedProcParam 1}
PBFDPauthorizedGvcidType               ::=   PFDPauthorizedGvcidType

pBFDPgvcidBitMask                OBJECT IDENTIFIER
                                    ::= {bfdpExtendedProcParam 2}
PBFDPgvcidBitMaskType                  ::=   PFDPgvcidBitMaskType

pBFDPmaxFrameLen                 OBJECT IDENTIFIER
                                    ::= {bfdpExtendedProcParam 3}
PBFDPmaxFrameLenType                   ::=   PFDPmaxFrameLenType
pBFDPminFrameLen                 OBJECT IDENTIFIER
                                    ::= {bfdpExtendedProcParam 4}
PBFDPminFrameLenType                   ::=   PFDPminFrameLenType



pBFDPnumberDataUnitsRcvd            OBJECT IDENTIFIER
                                    ::= {bfdpExtendedProcParam 5}
PBFDPnumberDataUnitsRcvdType  ::= PFDPnumberDataUnitsRcvdType

pBFDPnumberDataUnitsToProcessing OBJECT IDENTIFIER
                                    ::= {bfdpExtendedProcParam 6}
PBFDPnumberDataUnitsToProcessingType   ::=
                           PFDPnumberDataUnitsToProcessingType

pBFDPnumberDataUnitsProcessed    OBJECT IDENTIFIER
                                    ::= {bfdpExtendedProcParam 7}
PBFDPnumberDataUnitsProcessedType      ::=
                             PFDPnumberDataUnitsProcessedType

pBFDPframeTooLong       OBJECT IDENTIFIER    ::={bfdpEventsId 1}
pBFDPframeTooShort      OBJECT IDENTIFIER    ::={bfdpEventsId 2}
pBFDPinvalidGvcid       OBJECT IDENTIFIER    ::={bfdpEventsId 3}


-- MASTER THROW EVENT

pMTEenableThrowEvent    OBJECT IDENTIFIER ::=
                             {masterThrowEventExtendedProcParam 1}

PMTEenableThrowEventType   ::=    ENUMERATED
{  enabled              (0)
,  disabled             (1)
}

END
```

F2 TRANSFER SYNTAX

The `PFDPgvcidBitMaskType`, `PFDPauthorizedGvcidType`, `PFDPminFrameLenType`, `PFDPmaxFrameLenType`, `PFDPNumberDataUnitsRcvdType`, `PFDPNumberDataUnitsToProcessingType`, `PFDPNumberDataUnitsProcessedType`, and `PMTEenableThrowEventType` types specified in this module shall be encoded for transfer using the Basic Encoding Rules specified in reference [6].

ANNEX G

FORWARD FRAME SERVICE PRODUCTION REQUIREMENTS

(NORMATIVE)

G1 GENERAL

Overall, the requirements on the production processes that underlie the Forward Frame service are standard functions that are defined in various CCSDS carrier modulation, synchronization and channel coding, and space data link protocol Recommended Standards.

As described and illustrated in section 2, the Forward Frame service does not use a single combination of these carrier modulation, synchronization and channel coding, and SDLP standards. Rather, the Forward Frame service is intended to work with a variety of these standards in the various combinations in which they can be legally configured. It is therefore not viable to specify a single Forward Frame Service Production process. Instead, it is appropriate to identify the requirements that the Forward Frame service levies on all production processes.

The resources that constitute the production processes that perform both their normative functions (as defined by the appropriate CCSDS Recommended Standards) as well as these Forward Frame-specific requirements are necessary to the successful operation of the Forward Frame service but are not part of the Forward Frame transfer service. The Forward Frame transfer service instances and the production resources that support them are configured by Service Management to operate together.

As described in 2.2, there are two types of production configuration: the Transfer Frame configuration and the CADU configuration. The following subsections specify the requirements that the FF service levies on the underlying production processes in each of these configuration types.

NOTE – These requirements do not include any extended requirements that other CSTSes or SLE transfer services may levy on these production functions.

G2 TRANSFER FRAME CONFIGURATION

G2.1 GENERAL

The production for the Transfer Frame configuration is illustrated in figure 2-1, and consists of functions performed in the Data Link Protocol sublayer, Synchronization and Channel Coding sublayer, and Physical Layer.

Subsection I2 provides an example configuration of the Transfer Frame configuration using TC Transfer Frames. Subsection I3 provides an example configuration of the Transfer Frame configuration using AOS Transfer Frames. Subsection I4 provides an example configuration of the Transfer Frame configuration using variable-length USLP Transfer Frames. Subsection I5 provides an example configuration of the Transfer Frame configuration using variable-length Transfer Frames.

G2.2 DATA LINK PROTOCOL SUBLAYER

G2.2.1 General

The production process that underlies the Forward Frame service instance(s) performs four functions of the CCSDS Data Link Protocol sublayer: Virtual Channel Multiplexing, Master Channel Multiplexing, Only-Idle-Data Frame Generation (fixed-length frames only), and Frame Error Control (optional, as set by Service Management). The details of these functions are specified in the published CCSDS Recommended Standards for the applicable space data link protocols.

NOTE – In addition to the functions listed in the paragraph above, USLP (reference [9]) defines a Master Channel Generation function between the Virtual Channel Multiplexing and Master Channel Multiplexing functions. The sole purpose of the USLP Master Channel Generation function is to insert USLP Operational Control Field service data units into transfer frames if so configured to do so by Service Management. From the perspective of the FF service, this a pass-through function.

G2.2.2 Virtual Channel Multiplexing

NOTE – The Virtual Channel Multiplexing function is provided by the underlying production process through implementation of the VC Multiplexing functions defined by the applicable SDLPs. It is the VC Multiplexing function of the production process that allows multiple instances of the FF service and other sources of VC frames to share the same space link physical channel.

G2.2.2.1 The production process shall multiplex frames from different Virtual Channels into a single MC, in conformance with the requirements specified in the published CCSDS Recommended Standard for the applicable SDLP.

a) When the production functions process TC frames, the VC Multiplexing function shall conform to the VC Multiplexing function of the TC SDLP, as specified in reference [7].

b) When the production functions process AOS frames, the VC Multiplexing function shall conform to the VC Multiplexing function of the AOS SDLP, as specified in reference [8].

c) When the production functions process USLP frames, the VC Multiplexing function shall conform to the VC Multiplexing function of USLP, as specified in reference [9].

G2.2.2.2 Each instance of the VC Multiplexing function shall support one of three VC multiplexing schemes: absolute priority, polling vector, and First-In-First-Out (FIFO), as configured by Service Management.

NOTE – In the following subparagraphs, the descriptions of the multiplexing schemes are conceptual and do not levy any design constraints on actual implementations, as long as the resultant behavior occurs.

G2.2.2.2.1 In the absolute priority multiplexing scheme, a configurable vector specifies the priority of each VC that is handled by the VC Multiplexing function. The VC Multiplexing function contains a virtual queue for each VC that it handles. Frames are time tagged upon receipt by the VC Multiplexing function and placed into their respective VC queues in order of time of receipt. The VC Multiplexing function instance makes available to the associated MC Multiplexing function (a) whether it currently has any frames in any of its queues and (b) the time tag of the first frame in the queue of the highest-priority VC that contains a frame. When the MC Multiplexing function gives its release token to the VC Multiplexing function (see G2.2.3.2), if any of the VC queues has any frames, the VC Multiplexing function shall release the first frame in the queue of the highest-priority VC that contains a frame.

G2.2.2.2.2 In the polling vector scheme, a configurable vector specifies the sequence in which the VCs that are handled by the VC Multiplexing function are to be polled. The VC Multiplexing function contains a virtual queue for each VC that it handles. Frames are time tagged upon receipt by the VC Multiplexing function and placed into their respective VC queues in order of time of receipt. The VC Multiplexing function instance makes available to the associated MC Multiplexing function (a) whether it currently has any frames in any of its queues and (b) the time tag of the first frame in the queue of the next VC in the polling cycle that contains a frame. When the MC Multiplexing function gives its release token to the VC Multiplexing function (see G2.2.3.2), if any of the VC queues has any frames, the VC Multiplexing function shall release the first frame of the queue of the next VC in the polling sequence that has a frame. The VC Multiplexing function shall retain the position in the polling sequence from which the frame was released so that the next time that the release token is made available to the VC Multiplexing function it will resume polling at the next VC in the polling sequence.

G2.2.2.2.3 In the FIFO multiplexing scheme, frames are time tagged upon receipt by the VC Multiplexing function and placed into single virtual regardless of their VCs, in order of time of receipt. The VC Multiplexing function instance makes available to the associated MC Multiplexing function (a) whether it currently has any frames in its queue and (b) the time tag of the first frame in the queue. When the MC multiplexing function gives its release token to the VC Multiplexing function, if the VC Multiplexing function has any frames in its queue, it shall release the frame at the front of its queue.

G2.2.2.3 Each instance of the VC Multiplexing function shall be capable of receiving, multiplexing, and sending Transfer Frames that are annotated with the values of the `data-unit-id` of the source PROCESS-DATA invocation, the `procedure-instance-identifier` of the source (Sequence-Controlled or Buffered) Frame DP procedure instance, and the `service-instance-identifier` of the source Forward Frame service instance (see 4.6.7 of reference [1]).

G2.2.2.4 Each resource that performs the VC Multiplexing function shall make available its current resource status: 'configured', 'operational', 'interrupted', or 'halted'.

G2.2.2.5 Upon each change in resource status, each resource that performs the VC Multiplexing function shall emit a 'resource status change' event identifying the new resource status.

G2.2.2.6 Upon being requested to discard data units, each resource that performs the VC Multiplexing function shall discard all frames that are tagged with the `service-instance-identifier` value that is specified in the 'discard data units' request (see 4.6.7 of reference [1]).

G2.2.3 Master Channel Multiplexing

G2.2.3.1 The production process shall multiplex frames from different MCs into a single physical channel frame stream, in conformance with the requirements specified in the published CCSDS Recommended Standards for the applicable SDLP.

a) When the production functions process TC frames, the VC Multiplexing function shall conform to the MC Multiplexing function of the TC SDLP, as specified in reference [7].

b) When the production functions process AOS frames, the VC Multiplexing function shall conform to the MC Multiplexing function of the AOS SDLP, as specified in reference [8].

c) When the production functions process USLP frames, the VC Multiplexing function shall conform to the MC Multiplexing function of USLP, as specified in reference [9].

G2.2.3.2 Each instance of the MC Multiplexing function shall support one of three VC multiplexing schemes: absolute priority, polling vector, or FIFO, as configured by Service Management.

NOTE – In the following subparagraphs, the descriptions of the multiplexing schemes are conceptual and do not levy any design constraints on actual implementations, as long as the resultant behavior occurs.

G2.2.3.2.1 In the absolute priority multiplexing scheme, a configurable vector specifies the priority of each MC that is handled by the MC Multiplexing function. When the VC Multiplexing function needs to select the next frame to be released, the MC Multiplexing function scans the VC Multiplexing functions associated with it to determine which of the VC Multiplexing functions have a frame ready for release. The VC Multiplexing function gives the release token to the VC Multiplexing function instance that handles the highest-priority MC (according to the priority vector) that has a frame ready for release, and receives the frame from that VC Multiplexing function instance.

G2.2.3.2.2 In the polling vector scheme, a configurable vector specifies the sequence in which the MCs that are handled by the MC Multiplexing function are to be polled. When the VC Multiplexing function needs to select the next frame to be released, the MC Multiplexing function scans the VC Multiplexing functions associated with it to determine which of the VC Multiplexing functions have a frame ready for release. The VC Multiplexing function gives the release token to the VC Multiplexing function instance that handles the next MC in the polling cycle (according to the polling vector) that has a frame ready for release, and receives the frame from that VC Multiplexing function instance. The MC Multiplexing function shall retain the position in the polling sequence from which the frame was released so that the next time that a transmission timeslot is made available to the MC Multiplexing function it will resume polling at the next MC in the polling sequence.

G2.2.3.2.3 In the FIFO multiplexing scheme, when the VC Multiplexing function needs to select the next frame to be released, the MC Multiplexing function scans the VC Multiplexing functions associated with it to determine which of the VC Multiplexing functions have a frame ready for release. The VC Multiplexing function gives the release token to the VC Multiplexing function instance that that has the frame with the earliest time tag, and receives the frame from that VC Multiplexing function instance.

G2.2.3.3 Each instance of the MC Multiplexing function shall be capable of receiving, multiplexing, and sending Transfer Frames that are annotated with the values of the `data-unit-id` of the source PROCESS-DATA invocation, the `procedure-instance-identifier` of the source (Sequence-Controlled or Buffered) Frame DP procedure instance, and the `service-instance-identifier` of the source Forward Frame service instance (see 4.6.7 of reference [1]).

G2.2.3.4 Each resource that performs the MC Multiplexing function shall make available its current resource status: ‘configured’, ‘operational’, ‘interrupted’, or ‘halted’.

G2.2.3.5 Upon each change in resource status, each resource that performs the MC Multiplexing function emits a ‘resource status change’ event identifying the new resource status.

G2.2.3.6 Upon being requested to discard data units, each resource that performs the MC Multiplexing function shall discard all frames that are tagged with the `service-instance-identifier` value that is specified in the ‘discard data units’ request (see 4.6.7 of reference [1]).

G2.2.4 Only Idle Data Frame Generation

NOTE – Only Idle Data Frame generation is required when either AOS frames or fixed-length USLP frames are transferred by the FF service.

G2.2.4.1 When Only Idle Data Frame generation is required, the production process shall generate Only Idle Data Frames as necessary to preserve the continuity of the transmitted stream of fixed-length transfer frames in the event that there are no valid Transfer Frames

available for transmission at a release time, in conformance with the requirements specified in the published CCSDS Recommended Standards for the applicable SDLP.

a) When the production functions process AOS frames, the Only Idle Data Frame Generation function shall conform to the Only Idle Data Frame generation subfunction of the MC Multiplexing function of the AOS SDLP, as specified in reference [8].

b) When the production functions process USLP frames, the the Only Idle Data Frame Generation function shall conform to the Only Idle Data Frame generation subfunction of the MC Multiplexing function of USLP, as specified in reference [9].

G2.2.4.2 Each resource that performs the Only Idle Data Frame Generation function shall make available its current resource status: 'configured', 'operational', 'interrupted', or 'halted'.

G2.2.4.3 Upon each change in resource status, each resource that performs the Only Idle Data Frame Generation function emits a 'resource status change' event identifying the new resource status.

G2.2.4.4 Upon being requested to discard data units, each resource that performs the Only Idle Data Frame Generation function shall discard all frames that are tagged with the `service-instance-identifier` value that is specified in the 'discard data units' request (see 4.6.7 of reference [1]).

G2.2.5 Frame Error Control

G2.2.5.1 If configured to do so by Service Management, the production process shall generate and insert a Frame Error Control Field (FECF) in each frame, in conformance with the requirements specified in the published CCSDS Recommended Standards for the applicable SDLP.

a) When the production functions process TC frames, the FECF Generation function shall conform to the FECF generation requirements of the All Frames Generation function of the TC SDLP, as specified in reference [7].

b) When the production functions process AOS frames, the FECF Generation function shall conform to the FECF generation subfunction of the All Frames Generation function of the AOS SDLP, as specified in reference [8][7].

c) When the production functions process USLP frames, the FECF Generation function shall conform to the FECF generation requirements of the All Frames Generation function of USLP, as specified in reference [9].

G2.2.5.2 When the production functions process AOS frames **and** if configured to do so by Service Management, the production process shall generate Frame Header Error Control bits for each frame, in conformance with the Frame Header Error Control requirements the All Frames Generation function of the AOS SDLP, as specified in reference [8].

G2.2.5.3 Each resource that performs the FECF and/or Frame Header Error Control function(s) shall make available its current resource status: 'configured', 'operational', 'interrupted', or 'halted'.

G2.2.5.4 Upon each change in resource status, each resource that performs the FECF and/or Frame Header Error Control function(s) shall emit a 'resource status change' event identifying the new resource status.

G2.2.5.5 Upon being requested to discard data units, each resource that performs the FECF and/or Frame Header Error Control function(s) shall discard all frames that are tagged with the `service-instance-identifier` value that is specified in the 'discard data units' request (see 4.6.7 of reference [1]).

G2.3 SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

G2.3.1 The production process shall synchronize and encode frames from the source data unit stream to form a single coded symbol stream, in conformance with the requirements specified in the published CCSDS Recommended Standards that are applicable to the Synchronization and Channel Coding sublayer.

a) When the production functions process TC or variable-length USLP frames, the Synchronization and Channel Coding functions shall conform to the requirements specified in the *TC Synchronization and Channel Coding* Recommended Standard, reference [11].

b) When the production functions process AOS or fixed-length USLP frames, the Synchronization and Channel Coding functions shall conform to the requirements specified in the *TM Synchronization and Channel Coding* Recommended Standard, reference [10].

   NOTE – As of the publication of this Recommended Standard, reference [10] is not formally applicable to the forward link. However, a planned revised version of reference [10] will specify the synchronization and channel coding functions that are applicable to the forward link. For the purposes of this Reccommended Standard, whatever functions are identified by that revised version will be applicable to the production of the Forward Frame service.

G2.3.2 Each resource that performs the Synchronization and Channel Coding functions shall be capable of receiving frames or groups of frames that are annotated with the values of the `data-unit-id` parameter(s) of the source PROCESS-DATA invocation(s), the `procedure-instance-identifier` of the source (Sequence-Controlled or Buffered) Frame DP procedure instance, and the `service-instance-identifier` of the source Forward Frame service instance (see 4.6.7 of reference [1]).

G2.3.3 Each resource that performs the Synchronization and Channel Coding functions shall maintain the association of each frame with its `data-unit-id` and `service-instance-id` annotation until all encoding and/or synchronization functions have been performed for that frame.

G2.3.4 Each resource that performs the Synchronization and Channel Coding functions shall emit a 'data unit processing completed' event at the detected or estimated radiation time of each frame. Each 'data unit processing completed' event shall carry the `data-unit-id`, `procedure-instance-identifier`, and `service-instance-id` annotation that accompanied the radiated frame.

G2.3.5 Each resource that performs the Synchronization and Channel Coding functions shall make available its current resource status: 'configured', 'operational', 'interrupted', or 'halted'.

G2.3.6 Upon each change in resource status, each resource that performs the Synchronization and Channel Coding functions shall emit a 'resource status change' event identifying the new resource status.

G2.3.7 Upon being requested to discard data units, each resource that performs the Synchronization and Channel Coding functions shall discard all frames that are tagged with the `-instance-identifier` value that is specified in the 'discard data units' upon being requested to discard data units (see 4.6.7 of reference [1]).

G2.4 PHYSICAL LAYER

G2.4.1 The production process shall modulate the coded symbol stream for radiation across the space link, in conformance with the requirements specified in the published CCSDS Recommended Standards for forward link carrier modulation.

NOTE – At of the publication of this Recommended Standard, the set of published CCSDS Recommended Standards for forward link carrier modulation consists of references [L9] and [L10].

G2.4.2 Each resource that performs the Physical Layer functions shall make available its current resource status: 'configured', 'operational', 'interrupted', or 'halted'.

G2.4.3 Upon each change in resource status, each resource that performs the Physical Layer functions shall emit a 'resource status change' event identifying the new resource status.

G3 CADU CONFIGURATION

G3.1 OVERVIEW

The production for the CADU configuration is illustrated in figure 2-2, and consists of functions performed in the Synchronization and Channel Coding sublayer and Physical Layer.

Subsection I6 provides an example of the CADU configuration.

The Forward Frame service requirements on the underlying Physical Layer production processes in the CADU configuration are the same as those in the Transfer Frame configuration (see G2.4). Only the Synchronization and Channel Coding sublayer requirements are specific to the CADU configuration.

G3.2 SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

NOTE – Synchronization and Channel Coding for the CADU configuration consists of two functions: Only Idle Data Generation and Multiplexing, and Symbol Stream Generation.

G3.2.1 The Only Idle Data Generation and Multiplexing function shall generate Only Idle Data CADUs as necessary to preserve the continuity of the transmitted stream in the even that there are no valid Transfer Frames available for transmission at a release time, and multiplex the Only Idle Data CADUs with the CADUs received via the Forward Frame service instance.

G3.2.2 Each instance of the Only Idle Data CADU Generation and Multiplexing function shall be configured by Service Management through an Only Idle Data CADU configuration parameter. The Only Idle Data CADU shall be formed by starting with the Only Idle Data Frames for the appropriate SDLP (as specified in reference [8] for AOS and reference [9] for fixed-length USLP), and applying the same coding transformations as those that are applied by the user of the Forward Frame service instance:

a) If the Forward Frame service instance user has applied Reed-Solomon, Turbo, or LDPC encoding to the frames as specified in the *TM Synchronization and Channel Coding* Recommended Standard (reference [10]), the same encoding shall be applied to the Only Idle Data Frame.

b) If the Forward Frame service instance user has applied randomization to the frames as specified in the *TM Synchronization and Channel Coding* Recommended Standard (reference [10]), the same randomization shall be applied to the (unencoded or encoded) Only Idle Data Frame.

c) The resulting unencoded, encoded, and/or randomized Only Idle Data Frame shall have the Attached Synchronization Marker that is appropriate to the applied coding scheme attached, as specified in the *TM Synchronization and Channel Coding* Recommended Standard (reference [10]), to form Only Idle Data CADUs.

G3.2.3 The Only Idle Data CADU Generation and Multiplexing function shall multiplex the user-data-bearing CADUs received through the FF service instance with the Only Idle Data CADUs to form a continuous and contiguous stream of CADUs.

G3.2.4 The Symbol Stream Generation function shall form a continuous and contiguous stream of symbols from the stream of CADUs, as specified in the *TM Synchronization and Channel Coding* Recommended Standard (reference [10]).

G3.2.5 If configured to do so, the Symbol Stream Generation function shall convolutionally encode the stream of CADUs, as specified in the *TM Synchronization and Channel Coding* Recommended Standard (reference [10]).

G3.2.6 Each resource that performs CADU-configuration Synchronization and Channel Coding functions shall be capable of receiving CADUs that are annotated with the values of the `data-unit-id` parameter of the source PROCESS-DATA invocation, the `procedure-instance-identifier` of the source Frame DP procedure instance, and the `service-instance-identifier` of the source Forward Frame service instance (see 4.6.7 of reference [1]).

G3.2.7 Each resource that performs CADU-configuration Synchronization and Channel Coding functions shall make available its current resource status: 'configured', 'operational', 'interrupted', or 'halted'.

G3.2.8 Upon each change in resource status, each resource that performs CADU-configuration Synchronization and Channel Coding functions shall emit a 'resource status change' event identifying the new resource status.

G3.2.9 Upon being requested to discard data units, each resource that performs CADU-configuration Synchronization and Channel Coding functions shall discard all frames that are tagged with the `service-instance-identifier` value that is specified in the 'discard data units' request (see 4.6.7 of reference [1]).

ANNEX H

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

H1 SECURITY CONSIDERATIONS

H1.1 INTRODUCTION

This subsection describes security aspects of the Forward Frame service.

The CSTS SFW (reference [1]) explicitly provides authentication and access control for CSTSes. As one of the suite of CSTSes, the Forward Frame service inherits the authentication and access control capabilities defined in the CSTS SFW. The Forward Frame service provides no service-specific security capabilities. As specified in the CSTS SFW, additional security capabilities, if required, are levied on the underlying communications services that support the FF-CSTS. Specification of the various underlying communications technologies, and in particular their associated security provisions, are outside the scope of this Recommended Standard.

H1.2 SECURITY CONCERNS WITH RESPECT TO THE FORWARD FRAME SERVICE

The Statements of Security Concerns subsection of the CSTS SFW (H1 of reference [1]) identifies the support for capabilities that respond to security concerns in the areas of data privacy (also known as confidentiality), data integrity, authentication, access control, availability of resources, and auditing.

H1.3 POTENTIAL THREATS AND ATTACK SCENARIOS

H1.3.1 Breach of Privacy

As a member of the suite of CSTSes, the Forward Frame service does not in itself provide any mechanisms to detect or prevent breaches of security. Any detection or prevention of security breaches depends on unspecified security mechanisms operating in the underlying communications service, the use of the CCSDS Space Data Link Security (SDLS) protocol (reference [L15]) by the user of the FF service to secure the Transfer Frames and CADUs transferred by the Forward Frame service, and/or privacy-ensuring capabilities in the user's service-specific application processes that interoperate through the Framework procedures, to ensure data privacy (confidentiality). If no such mechanisms are actually implemented, or if the mechanisms selected are inadequate or inappropriate to the network environment in which the mission is operating, an attacker could read the data contained in the Transfer Frames or CADUs as they traverse the wide area network from the service user to the service provider.

H1.3.2 PDU Interception and Replay

The CSTS SFW Recommended Standard (reference [1]) constrains the ability of a third party to seize control of an active CSTS instance. In addition, when operating in the sequence-controlled data processing mode (see 1.6.1.12.2), the Forward Frame service strictly enforces sequencing of data units, such that the repetition of data unit sequence numbers (as would occur if an attacker were to attempt to inject Transfer Frames into an active service association) would cause that service association to be aborted.

Beyond those capabilities, the Forward Frame service does not specify mechanisms that would prevent an attacker from intercepting the PDUs and replacing the payload data (in this case Transfer Frames or CADUs) of those PDUs. Successful interception and replacement could allow the attacker to seize control of the spacecraft and/or its payload(s). Other than the sequencing enforcement performed when operating in the sequence-controlled data processing mode, the prevention of interception and replay attacks depends on unspecified mechanisms in the underlying communications service and/or the use of SDLS (reference [L15]) by the user of the FF service prior to transferring the frames or CADUs through the FF service. 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 inject Transfer Frames transferred between the service user and the service provider without detection.

H1.3.3 Unauthenticated Access

The Forward Frame service uses the optional CSTS authentication capability specified in 3.2.4 of reference [1]. Beyond that authentication, each Forward Frame service instance is configured to accept the Transfer Frames for only a single designated VC and frame size constraints, rejecting any Transfer Frames that do not have the GVCID or proper frame size for that service instance. If the CSTS authentication capability is not used, and if authentication is not ensured by the underlying communications service, an attacker could somehow obtain the valid `initiator-identifier` values, associated GVCID, and frame size constraints for a given Forward Frame service instance and use them to bind to and activate that Forward Frame service instance and thereby inject Transfer Frames or CADUs into the forward space link associated with that service instance.

H1.3.4 Denial of Service Attacks

The Forward Frame service depends on unspecified mechanisms operating in the underlying communications service to ensure that the supporting network has sufficient resources to provide sufficient support to legitimate service 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 service users from using the Forward Frame service.

H1.3.5 Failure to Detect Breach Attempts

The Forward Frame service authenticates attempts to bind to it, accepts only those inputs that meet VC and Transfer Frame size constraints, and enforces the protocol on the interface with the service user. Errors in any of these areas could indicate a breach attempt. However, the Forward Frame service contains no specific capabilities to log and/or analyze such errors. Any such security auditing capability must be provided by the service provider that implements the Forward Frame service. If the service provider of the Forward Frame service provides no security auditing capabilities, or if a service user chooses not to employ auditing capabilities that do exist, then attackers may delay or escape detection while probing the service to determine the right combination of credentials and service parameters needed to successfully access the service.

H2 SANA CONSIDERATIONS

H2.1 CCSDS CSTS SERVICES REGISTRY

As described in H2.3 of reference [1], SANA has established the CSTS `services` subtree for the registration of Object Identifiers (OIDs) for CSTS types and their associated service-specific parameters, procedures, and ASN.1 modules. This Recommended Standard adds the OIDs and labels contained in annexes B, C, D, E, and F to the CCSDS OID registry CSTS services subtree.

H2.2 FUNCTIONAL RESOURCES REGISTRY

The FF-CSTS relies on the SANA Functional Resources registry (reference [4]) to provide the identification and definition of FR parameters and events.

As described in this Recommended Standard, the FF-CSTS configures and reports parameters and notifies events that are named in the context of FRs. Functional Resource Types are registered under the

```
{iso identified-organization (3) standards-producing-organization (112)
ccsds (4) css (4) crossSupportResources (2)}
```

node of the OID registration tree.

There are two subnodes under the `crossSupportResources` node: `crossSupportFunctionalities` and `agencyFunctionalities`, used to register CCSDS-standard Functional Resource Types and agency-unique Functional Resource Types, respectively. Under each Functional Resource Type OID, the parameters, events, and directives are registered under dedicated subnodes.

The FF-CSTS relies on the SANA Functional Resource registry to register the following:

- the FF-CSTS Provider Functional Resource Type, registered under the `crossSupportFunctionalities` with the classifier `ffCstsProvider`;
- the parametersId node of the `ffCstsProvider` subtree as {`ffCstsProvider 1`};
- the eventsId node of the `ffCstsProvider` subtree as {`ffCstsProvider 2`};
- the directivesId node of the `ffCstsProvider` subtree as {`ffCstsProvider 3`}.

Maintenance of the SANA registry of the FR types, parameters, events, and directives under the `crossSupportFunctionalities` subnode is under the purview of the CCSDS Cross Support Services Area in accordance with the process and procedures identified in the CSTS SFW.

Maintenance of the SANA registry of the FR types, parameters, events, and directives under the `agencyFunctionalities` subnode is under the purview of designated Agency-level control authorities. The process and procedure for designating Agency-level control authorities is documented in the CSTS SFW.

H3 PATENT CONSIDERATIONS

There are no patents that are known to apply to the technology used in the Forward Frame service.

ANNEX I

EXAMPLE FORWARD FRAME PROVISION AND PRODUCTION CONFIGURATIONS

(INFORMATIVE)

I1 GENERAL

As described in other sections of this Recommended Standard, the Forward Frame service is designed to transfer Telecommand transfer frames (as defined in reference [7]), AOS transfer frames (as defined in reference [8], variable- and fixed-length USLP transfer frames (as defined in reference [9]), and CADUs (as defined in reference [10]).

This annex illustrates each of these five service configurations as compositions of the CCSDS-standard space data link protocol, synchronization and channel coding, and radio frequency modulation functions that are applicable to each service configuration. For each Forward Frame service configuration, the relevant layers of the CCSDS protocol stack and the CCSDS Recommended Standards that specify the functions for each of those layers as appropriate to the given service configuration are identified.

All five of these service configurations can operate with the Physical Layer functionality specified by either the *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft* Recommended Standard (CCSDS 401.0, reference [L9]) or the *Data Transmission and PN Ranging for 2 GHz CDMA Link via Data Relay Satellite* Recommended Standard (CCSDS 415.1, reference [L10]). These Physical Layer functions are not further addressed in the following subsections, although they are included in the diagrams depicting each of the service configurations.

NOTE – The CCSDS Recommended Standards identified in this annex are the ones that are relevant to the five Forward Frame service configurations as of the publication of this Recommended Standard. Future Recommended Standards that define functions that conform to the CCSDS space link layers may also be able to be used in conjunction with the Forward Frame service, but validation of such use is outside the scope of this Recommended Standard.

I2 TRANSFER FRAME CONFIGURATION FOR TELECOMMAND FRAMES

I2.1 GENERAL

Figure I-1 depicts the functions that comprise the provision and production of the Forward Frame service when configured to support the transfer and radiation of TC frames. These functions correspond to the operational scenario described in 2.5.2.

NOTE – Figure 2-5 shows a 'CLCWs from return link VC' arrow into the *TC Synchronization and Channel Coding* functions that does not appear in figure I-1. As discussed in 2.5.2 the values of the CLCW flags are used to determine the resource status of the functional resource that represents the *TC Synchronization and Channel Coding* functions but does not directly affect the *TC Synchronization and Channel Coding* functions themselves. The CLCW feedback is outside the focus of this subsection.

I2.2 FORWARD FRAME CSTS PROVIDER

The FF-CSTS Provider represents an instance of an entity that performs the functions that are specified in this Recommended Standard. In the Transfer Frame configuration, multiple instances of the FF-CSTS Provider may exist for one space link physical channel. Each FF-CSTS Provider supplies the frames from one virtual channel. In the TC Frames configuration, the FF-CSTS Provider bit mask is configured to match data units for which the TFVN, SCID, and VCID fields in the first four octets of the TC Transfer Frame Primary Header correspond to the GVCID of the virtual channel assigned to that transfer service instance.

I2.3 DATA LINK PROTOCOL SUBLAYER

I2.3.1 General

For the TC Frames configuration, the Data Link Protocol Sublayer functions are defined in the *TC Space Data Link Protocol* Recommended Standard (reference [7]). The functions of this sublayer that are relevant to the transfer of TC Frames are the Virtual Channel Multiplexing Function, the Master Channel Multiplexing Functions, and the All Frames Generation Function.

I2.3.2 Virtual Channel Multiplexing Function

The Virtual Channel Multiplexing function of reference [7] multiplexes the Transfer Frames from one or more VCs with the same MCID into a single stream of Transfer Frames. The sources of these VCs can be multiple FF-CSTS service instances, VC frames generated by the TC SDLP's Virtual Channel Generation Function (see reference [7]) and/or other VC-generating sources of externally-generated transfer frames input via the TC SDLP's VC Frame Service (see reference [7]).

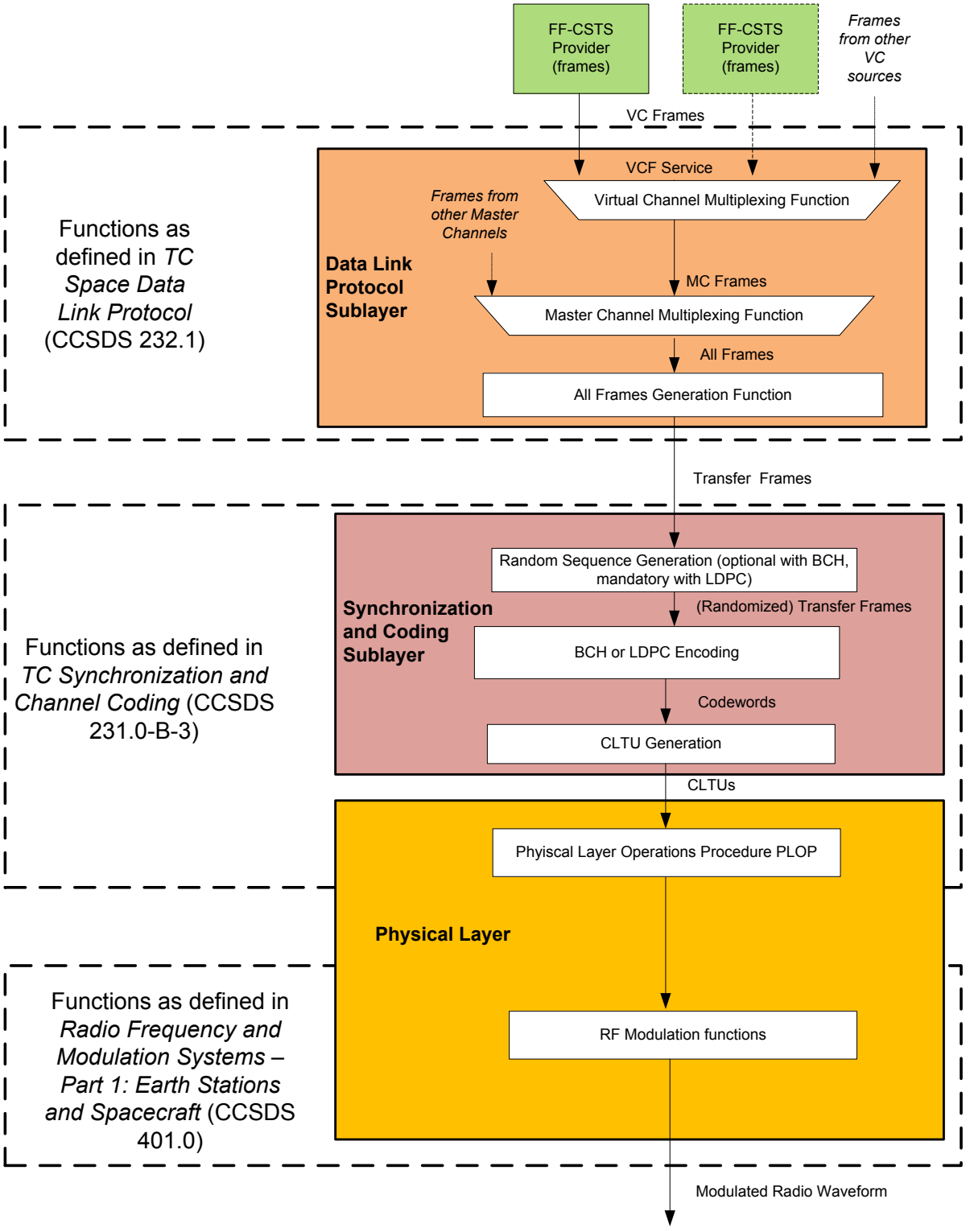


Figure I-1: Forward Frame Service—Transfer Frame Configuration—TC Frames

The specification of the Virtual Channel Multiplexing function in reference [7] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component VCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. When used with the Forward Frame service the Virtual Channel Multiplexing function supports the three multiplexing schemes (absolute priority, polling vector, and FIFO) that G2.2.2.2 specifies must be implemented by any instance of the Virtual Channel Multiplexing function that receives its frames from an instance of the Forward Frame service.

I2.3.3 Master Channel Multiplexing Function

The Master Channel Multiplexing function of reference [7] multiplexes the Transfer Frames from one or more Master Channels into a single stream of Transfer Frames destined for the space Physical Channel. The sources of these Master Channels can be one or more Virtual Channel Multiplexing function instances and/or other VC-generating sources of externally-generated transfer frames input via the TC SDLP's MC Frame Service (see reference [7]).

The specification of the Master Channel Multiplexing function in reference [7] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component MCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. When used with the Forward Frame service the Master Channel Multiplexing function supports the three multiplexing schemes (absolute priority, polling vector, and FIFO) that G2.2.3.2 specifies must be implemented by any instance of the Master Channel Multiplexing function that receives frames from any VC Multiplexing function instance used by a Forward Frame service instance.

I2.3.4 All Frames Generation Function

The All Frames Generation function of reference [7] optionally adds an FECF to the trailer of each frame and groups Transfer Frames together into a data unit that will be transformed by the *TC Synchronization and Channel Coding* sublayer (see reference [11]) into a single CLTU. How many frames are placed in any individual data unit is based on configuration parameters set by Service Management that specify the maximum allowed number of frames in a data unit and the maximum allowed size (in octets) of a data unit.

When being submitted to the underlying Synchronization and Channel Coding sublayer (I2.4), the same data unit may be submitted multiple times. The number of times a data unit is submitted is based on configuration parameters set by Service Management that specify how many times Sequence-Controlled (type AD) and COP Control Command (type BC) Telecommand frames for each virtual channel are to be repeated, and whether the specific group-of-frames data unit contains any AD or BC frames that are specified to be repeated (Expedited (type BD) frames are not repeated; see reference [7]).

NOTE – As specified in references [11] and [7], the Data Link Protocol Sublayer functions include the capability to cause the Synchronization and Channel Coding Sublayer (I2.4) to repeat AD and BC frames within CLTUs. The mechanism for accomplishing this is formally specified in reference [11] as a 'data unit' consisting of a group of frames to be transmitted in a single CLTU, accompanied by a *Repetitions* parameter that specifies the number of times that the resultant CLTU is to be transmitted. The same effect on the space link can be accomplished by having the Data Link Protocol Sublayer submit the group-of-frames data unit to the Synchronization and Channel Coding Sublayer *Repetitions* times. Having the group-of-frames submitted to the Sync and Channel Coding Sublayer *Repetitions* times is the way that the repetition capability is implemented for SLE Forward CLTU (reference [L4]) and Forward Space Packet (FSP - reference [L14]): for the F-CLTU service the service user transfers the same (already formed) CLTU *Repetitions* times, and for the FSP service the Data Link Protocol Sublayer forms and submits the group-of-frames data unit to the Synchronization and Channel Coding Sublayer *Repetitions* times (based on Service Management configuration parameters). For consistency with those SLE implementations and in recognition that Forward Frame service instances may share space links with FSP service instances, the description of the repetition capability in this informative annex is phrased in terms of the approach in which the Data Link Protocol Sublayer submits the group-of-frames data unit to the Synchronization and Channel Coding Sublayer *Repetitions* times.

I2.4 SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

For the TC frames configuration, the Synchronization and Channel Coding sublayer functions are defined in the *TC Synchronization and Channel Coding* Recommended Standard (reference [11]). The functions of reference [11] that are relevant to the Forward Frame service are:

a) the Random Sequence Generation function, which is optional when BCH encoding is applied but mandatory when LDPC encoding is applied;

b) either the modified BCH Coding function (as specified reference [11]) or the LDPC Coding function; and

c) the CLTU Generation function.

NOTE – As illustrated in figure I-1, the Random Sequence Generation function is performed before either BCH or LDPC encoding, which is as specified in the referenced Issue 3 of the *TC Synchronization and Channel Coding* Recommended Standard (reference [11]). As of the publication of this Recommended Standard, the *TC Synchronization and Channel Coding* Recommended Standard is being modified to specify that the Random Sequence Generation function be performed *after* LDPC encoding.

Reference [11] also specifies two Physical Layer Operations Procedures (PLOPs), PLOP-1 and PLOP-2. PLOP-1 is deprecated, and only PLOP-2 is permitted to be used by missions whose planning began after September 2010. However, since the Forward Frame service is a cross support service of ESLTs that can reasonably be expected to support legacy missions, the production functions supporting Forward Frame service instances that transfer TC frames are expected to implement both PLOP-1 and PLOP-2.

NOTE – Although the definitions of the PLOPs are specified in reference [11], they are formally functions of the Physical Layer.

I3 TRANSFER FRAME CONFIGURATION FOR AOS FRAMES

I3.1 GENERAL

Figure I-2 depicts the functions that comprise the provision and production of the Forward Frame service when configured to support the transfer and radiation of AOS frames. These functions correspond to the operational scenario described in 2.5.3.

I3.2 FORWARD FRAME CSTS PROVIDER

The FF-CSTS Provider represents an instance of an entity that performs the functions that are specified in this Recommended Standard. In the Transfer Frame configuration, multiple instances of the FF-CSTS Provider may exist for one space link physical channel. Each FF-CSTS Provider supplies the frames from one virtual channel. In the AOS Frames configuration, the FF-CSTS Provider bit mask is configured to match data units for which the TFVN, SCID, and VCID fields in the first four octets of the AOS Transfer Frame Primary Header correspond to the GVCID of the virtual channel assigned to that transfer service instance.

I3.3 DATA LINK PROTOCOL SUBLAYER

I3.3.1 General

For the AOS Frames configuration, the Data Link Protocol Sublayer functions are defined in the *AOS Space Data Link Protocol* Recommended Standard (reference [8]). The functions of this sublayer that are relevant to the transfer of AOS Frames are the Virtual Channel Multiplexing Function, the Master Channel Multiplexing Functions, and the All Frames Generation Function.

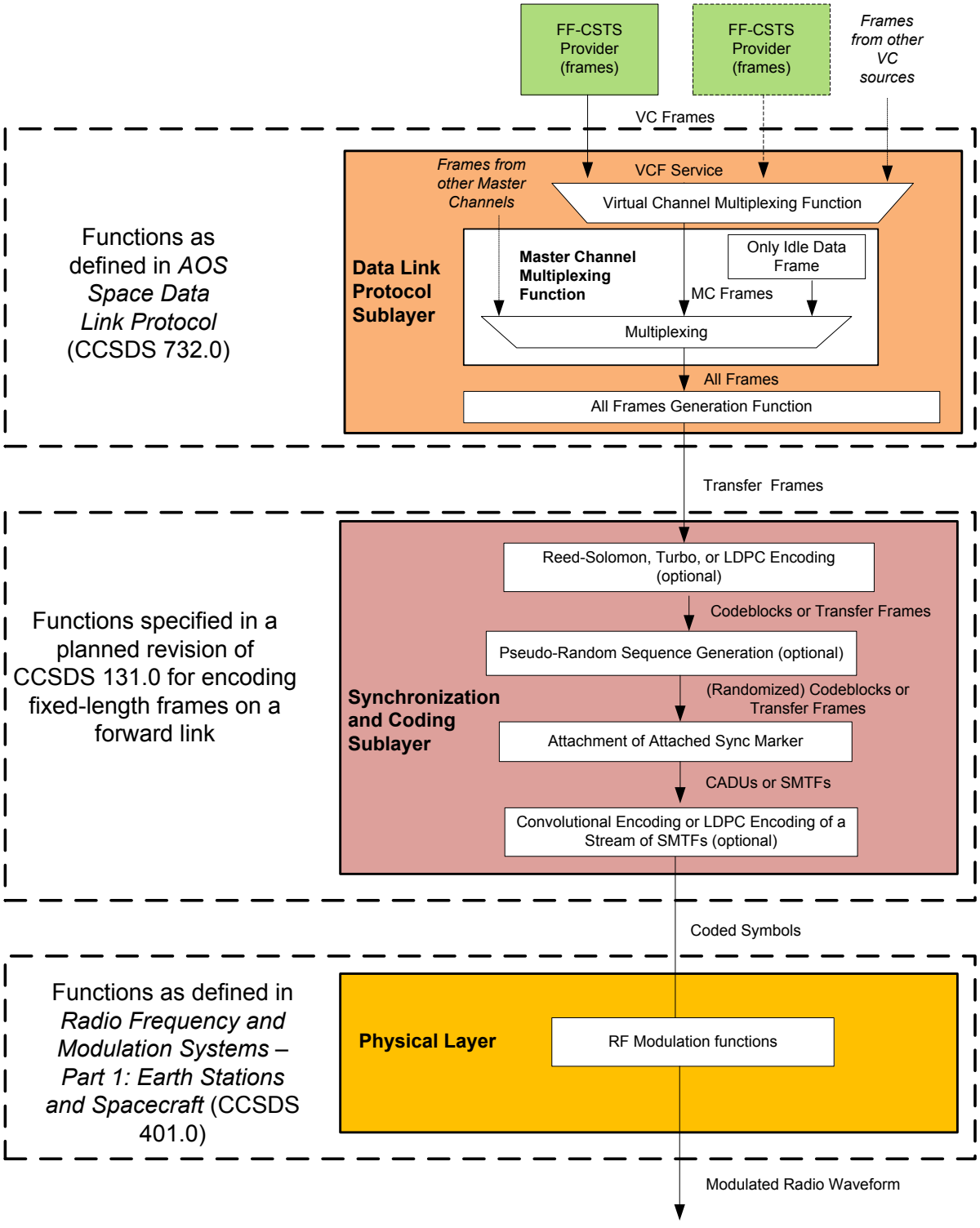


Figure I-2: Forward Frame Service—Transfer Frame Configuration—AOS Frames

I3.3.2 Virtual Channel Multiplexing Function

The Virtual Channel Multiplexing function of reference [8] multiplexes the Transfer Frames from one or more VCs with the same MCID into a single stream of Transfer Frames. The sources of these VCs can be multiple FF-CSTS service instances, VC frames generated by the AOS SDLP's Virtual Channel Generation Function (see reference [8]) and/or other VC-generating sources of externally-generated transfer frames input via the AOS SDLP's VC Frame Service (see reference [8]).

The specification of the Virtual n Multiplexing function in reference [8] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component VCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. Section G2.2.2.2 specifies three multiplexing schemes (absolute priority, polling vector, and FIFO) that must be implemented by any instance of the Virtual Channel Multiplexing function that receives its frames from an instance of the Forward Frame service.

NOTE – The VC Multiplexing function defined in reference [8] also provides for generation of Only Idle Data frames in the absence of user-data-bearing Transfer Frames from any of the input VCs and when there is only a single MC on the Physical Channel. However, for the purposes of this example configuration, it is assumed that the Only Idle Data frames are generated by the Master Channel Multiplexing function (see I3.3.3).

I3.3.3 Master Channel Multiplexing Function

The Master Channel Multiplexing function of reference [8] multiplexes the Transfer Frames from one or more Master Channels into a single stream of Transfer Frames destined for the space Physical Channel. The sources of these Master Channels can be one or more Virtual Channel Multiplexing function instances and/or other VC-generating sources of externally-generated transfer frames input via the AOS SDLP's MC Frame Service (see reference [8]).

The Master Channel Multiplexing function also generates Only Idle Data frames 'to preserve the continuity of the transmitted stream in the event that there are no valid Transfer Frames available for transmission at a release time' (4.2.6.4 of reference [8]).

The specification of the Master Channel Multiplexing function in reference [8] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component MCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. Section G2.2.3 specifies three multiplexing schemes (absolute priority, polling, and FIFO) that must be implemented by any instance of the Master Channel Multiplexing function that receives frames from any VC Multiplexing function instance used by a Forward Frame service instance.

I3.3.4 All Frames Generation Function

The All Frames Generation function of reference [8] optionally adds an FECF to the trailer of each frame if the function is configured to do so.

NOTE – As specified in the AOS Space Data Link Protocol specification (reference [8]), the All Frames Generation function is also 'used to insert Insert Service data units into the Transfer Frames of a Physical Channel'. However, as currently defined the AOS protocol prohibits the concurrent use of the Insert Service with entities (such as the Forward Frame service) that provide frames via the VC Frames service interface of the Virtual Channel Multiplexing function. It is possible that a future version of the AOS SDLP may remove the constraints that prohibit concurrent use of the Insert Service and Forward Frame service, but at this time the Insert Service is not addressed by this Recommended Standard.

I3.4 SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

NOTE – As of the publication of this Recommended Standard, the Synchronization and Channel Coding sublayer functions used to support fixed-length frames such as AOS and fixed-length USLP frames on the forward link are planned to be specified in a revised version of reference [10], which will recommend the use of Reed-Solomon and LDPC encoding for forward link frames, and LDPC coding of a stream of SMTFs (see 1.6.1.6 e)).

The functions of reference [10] that are relevant to the Forward Frame service are:

a) the choice between Reed-Solomon, LDPC encoding of individual frames, LDPC coding of a stream of SMTFs, or no encoding of individual transfer frames;

b) the (optional) Pseudo-Randomizer function; and

c) attachment of Attached Sync Marker.

Reference [10] specifies the permissible combinations of these synchronization and channel coding functions.

I4 TRANSFER FRAME CONFIGURATION FOR VARIABLE-LENGTH USLP FRAMES

I4.1 GENERAL

Figure I-3 depicts the functions that comprise the provision and production of the Forward Frame service when configured to support the transfer and radiation of variable-length USLP frames.

I4.2 FORWARD FRAME CSTS PROVIDER

The FF-CSTS Provider represents an instance of an entity that performs the functions that are specified in this Recommended Standard. In the Transfer Frame configuration, multiple instances of the FF-CSTS Provider may exist for one space link physical channel. Each FF-CSTS Provider supplies the frames from one virtual channel. In the variable-length USLP Frames configuration, the FF-CSTS Provider bit mask is configured to match data units for which the TFVN, SCID, and VCID fields in the first four octets of the USLP Transfer Frame Primary Header correspond to the GVCID of the virtual channel assigned to that transfer service instance.

I4.3 DATA LINK PROTOCOL SUBLAYER

I4.3.1 General

For the variable-length USLP Frames configuration, the Data Link Protocol Sublayer functions are defined in the *Unified Space Data Link Protocol* Recommended Standard (reference [9]). The functions of this sublayer that are relevant to the transfer of USLP Frames are the Virtual Channel Multiplexing Function, the Master Channel Multiplexing Functions, and the All Frames Generation Function.

I4.3.2 Virtual Channel Multiplexing Function

The Virtual Channel Multiplexing function of reference [7] multiplexes the Transfer Frames from one or more VCs with the same MCID into a single stream of Transfer Frames. The sources of these VCs can be multiple FF-CSTS service instances, VC frames generated by the USLP's Virtual Channel Generation Function (see reference [9]) and/or other VC-generating sources of externally-generated transfer frames input via the USLP's VC Frame Service (see reference [9]).

The specification of the Virtual Channel Multiplexing function in reference [9] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component VCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. Section G2.2.2 specifies three multiplexing schemes (absolute priority, polling, and FIFO) that must be implemented by any instance of the Virtual Channel Multiplexing function that receives its frames from an instance of the Forward Frame service.

I4.3.3 Master Channel Multiplexing Function

The Master Channel Multiplexing function of reference [9] multiplexes the Transfer Frames from one or more Master Channels into a single stream of Transfer Frames destined for the space Physical Channel. The sources of these Master Channels can be one or more Virtual Channel Multiplexing function instances and/or other VC-generating sources of externally-generated transfer frames input via the USLP's MC Frame Service (see reference [9]).

The specification of the Master Channel Multiplexing function in reference [9] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component MCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. Annex subsection G2.2.3 specifies three multiplexing schemes (absolute priority, polling, and FIFO) that must be implemented by any instance of the Master Channel Multiplexing function that receives frames from any VC Multiplexing function instance used by a Forward Frame service instance.

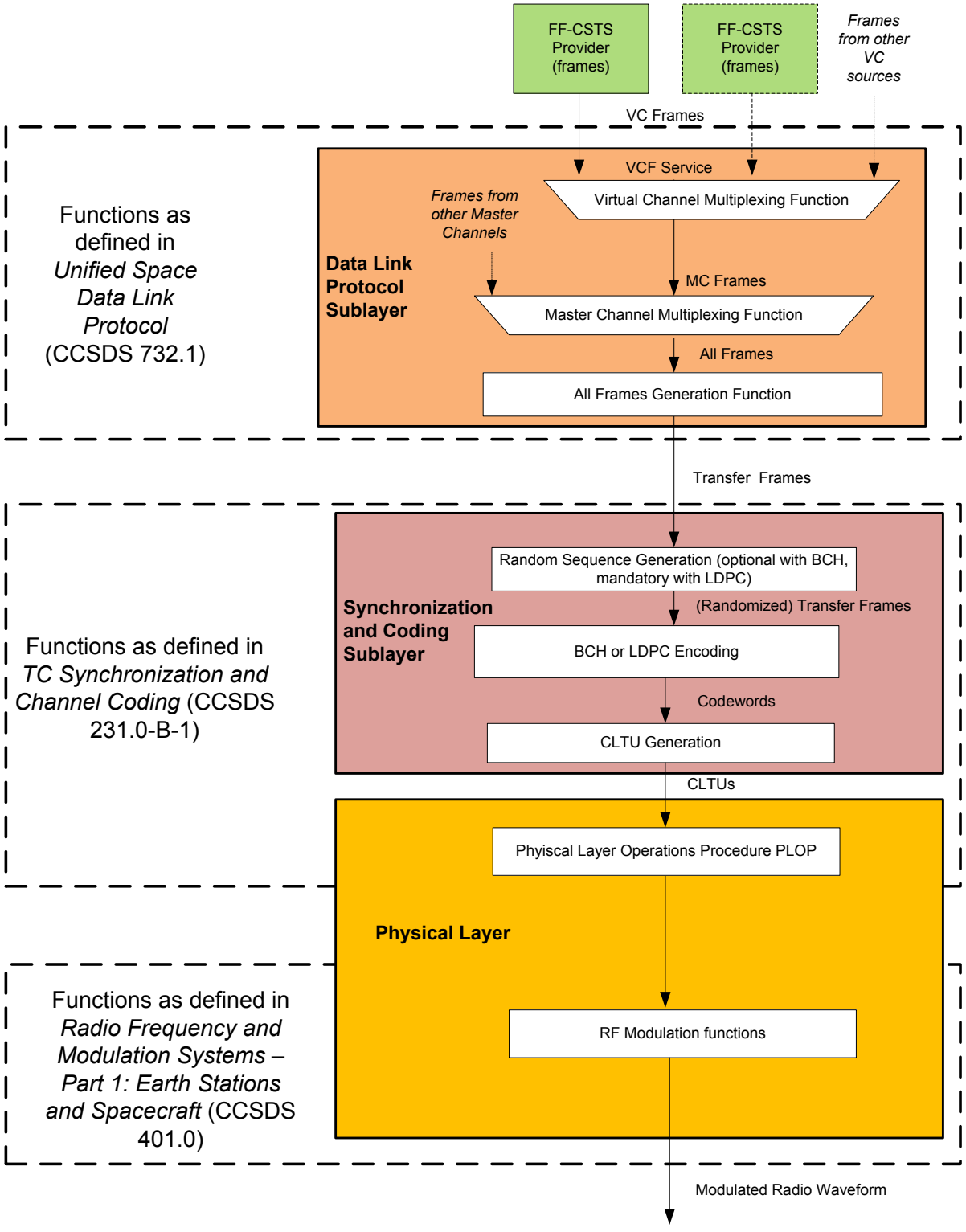


Figure I-3: Forward Frame Service—Transfer Frame Configuration—Variable-Length USLP Frames

I4.3.4 All Frames Generation Function

The All Frames Generation function of reference [9] optionally adds an FECF to the trailer of each frame. For USLP, only single Transfer Frames are submitted to the *TC Synchronization and Channel Coding* sublayer (see reference [11]) to be transformed into a single CLTU.

When being submitted to the underlying Synchronization and Channel Coding sublayer (I4.4), the same frame may be submitted multiple times. The number of times a frame is submitted is based on configuration parameters set by Service Management that specify how many times Sequence-Controlled (type AD) and COP Control Command (type BC) USLP frames for each virtual channel are to be repeated (Expedited [type BD] frames are not repeated) (see reference [9]).

NOTE – As specified in references [11] and [9], the Data Link Protocol Sublayer functions include the capability to cause the Synchronization and Channel Coding Sublayer (I2.4) to repeat AD and BC frames within CLTUs. The mechanism for accomplishing this is formally specified in references [11] as a 'data unit' consisting of a group of frames (for USLP this group is limited to a single frame) to be transmitted in a single CLTU, accompanied by a *Repetitions* parameter that specifies the number of times that the resultant CLTU is to be transmitted. The same effect on the space link can be accomplished by having the Data Link Protocol Sublayer submit the frame to the Synchronization and Channel Coding Sublayer *Repetitions* times. Having the frame submitted to the Sync and Channel Coding Sublayer *Repetitions* times is the way that the repetition capability is implemented for SLE Forward CLTU (reference [L4]) and Forward Space Packet (FSP - reference [L14]): for the F-CLTU service, the service user transfers the same (already formed) CLTU *Repetitions* times, and for the FSP service, the Data Link Protocol Sublayer forms and submits the group-of-frames data unit to the Synchronization and Channel Coding Sublayer *Repetitions* times (based on Service Management configuration parameters). For consistency with those SLE implementations and in recognition that Forward Frame service instances may share space links with FSP service instances, the description of the repetition capability in this informative annex is phrased in terms of the approach in which the Data Link Protocol Sublayer submits the USLP frame to the Synchronization and Channel Coding Sublayer *Repetitions* times.

I4.4 SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

For the variable-length USLP frames configuration, the Synchronization and Channel Coding sublayer functions are the same as those identified in I2.4.

I5 TRANSFER FRAME CONFIGURATION FOR FIXED-LENGTH USLP FRAMES

I5.1 GENERAL

Figure I-4 depicts the functions that comprise the provision and production of the Forward Frame service when configured to support the transfer and radiation of fixed-length frames.

I5.2 FORWARD FRAME CSTS PROVIDER

The FF-CSTS Provider represents an instance of an entity that performs the functions that are specified in this Recommended Standard. In the Transfer Frame configuration, multiple instances of the FF-CSTS Provider may exist for one space link physical channel. Each FF-CSTS Provider supplies the frames from one virtual channel. In the fixed-length USLP Frames configuration, the FF-CSTS Provider bit mask is configured to match data units for which the TFVN, SCID, and VCID fields in the first four octets of the USLP Transfer Frame Primary Header correspond to the GVCID of the virtual channel assigned to that transfer service instance.

I5.3 DATA LINK PROTOCOL SUBLAYER

I5.3.1 General

For the fixed-length USLP Frames configuration, the Data Link Protocol Sublayer functions are defined in the *Unified Space Data Link Protocol* Recommended Standard (reference [9]). The functions of this sublayer that are relevant to the transfer of USLP Frames are the Virtual Channel Multiplexing Function, the Master Channel Multiplexing Functions, and the All Frames Generation Function.

I5.3.2 Virtual Channel Multiplexing Function

The Virtual Channel Multiplexing function of reference [9] multiplexes the Transfer Frames from one or more VCs with the same MCID into a single stream of Transfer Frames. The sources of these VCs can be multiple FF-CSTS service instances, VC frames generated by the USLP's Virtual Channel Generation Function (see reference [9]) and/or other VC-generating sources of externally-generated transfer frames input via the USLP's VC Frame Service (see reference [9]).

The specification of the Virtual Channel Multiplexing function in reference [9] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component VCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. Section G2.2.2 specifies three multiplexing schemes (absolute priority, polling, and FIFO) that must be implemented by any instance of the Virtual Channel Multiplexing function that receives its frames from an instance of the Forward Frame service.

NOTE – The VC Multiplexing function defined in reference [9] also provides for generation of Only Idle Data frames in the absence of user-data-bearing Transfer Frames from any of the input VCs and when there is only a single MC on the

Physical Channel. However, for the purposes of this example configuration, it is assumed that the Only Idle Data frames are generated by the Master Channel Multiplexing function (see I5.3.3).

I5.3.3 Master Channel Multiplexing Function

The Master Channel Multiplexing function of reference [9] multiplexes the Transfer Frames from one or more Master Channels into a single stream of Transfer Frames destined for the space Physical Channel. The sources of these Master Channels can be one or more Virtual Channel Multiplexing function instances and/or other VC-generating sources of externally-generated transfer frames input via the USLP's MC Frame Service (see reference [9]).

The Master Channel Multiplexing function also generates Only Idle Data frames 'to preserve the continuity of the transmitted stream in the event that there are no valid Transfer Frames available for transmission at a release time' (4.2.8.4 of reference [9]).

The specification of the Master Channel Multiplexing function in reference [9] allows for the implementation of a multiplexing scheme that determines the order in which frames from the component MCs are multiplexed into the resulting master channel, but defers specification of the details of such a multiplexing scheme. Annex subsection G2.2.3 specifies three multiplexing schemes (absolute priority, polling, and FIFO) that must be implemented by any instance of the Master Channel Multiplexing function that receives frames from any VC Multiplexing function instance used by a Forward Frame service instance.

I5.3.4 All Frames Generation Function

The All Frames Generation function of reference [9] optionally adds an FECF to the trailer of each frame if the function is configured to do so.

NOTE – As specified in the Unified Space Data Link Protocol specification (reference [9]), the All Frames Generation function is also 'used to insert Insert Service data units into the Transfer Frames of a Physical Channel'. However, as currently defined USLP puts constraints on entities (such as the Forward Frame service) that provide frames via the VC Frames service interface of the Virtual Channel Multiplexing function. These constraints make the concurrent use of the Insert Service with Forward Frame service impractical. It is possible that a future version of USLP may remove the constraints that prohibit concurrent use of the Insert Service and Forward Frame service, but at this time the Insert Service is not addressed by this Recommended Standard.

The insertion of Insert Service data units is optional, and its use is outside the scope of the Forward Frame service. However, if the Insert Service is used on a given Physical Channel, the users of all Forward Frame service instances associated with that Physical Channel must generate their transfer frames with empty Insert Zones corresponding to the size of the Insert Service data units. The presence or absence of the Insert Zones, and their size if present, are coordinated through Service Management.

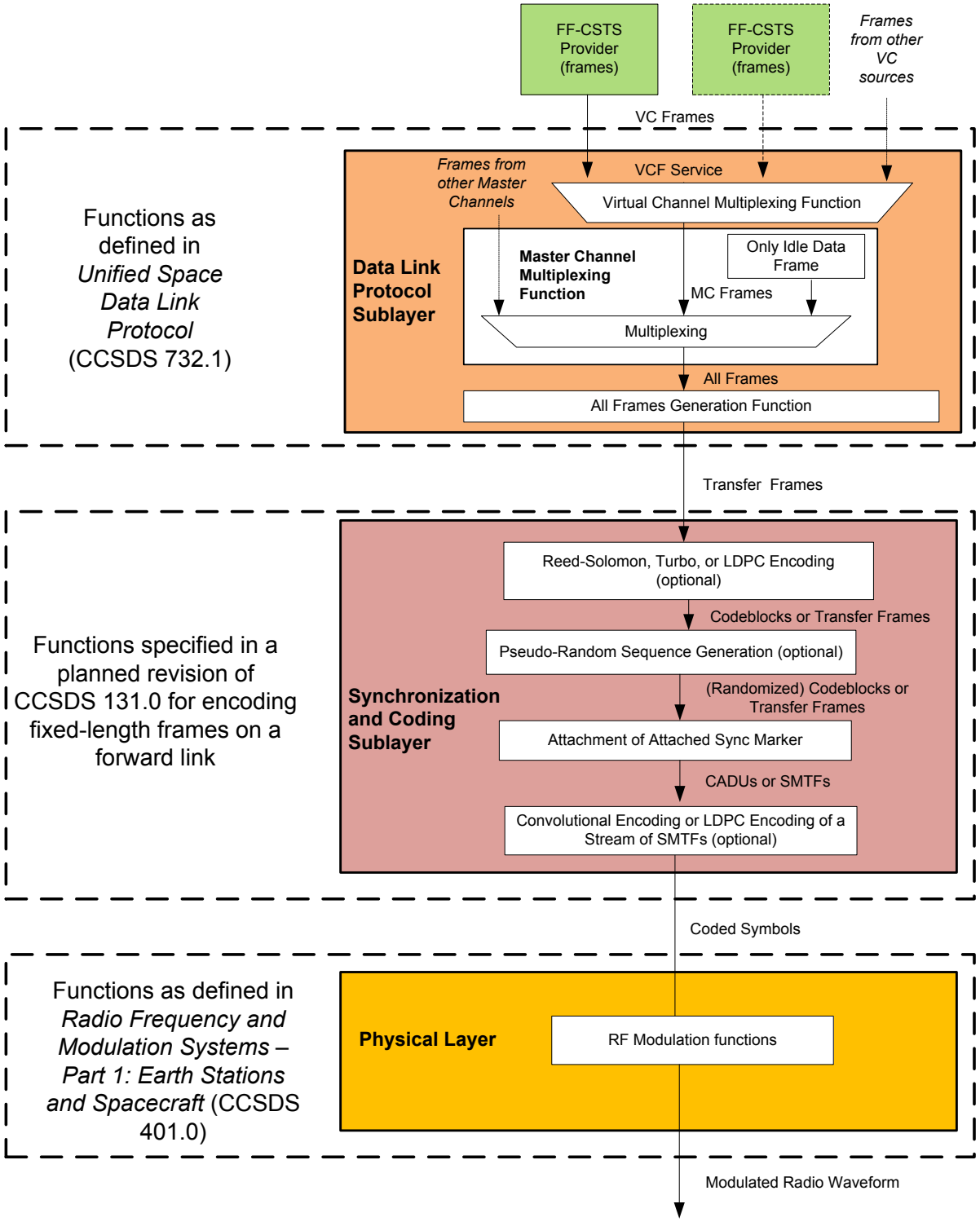


Figure I-4: Forward Frame Service—Transfer Frame Configuration—Fixed-Length USLP Frames

I5.4 SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

For the fixed-length USLP frames configuration, the Synchronization and Channel Coding sublayer functions are the same as those identified in I3.4.

I6 CADU CONFIGURATION

I6.1 GENERAL

The CADU configuration is used when the Forward Frame service user generates and transfers to the ESLT CADUs, which are fixed-length data units that are continuously and contiguously into the forward link. The CADU configuration supports the transfer and transmission of CADUs bearing AOS or USLP fixed-length frames.

The processing functions performed by the ESLT in the CADU configuration are:

a) Multiplexing of Only Idle Data CADUs into the stream of user-supplied CADUs to preserve the continuity of the transmitted stream in the event that there are no valid CADUs available for transmission at a release time;

b) RF modulation and radiation of the signal.

The nominal use case for the CADU configuration is it's use by rudimentary ESLTs that do not perform CCSDS space link protocol functions or any CCSDS frame coding, randomization, or synchronization marker attachment functions. However, the CADU configuration can also be used by missions that use mission-specific frame protocols and/or coding schemes for their frames, which result in fixed-length data units that must be transmitted continuously and contiguously.

The CADU configuration does not accommodate the AOS or USLP Insert Service because any encoding of the frames enclosed by the CADUs must include the data in the Insert Zones, but with the Insert Service this data is not put into Insert Zones until after the frames have been encoded.

Figure I-5 depicts the functions that comprise the provision and production of the Forward Frame service when configured to support the transfer and radiation of CADUs. These functions correspond to the operational scenario described in 2.5.4.

I6.2 FORWARD FRAME CSTS PROVIDER

The FF-CSTS Provider represents an instance of an entity that performs the functions that are specified in this Recommended Standard. In the CADU configuration, only one instance of the FF-CSTS Provider may exist for one space link physical channel. In the CADU configuration, the FF-CSTS Provider bit mask is configured to match data units for which the first four octets of the CADU correspond to the first four octets of the Attached Sync Marker of the frame synchronization scheme used on the physical channel.

I6.3 SYNCHRONIZATION AND CHANNEL CODING SUBLAYER

I6.3.1 General

For the CADU configuration, the Synchronization and Channel Coding Sublayer consists of the Only Idle Data CADU Generation and Multiplexing and the Symbol Stream Generation functions.

I6.3.2 Only Idle Data CADU Generation and Multiplexing Function

The Only Idle Data CADU Generation and Multiplexing function (defined in G3.2.1) does not map directly to any function of a CCSDS Recommended Standard for the processing of fixed-length transfer frames. It is a function that must necessarily be performed in support of the Forward Frame service operating in the CADU configuration. In the CADU configuration, there is no multiplexing of virtual channels or master channels, and so the Only Idle Data Frame generation functions that are performed as part of those multiplexing functions in CCSDS fixed-frame SDLPs are not available for the stream of CADUs that bypass those SDLP multiplexing functions. The Only Idle Data CADU Generation and Multiplexing function preserves the continuity of the transmitted stream in the even that there are no valid CADUs available for transmission at release time. The resulting waveform is therefore conformant with that generated by a system that performs the appropriate CCSDS-standard SDLP (AOS or USLP for fixed-length frames) over the CCSDS-standard Synchronization and Channel Coding functions for fixed-length frames.

The Only Idle Data CADU Generation and Multiplexing function is categorized as a Synchronization and Channel Coding function because its purpose is to maintain the synchronization of the forward link in the absence of valid user-data-bearing CADUs.

I6.3.3 Symbol Stream Generation Function

For AOS and fixed-length USLP frames, the requirement to generate the resulting contiguous stream of coded symbols is specified in the *TM Synchronization and Channel Coding* Recommended Standard (reference [10]).

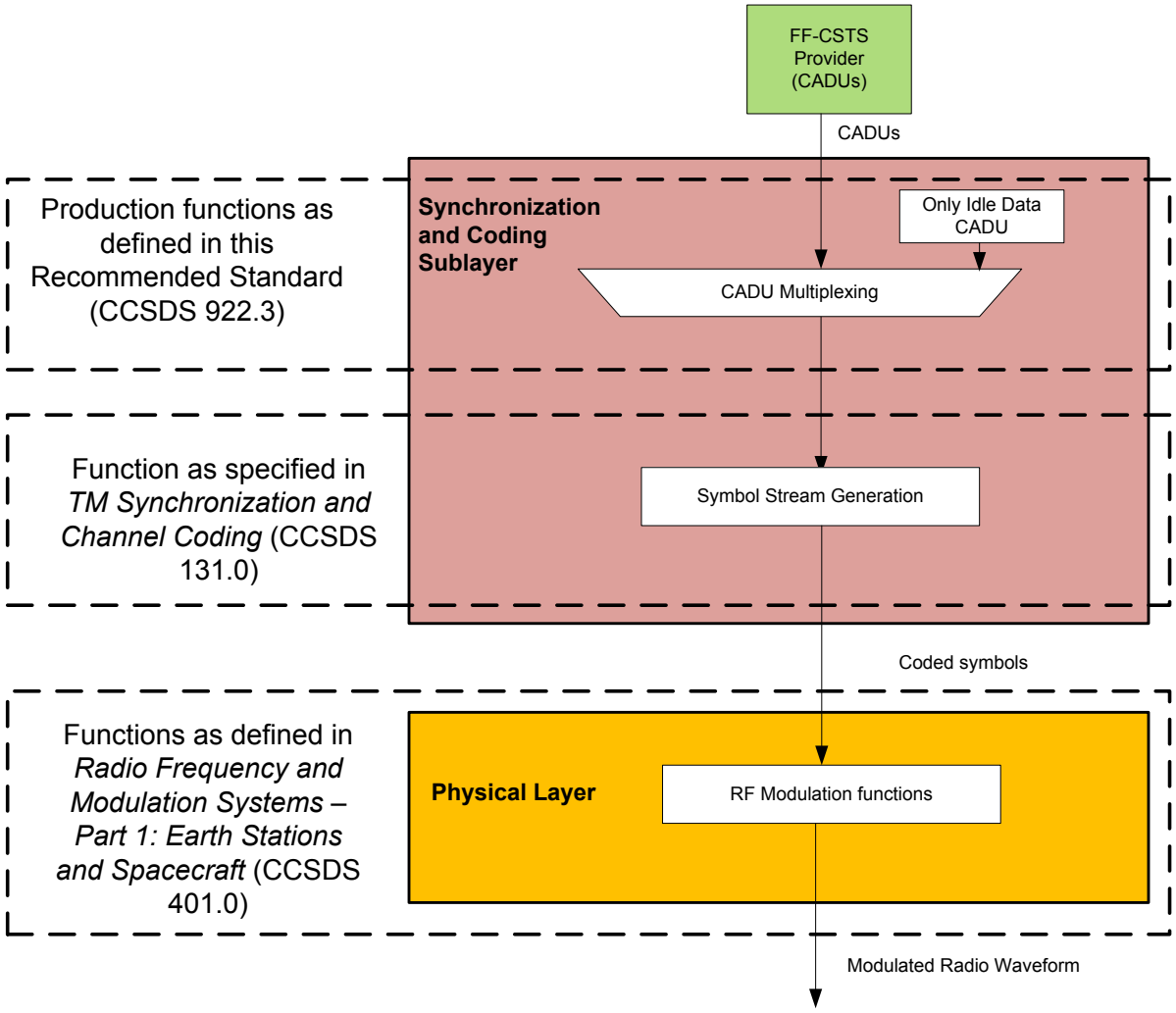


Figure I-5: Forward Frame Service—CADU Configuration

ANNEX J

EXAMPLE EXTENDED USE CASES FOR THE FORWARD FRAME SERVICE

(INFORMATIVE)

J1 GENERAL

The Forward Frame service formally defined to support the transfer of TC Transfer Frames, AOS Transfer Frames, USLP Transfer Frames (both fixed and variable length), and CADUs. However, the Forward Frame service itself does not concern itself with the contents of the data units being transferred beyond two minimal criteria:

a) That the bits of the first four octets of the data unit that correspond to the subfields defined by the `gvcid-bit-mask` parameter, match the corresponding bits of the `authorized-gvcid` parameter.

b) That the data unit be no smaller than the size specified by the `minimum-frame-length` parameter, and no larger than the size specified by the `maximum-frame-length` parameter. The sizes permitted by these parameters range from one to 4294967295.

As defined for use with the CCSDS protocols listed above, the subfields in `gvcid-bit-mask` correspond to the TFVN, SCID, and VCID subfields of the respective Transfer Frame Primary Headers. The Forward Frame service uses these parameters to ensure that only the frames for the VC that a Forward Frame service instance is authorized to transfer are processed by that service instance. But the subfields can be made to specify any subfields of those four octets, including none at all. In fact, for the CADU configuration, both the `gvcid-bit-mask` parameter and the `authorized-gvcid` parameter are set to all zeroes, which are the 'don't care' values that bypass header checking altogether.

In addition to the flexibility provided by the Forward Frame service provision itself, the service places almost no requirements (other than those specified in annex G) on the underlying space data link protocols, synchronization and coding schemes, and physical channel. This allows the Forward Frame service to be potentially useful in space communication configurations beyond those for which the service was explicitly developed. For example, in addition to the use of TM Sync and Channel Coding to encode fixed length AOS and USLP frames on the forward link as described in I3 and I5, as of the publication of this Recommended Standard, CCSDS is planning to allow the use of Serially Concatenated Convolutional (Turbo) Code (SCCC, reference [L11]) and CCSDS Space Link Protocols over DVB-S2 (reference [L22]) on the forward link. When SCCC and DVB-S2 become available for use on the forward link, they will effectively be applicable to the Forward Frame service, and a future version of this Recommended Standard may add them as normative options for the Synchronization and Channel Coding sublayer and Physical Layer.

The following subsections briefly identify a few examples of such space communication configurations. This set of example extended use cases is not exhaustive: other extended use cases can be formulated that combine various aspects of these examples. Of course, in each of these extended use case examples, the differences in the configurations of the underlying production processes would have to be supported by the capabilities of the ESLT and the ability of Service Management to address such configurations.

J2 SUPPORT FOR TRANSFER OF A MASTER CHANNEL

In the Transfer Frame configuration, the definition of the Forward Frame service limits each service instance to a single Virtual Channel. However, there may be situations in which it is desirable to transfer a full Master Channel. Such possible uses cases could include large, multi-component, multi-Agency spacecraft for which each component has its own MC supplied by its own Control Center, or a relay satellite in which the satellite uses its own MC for its operations and supports one or more other MCs for the end-point Space User Nodes (e.g., rovers).

The Forward Frame service can be configured to support transfer of a full MC by configuring the `gvcid-bit-mask` and `authorized-gvcid` parameters to operate on only the TFVN and SCID fields (i.e., set the VCID field bits of each to all zeroes).

Depending on the implementation of an ESLT capable of supporting this extended use case, the associated production processes would have to allow either a single VC Multiplexing function instance to receive multiple VCs for the same MC through a single service interface, or allow the data flow to bypass the VC Multiplexing functions and interface directly to a Master Channel Multiplexing function instance via the MC Frames service interface.

J3 SUPPORT FOR TRANSFER OF SYSTEMATIC-ENCODED CCSDS-COMPLIANT TRANSFER FRAMES

Some ESLTs may support multiplexing of CCSDS-compliant transfer frames but not perform the frame level error correction coding. When the applicable error correction coding is systematic and therefore leaves the Transfer Frame Primary Header undisturbed, such as in the case of CCSDS-compliant Reed-Solomon and LDPC frame encoding, the frame encoding can be performed in the Earth User Node prior to transfer of the coded frame via the Forward Frame service. In this extended use case, the same `gvcid-bit-mask` and `authorized-gvcid` parameter settings for the fixed-length frame SDLP (e.g., AOS or USLP) can be used for both uncoded and already-encoded frames because the TFVN, SCID, and VCID subfields appear in the same positions of the first four octets of the data unit that is transferred.

ESLTs that do not perform frame-level error correction encoding may still optionally randomize the already-encoded frames and attach the ASMs to form the resulting stream of CADUs.

ESLTs that do perform the full set of fixed-length frame synchronization and channel coding functions (including, for this example, Reed-Solomon encoding) can accommodate user missions that transfer already-encoded simply be configuring (via Service Management) the production processing the treat the frames as uncoded frames, thereby bypassing the frame encoding function of the ESLT.

J4 SUPPORT FOR NON-CCSDS-COMPLIANT SPACE DATA LINK TRANSFER OF NON-CCSDS-COMPLIANT CADUS

Some missions may use non-CCSDS-compliant SDLPs and/or non-CCSDS-compliant sync and coding schemes to produce fixed-length data units that must be continuously and contiguously transmitted on the space link. If these non-CCSDS-compliant SDLPs also define their own fixed-pattern Only Idle Data frames, then the Forward Frame service can be used to support such protocols in the CADU configuration.

This extended use case can be supported by any ESLT that supports the CADU configuration by configuring the Only Idle Data CADU parameter (see G3.2.2) of the Only Idle Data CADU Generation and Multiplexing function to contain the Only Idle Data frame of the SDLP with the corresponding synchronization and channel coding transformations.

J5 TRANSFER OF SYNC-MARKED TRANSFER FRAMES

When a mission uses LDPC coding of a stream of SMTFs (see reference [10] and 1.6.1.6 e)), the CADU configuration cannot be used to transfer CADUs because there is no fixed-pattern Only Idle Data CADU that can be configured for the Only Idle Data CADU Generation and Multiplexing function.

However, LDPC coding of a stream of SMTFs can be supported by the Forward Frame service by a hybrid of the fixed-frame synchronization and channel coding functions of the fixed-length frame Transfer Frame configurations (see I3 and I5) and the CADU configuration (see I6). Specifically, a single Forward Frame service instance is configured to supply SMTFs to the LDPC Coding of a Stream of SMTFs function, as illustrated in figure J-1. The Only Idle Data CADU configuration parameter is populated with an Only Idle Data SMTF; that is, an Only Idle Data Transfer Frame of the appropriate SDLP, with an ASM attached. As shown in the figure, the frame-level encoding functions, pseudo-random sequence generation, and ASM attachment functions are bypassed in this configuration.

Support for this extended configuration requires that the ESLT have the capabilities to perform this combination of functions and the ability of Service Management to support the configuration.

When used to support missions that use CCSDS-compliant space data link protocols and LDPC encoding of SMTF streams, this extended configuration produces waveforms that are fully CCSDS-compliant. However, this extended configuration can also support missions for which either or both the transfer frame format or the sync marker format are not CCSDS-compliant; that is, only the LDPC slicing function that is performed by the ESLT is CCSDS-compliant.

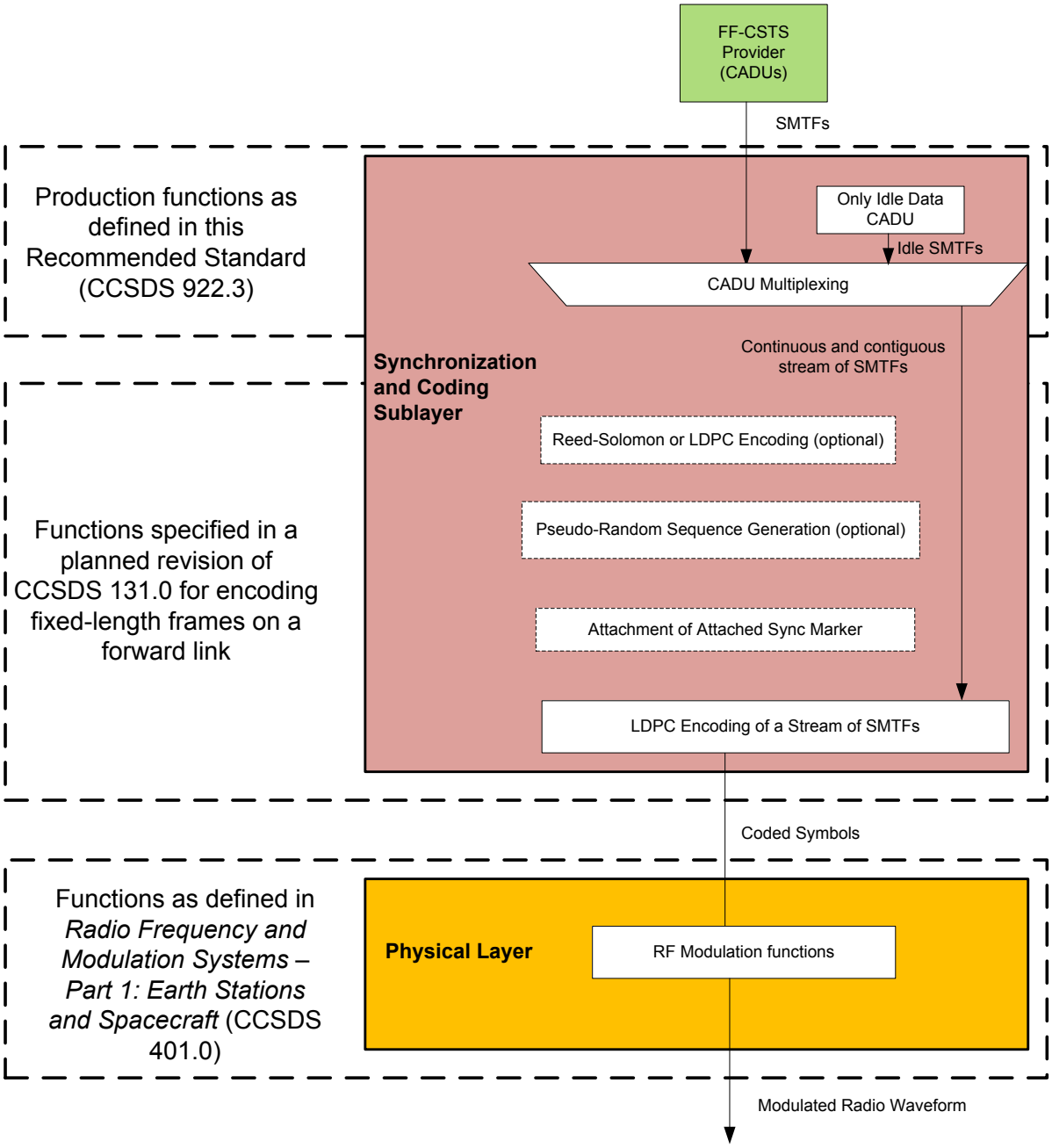


Figure J-1: Forward Frame Service—Extended CADU Configuration—SMTFs

ANNEX K

USING THE FORWARD FRAME SERVICE TO SHARE ACCESS TO A FORWARD LINK WITH DTN BUNDLES

(INFORMATIVE)

As illustrated in annexes I and J, the Forward Frame service can be used to allow multiple sources of virtual channel frames to deliver those frames to an ESLT for multiplexing into a single forward link, as illustrated by the nominal and extended use case examples described in annex I and annex J. However, sharing of the same forward space link is not limited to only the use of multiple instances of the Forward Frame service. The ESLT may receive data destined for the shared space link in forms other than VC transfer frames, and the ESLT can embed that data into VCs that are then multiplexed with the VCs carried by Forward Frame service instances.

One such link-sharing scenario involves the case in which DTN (reference [L17]) *bundles* are transferred across the Internet to be multiplexed with Forward Frame-transferred transfer frames into a forward space link. This approach is recommended by the Interagency Operations Advisory Group (IOAG - reference [L20]) as a strategy for introducing DTN networking into communications with mission spacecraft, especially via an intermediate relay spacecraft. This use case assumes that relay missions that are service providers of DTN will want to separate use of DTN data for relay through the spacecraft, or for their own local DTN data destined for onboard payloads, but continue to use traditional CCSDS space link protocols for exchange of the relay spacecraft operational data (e.g., commands and telemetry). Virtual channel transfer frames are the lowest-level space data link protocol data units that can be transferred via the ESLT while still supporting multiplexing with DTN traffic. In this use case, transfer frames destined for the relay spacecraft operations functions would be delivered to the ESLT using FF-CSTS. DTN traffic destined for any DTN node, including any DTN nodes on board the relay spacecraft, would use the forward link shared access capability. This annex describes two examples of the protocol and service entities that would be performed by the ESLT when configured to support the DTN use case.

Figure K-1 illustrates the first example, and is an adaptation of figure 7-5 from the *Space Communications Cross Support - Architecture Description Document* (reference [L8]) that has been modified to show the multiplexing of the VCs in the ESLT in greater detail. This first example involves a single Earth User Node belonging to Agency ‘A’ communicating with a single Space User Node belonging to the same Agency through an ESLT operated by Agency ‘B’, in what is referred to as the ‘ABA’ configuration. The key feature of this example is that the Earth User Node simultaneously transfers DTN bundles and Earth User Node-generated VC transfer frames to the ESLT for transmission to the Space User Node over the same space data link. The particular example that is illustrated in the diagram shows the use of DTN to transfer files across the space link using CCSDS File Delivery Protocol (CFDP – reference [L18]) over the DTN bundle protocol (BP). From the perspective of the ESLT, the content of the DTN bundles is immaterial. Additional details of this configuration can be found in reference [L8].

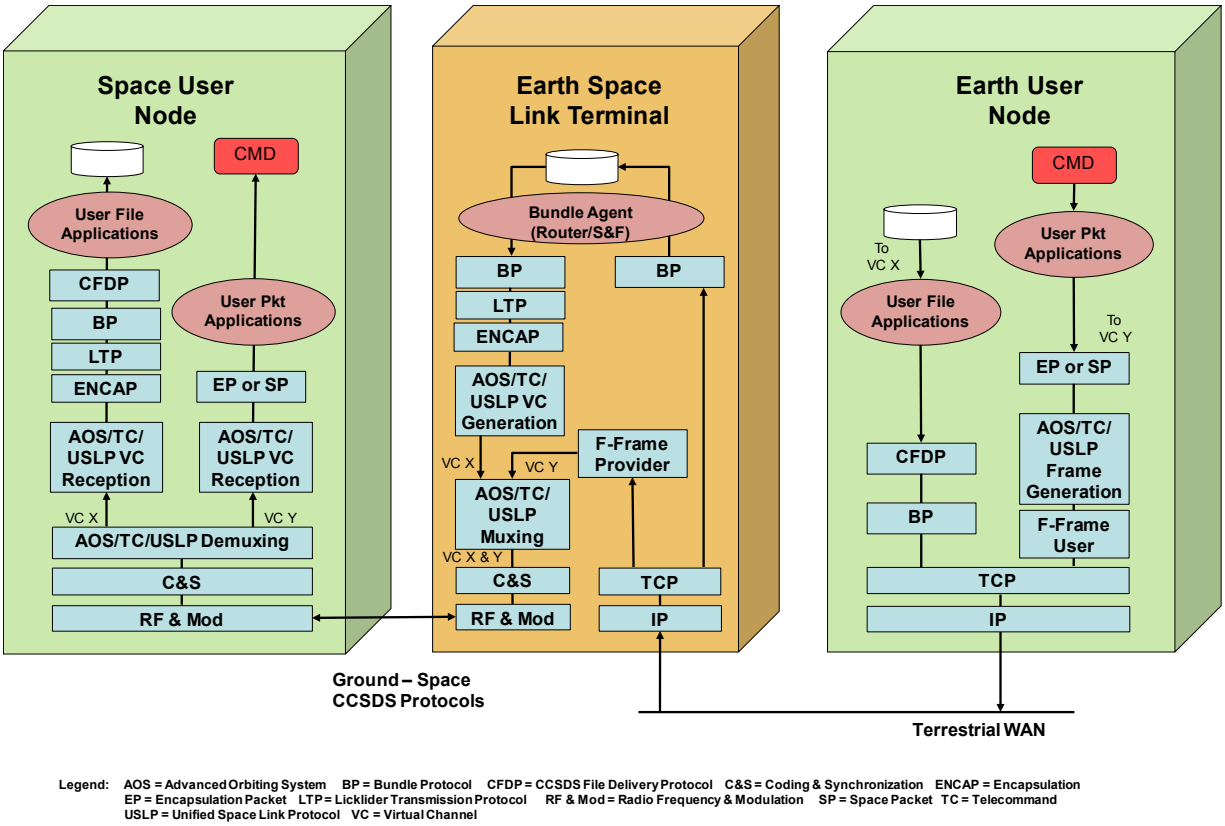
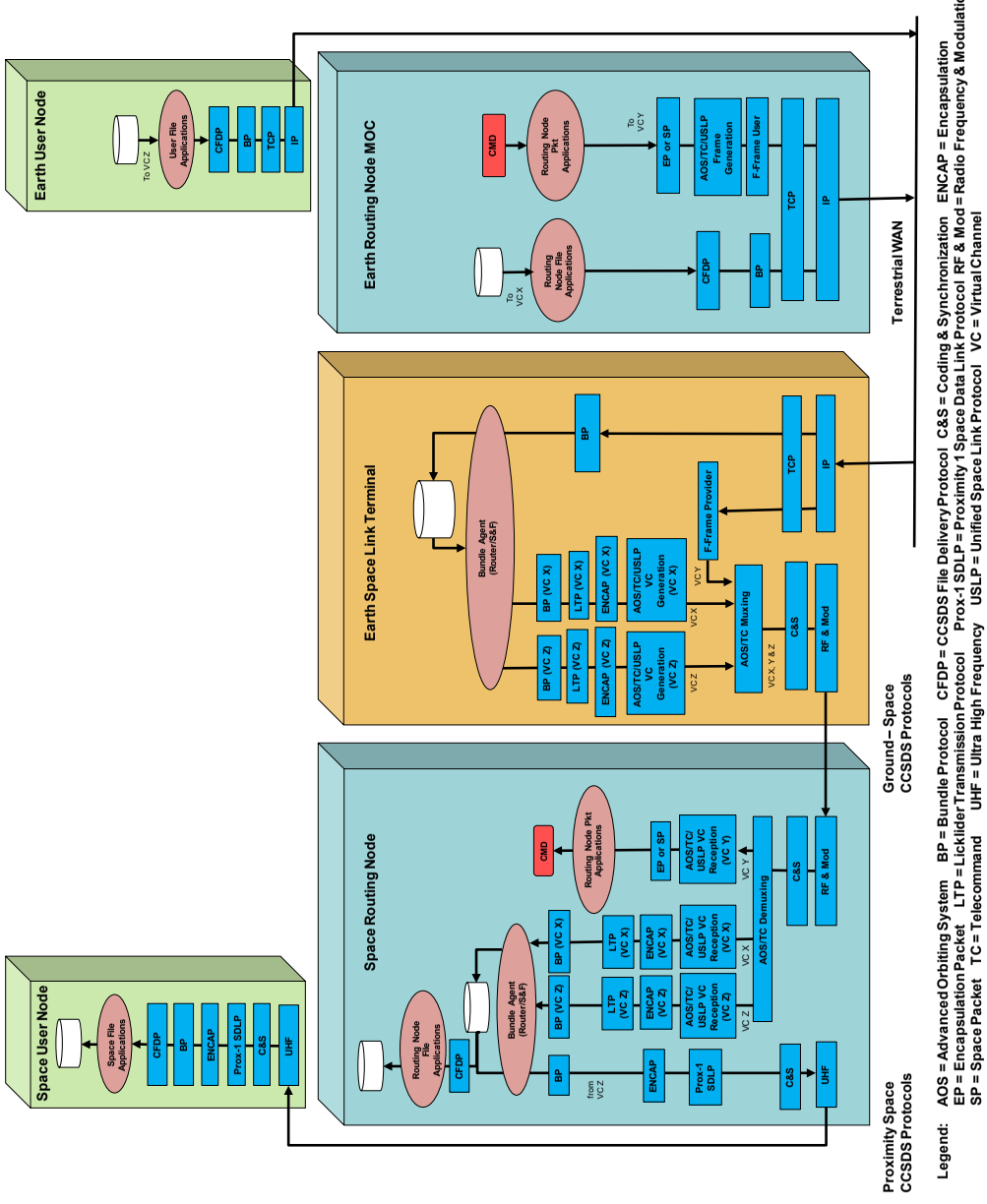


Figure K-1: DTN ABA Architecture

Figure K-2 illustrates the second example addressed in this annex. The figure is an adaptation of figure 7-2 from the *Space Communications Cross Support - Architecture Requirements Document* (reference [L16]) that has been modified to show the multiplexing and demultiplexing of the VCs in greater detail. In this example, DTN protocols are used by an Earth User Node to send CFDP-segmented files through the ESLT to a Space Routing Node (e.g., a relay satellite) that relays the Earth-User Node-generated bundles to their ultimate destination, the Space User Node. The Space Routing Node in this example uses DTN for some file-related applications but uses traditional CCSDS space data link protocols for communication of spacecraft operations data. As in the first example, the Forward Frame CSTS instance in the ESLT provides the means for the Space Routing Node MOC to supply the Space Routing Node command-bearing transfer frames to be received by the ESLT for multiplexing into the space link with the DTN traffic destined for both the Space Routing Node and the Space User Node. Additional details of this configuration can be found in reference [L16].



Legend: AOS = Advanced Orbiting System BP = Bundle Protocol CFDP = CCSDS File Delivery Protocol C&S = Coding & Synchronization ENCAP = Encapsulation
EP = Encapsulation Packet LTP = Licklider Transmission Protocol Prox-1 SDLP = Proximity 1 Space Data Link Protocol RF & Mod = Radio Frequency & Modulation
SP = Space Packet TC = Telecommand UHF = Ultra High Frequency USLP = Unified Space Link Protocol VC = Virtual Channel

Figure K-2: DTN Relay Satellite Architecture

There are other possible DTN configurations, for example, one in which the space link between the Space Routing Node and the Space User Node uses a 'long haul' space data link protocol (TC, AOS, or USLP) instead of Prox-1. With respect to the Forward Frame service, the common characteristic is that the ESLT is able to combine DTN traffic and User-generated transfer frames into the single forward space link physical channel.

Figure K-3 shows the integration of DTN into the space link protocol stack for the transfer frame configuration for variable-length USLP frames that is described in I4. This protocol stack corresponds to the left-hand side protocol stack of the ESLT in figures K-1 and K-2, and identifies the specific CCSDS Recommended Standards that apply at each layer.

NOTE – Multiplexing of IP datagrams (instead of DTN bundles) into a shared forward link would be achieved by a comparable protocol stack that substitutes the Internet Protocol Extension function defined in the *IP over CCSDS Space Links* Recommended Standard (reference [L19]) for the Bundle Protocol Agent, BP, and LTP layers in figure K-3.

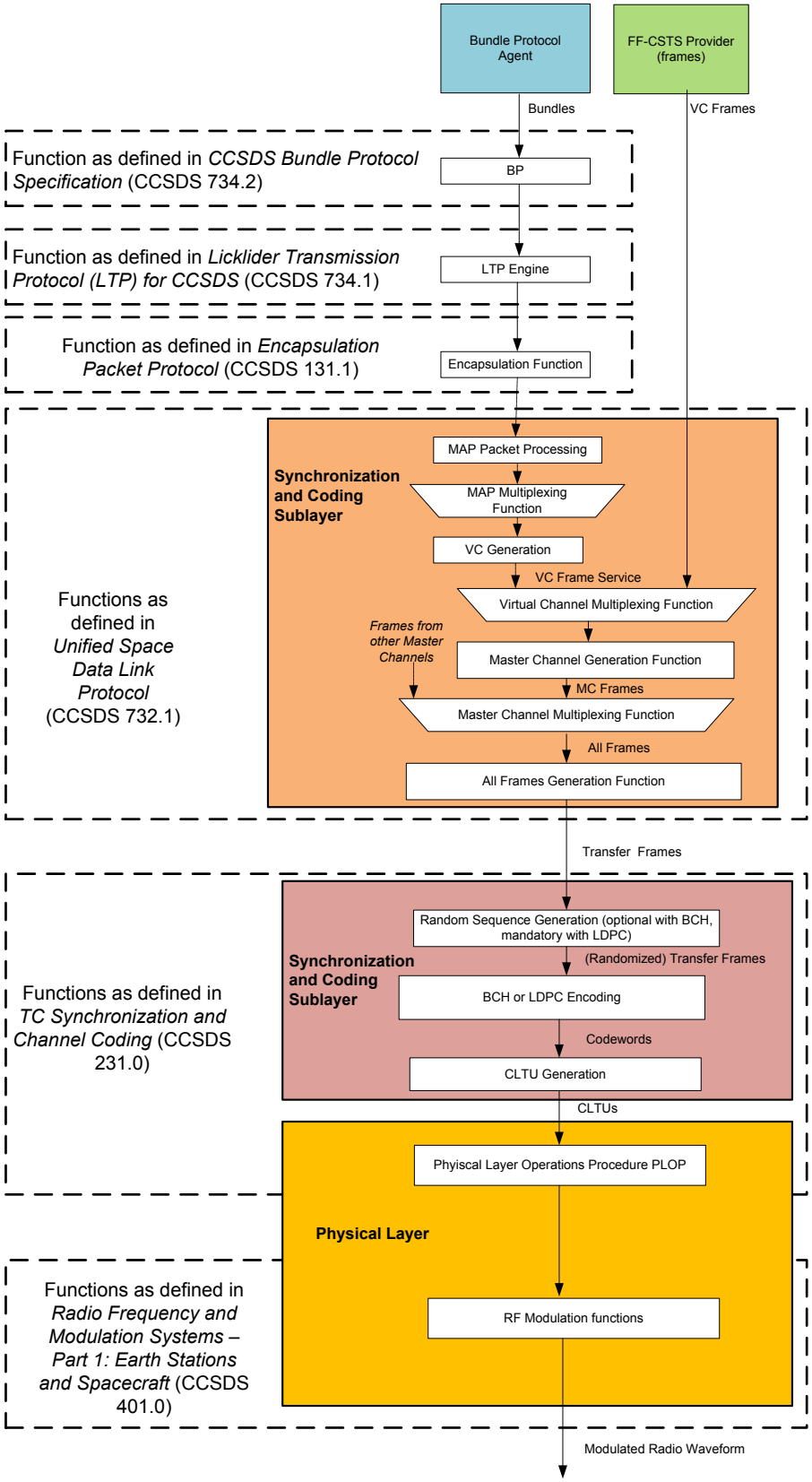


Figure K-3: DTN and Forward Frame over Variable-Length-Frame USLP

ANNEX L

INFORMATIVE REFERENCES

(INFORMATIVE)

[L1] *Cross Support Concept—Part 1: Space Link Extension Services*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 910.3-G-3. Washington, D.C.: CCSDS, March 2006.

[L2] *Space Link Extension—Internet Protocol for Transfer Services*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 913.1-B-2. Washington, D.C.: CCSDS, September 2015.

[L3] *Cross Support Transfer Service Specification Framework Concept*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 920.0-G-1. Washington, D.C.: CCSDS, forthcoming.

[L4] *Space Link Extension—Forward CLTU Service Specification*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 912.1-B-4. Washington, D.C.: CCSDS, August 2016.

[L5] *Cross Support Service Management—Service Management Utilization Request Formats*. Recommendation for Space Data System Standards, under development.

[L6] *Cross Support Service Management—Simple Schedule Format Specification*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 902.1-B-1. Washington, D.C.: CCSDS, May 2018.

[L7] *Extensible Space Communication Cross Support—Service Management—Concept*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 902.0-G-1. Washington, D.C.: CCSDS, September 2014.

[L8] *Space Communications Cross Support—Architecture Description Document*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 901.0-G-1. Washington, D.C.: CCSDS, November 2013.

[L9] *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft*. Issue 31. Recommendations for Space Data System Standards (Blue Book), CCSDS 401.0-B-31. Washington, D.C.: CCSDS, February 2021.

[L10] *Data Transmission and PN Ranging for 2 GHz CDMA Link via Data Relay Satellite*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 415.1-B-1. Washington, D.C.: CCSDS, September 2011.

[L11] *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.

[L12] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[L13] K. McCloghrie and M. Rose, eds. *Management Information Base for Network Management of TCP/IP-Based Internets: MIB-II*. STD 17 (RFC 1213). Reston, Virginia: ISOC, March 1991.

[L14] *Space Link Extension—Forward Space Packet Service Specification*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 912.3-B-3. Washington, D.C.: CCSDS, August 2016.

[L15] *Space Data Link Security Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 355.0-B-1. Washington, D.C.: CCSDS, September 2015.

[L16] *Space Communications Cross Support—Architecture Requirements Document*. Issue 1. Recommendation for Space Data System Practices (Magenta Book), CCSDS 901.1-M-1. Washington, D.C.: CCSDS, May 2015.

[L17] *Rationale, Scenarios, and Requirements for DTN in Space.* Issue 1. Report Concerning Space Data Systems (Green Book), CCSDS 734.0-G-1. Washington, D.C.: CCSDS, August 2010.

[L18] *CCSDS File Delivery Protocol (CFDP)*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 727.0-B-5. Washington, D.C.: CCSDS, July 2020.

[L19] *IP over CCSDS Space Links*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 702.1-B-1. Washington, D.C.: CCSDS, September 2012.

[L20] *Operations Concept for a Solar System Internetwork (SSI).* Report of the Interagency Operations Advisory Group Space Internetworking Strategy Group, IOAG.T.RC.001.V1. Washington, DC: IOAG, October 15, 2010.

[L21] *Space Data Link Security Protocol - Extended Procedures*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 355.1-B-1. Washington, D.C.: CCSDS, February 2020.

[L22] *Digital Video Broadcasting (DVB); Second Generation Framing Structure, Channel Coding and Modulation Systems for Broadcasting, Interactive Services, News Gathering and other Broadband Satellite Applications*. ETSI EN 302 307 V1.2.1 (2009-08). Sophia-Antipolis: ETSI, 2009.

ANNEX M

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

Term	Meaning
AOS	Advanced Orbiting System
ASM	attached synchronization marker
ASN.1	Abstract Syntax Notation One
BCH	Bose–Chaudhuri–Hocquenghem
BFDP	buffered frame data processing [procedure]
CADU	channel access data unit
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
CLCW	communications link control word
CLTU	communication link transmission unit
COP	Communications Operation Procedure
CSSS	Cross Support Service System
CSTS	Cross Support Transfer Service
DTN	Delay-Tolerant Network
DVB-S2	Digital Video Broadcasting—Second Generation
EM	element management
ESLT	earth space link terminal
FECF	frame error control field
FF	Forward Frame [CSTS]
FIFO	first-in-first-out
FR	functional resource
GVCID	global virtual channel identifier
ICS	implementation conformance statement
IOAG	Interagency Operations Advisory Group
IP	Internet Protocol
ISO	International Organization for Standardization
LDPC	low density parity check
MC	master channel
MCID	master channel identifier
MIB	management information base
MUE	mission user entity

Term	Meaning
OID	object identifier
PICS	protocol implementation conformance statement
PDU	protocol data unit
PLOP	Physical Layer operations procedure
PM	provision management
Prox-1	Proximity-1 (space data link protocol)
RF	radio frequency
RL	requirements list
SANA	Space Assigned Numbers Authority
SCCC	Serially Concatenated Convolutional (Turbo) Codes
SC-CSTS	service control CSTS
SCFDP	sequence-controlled frame data processing [procedure]
SCID	spacecraft identifier
SDLP	space data link protocol
SDLS	space data link security
SFW	[CSTS] Specification Framework
SLE	Space Link Extension
SL-PDU	space link protocol data unit
SMTF	Sync-Marked Transfer Frame
SNMP	Simple Network Management Protocol
Sync	synchronization
TC	telecommand
TCP	transmission control protocol
TFVN	Transfer Frame Version Number
TM	telemetry
UM	utilization management
USLP	Unified Space Data Link Protocol
VC	virtual channel
VCID	virtual channel identifier

ANNEX N

CROSS REFERENCES TO CROSS SUPPORT TRANSFER SERVICE SPECIFICATION FRAMEWORK

(INFORMATIVE)

Table N-1 lists the specific sections, subsections, paragraphs, and tables of the CSTS SFW (reference [1]) that are normatively referenced by this Recommended Standard, and identifies the sections, subsections, paragraphs, and tables of this Recommended Standard that make specific references to each of those sections/paragraphs in reference [1].

Table N-1: Cross References to CSTS Specification Framework Subsections

Referenced CSTS SFW Section/Subsection/ Paragraph/Table	Referencing Section/Subsection/Paragraph/Table of this Recommended Standard
1.6.3.1	1.5.2 f)
2.2	1.5.2 f)
2.2.2.2	8.3
3.2.1.2	8.2
3.2.3.6	table 4-6, table 5-6
3.2.4	H1.3.3
3.3.2.7	C1 (4 references), D1 (2 references), E1 (2 references)
3.3.2.7.1	table 4-7, table 5-7
3.3.2.7.1 c)	9.2
3.4.2.2.4.3	7.2.4
3.7.2.3.1	table 4-7, table 5-7
3.11.2.2.3.2 a)	8.4
3.11.2.2.3.2 b)	table 4-6, table 5-6, 8.5
3.13.1.1	6.3
4.2.2.3	table 4-8, table 5-9
4.2.2.4	table 4-6, table 5-6
4.2.2.5	table 4-6, table 4-8, table 5-6, table 5-9
4.2.3	table 4-6, table 5-6
4.3	table 3-1, table 3-2, table A-5
4.3.5	7.2.1, 7.2.2, 7.2.3, 7.2.4
4.6	table A-5
4.6.3.1 a)	table 4-7, table 5-7
4.6.3.2.3	table 4-3, table 5-3
4.6.3.3.1	table 5-6
4.6.3.3.6	table 4-8, table 5-9
4.6.3.5.1.1	table 4-8, table 5-9

Referenced CSTS SFW Section/Subsection/ Paragraph/Table	**Referencing Section/Subsection/Paragraph/Table of this Recommended Standard**
4.6.3.5.2	table 4-8, table 5-9
4.6.3.5.3	table 4-8, table 5-9
4.6.3.6.2 a)	table 4-8, table 5-9
4.6.3.6.2 b)	table 4-8, table 5-9
4.6.3.7	table 4-8, table 5-9
4.6.4.1.4	4.5.5 b), 5.5.5 b), table 4-7, table 5-7
4.6.4.2.3	5.6.7.2.1.1 a), A2.2 AV29
4.6.4.2.3 a)	table 4-8, table 5-9
4.6.4.2.3 b)	table 4-8, table 5-9
4.6.4.2.3 c)	table 4-6, table 4-8, table 5-9
4.6.7	G2.2.2.3, G2.2.2.6, G2.2.3.3, G2.2.3.6, G2.3.2, G2.3.7
4.7	table 3-2, table A-5
4.7.3.1	5.5.2
4.7.3.2	5.5.3, table 5-9
4.7.3.2.1.2	table 5-3
4.7.3.2.1.4	table 5-6
4.7.3.2.2.3	table 5-7
4.7.3.2.2.4	table 5-7
4.7.3.2.2.7	table 5-3
4.7.3.2.2.11	table 5-6, table 5-9
4.7.3.3	5.5.4
4.7.3.4	5.5.5
4.7.3.5	5.5.1
4.7.3.6	5.5.1
4.7.3.7	5.5.1
4.7.3.8	5.5.1
4.7.4.1	5.6.5.1.1
4.7.4.2	5.6.7.1
4.7.4.2.2	A2.2 AV29
4.7.4.2.2.2	table 5-5, table 5-6, table 5-9
4.7.5	7.4.1, 7.4.2, 7.4.3
4.8	table 3-1, 4.1.1, 4.6.4.1.1, table A-5, C1
4.8.2.2	4.1.2
4.8.3.1	4.5.2
4.8.3.2	4.5.3
4.8.3.3	4.5.4
4.8.3.3.2	table 4-6
4.8.3.3.2.5	table 4-6, table 4-8
4.8.3.4	4.5.5
4.8.3.5	4.5.1
4.8.3.6	4.5.1

Referenced CSTS SFW Section/Subsection/ Paragraph/Table	**Referencing Section/Subsection/Paragraph/Table of this Recommended Standard**
4.8.3.7	4.5.1
4.8.3.8	4.5.1
4.8.3.8 b)	table 4-8
4.8.3.8 c)	table 4-8
4.8.3.8 d)	table 4-8
4.8.3.8 e)	table 4-8
4.8.3.9	4.5.1
4.8.3.10	4.5.1
4.8.3.11	4.5.1
4.8.4.2.1	4.6.5.1.1
4.8.4.2.7.1	4.6.5.1.2.1
4.8.4.3.2	table 4-6
4.8.4.3.3	A2.2 AV29
4.8.4.3.3.1	table 4-8
4.8.4.3.4	A2.2 AV29
4.8.4.3.4.1	table 4-5
4.8.5	7.3
4.9	table 3-1, table 3-2, table A-5
4.9.5	7.7
4.10	table 3-1, table 3-2, table A-5
4.10.5	7.5.3, 7.5.5
4.11	table 3-1, table 3-2, table A-5
4.11.5	7.6.1, 7.6.3
4.12	table 3-1, table 3-2, 6-3, table A-5
4.12.4.1.3.1	6.6.2.1 a), 6.8.2
annex B	2.5.2.2h) i) Note 2
B2.5	table 4-6, table 5-6
F	A1.2
F3.3	5.6.7.2.1.2, A2.2 (numerous instances in the text), table A-7, table A-8, A2.2 AV2, A2.2 AV9, table A-10, table A-11, table A-12, table A-13, A2.2 AV9, table A-14, A2.2 AV10, table A-15, table A-16, table A-17, table A-19, table A-20, A2.2 AV25, table A-21, table A-22, A2.2 AV27, table A-23, A2.2 AV29, table A-24, C1 (5 instances), D1 (3 instances), E1 (2 instances), F1.
F3.4	A2.2 (numerous instances in the text), table A-6, table A-12, A2.2 AV9, A2.2 AV10, table A-15, table A-16, A2.2 AV12, A2.2 AV13, A2.2 AV14, table A-17, table A-18, A2.2 AV20, table A-19, A2.2 AV25, table A-21, table A-23, table A-24, C1 (2 instances), D1, E1 (2 instances)
F3.5	A2.2 (3 instances in the text), table A-6, table A-7, table A-8, A2.2 AV2, table A-9, table A-10
F3.8	table A-17, table A-23

Referenced CSTS SFW Section/Subsection/ Paragraph/Table	**Referencing Section/Subsection/Paragraph/Table of this Recommended Standard**
F3.9	table A-6, D1 (2 instances)
F3.10	table A-17, table A-18, A2.2 AV19, A2.2 AV20, A2.2 AV21, table A-19, C1 (3 instances)
F3.12	table A-19, A2.2, AV25, table A-24
F3.13	table A-19, A2.2 AV25
F3.14	A2.2, AV10, E1 (2 instances)
F3.16	table 4-3, table 5-3 (4 instances), A2.2, C11
annex L	2.2.2.12.3.1
G3	3.5
H2.3	H2.1
table 4-71	6.8.1
table 4-72	6.8.1
table 4-73	6.8.2
table 4-74	6.8.1