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Space data and information transfer systems — Operation of CFDP over encapsulation service

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Systèmes de transfert des informations et données spatiales — Exploitation du CFDP lors des services d'encapsulation

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The Consultative Committee for Space Data Systems

Recommendation for Space Data System Practices

OPERATION OF CFDP OVER ENCAPSULATION SERVICE

RECOMMENDED PRACTICE

CCSDS 722.1-M-1

MAGENTA BOOK

March 2014

AUTHORITY

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This document has been approved for publication by the Management Council of the Consultative Committee for Space Data Systems (CCSDS) and represents the consensus technical agreement of the participating CCSDS Member Agencies. The procedure for review and authorization of CCSDS documents is detailed in *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-3), and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

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CCSDS Recommendations take two forms: **Recommended Standards** that are prescriptive and are the formal vehicles by which CCSDS Agencies create the standards that specify how elements of their space mission support infrastructure shall operate and interoperate with others; and **Recommended Practices** that are more descriptive in nature and are intended to provide general guidance about how to approach a particular problem associated with space mission support. This **Recommended Practice** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommended Practice** is entirely voluntary and does not imply a commitment by any Agency or organization to implement its recommendations in a prescriptive sense.

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FOREWORD

This document is a technical **Recommended Practice** for use in developing flight and ground systems for space missions and has been prepared by the **Consultative Committee for Space Data Systems** (CCSDS). The **Recommended Practice** described herein is intended for missions that are cross-supported between Agencies of the CCSDS.

This **Recommended Practice** specifies methods for operating the CCSDS File Delivery Protocol (CFDP) over the CCSDS Encapsulation Service.

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DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 722.1-M-1	Operation of CFDP over Encapsulation Service, Recommended Practice, Issue 1	March 2014	Original issue

CONTENTS

1 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THIS DOCUMENT

The CCSDS File Delivery Protocol (CFDP—reference [1]) has been designed to support the transfer of files in a variety of mission scenarios. CFDP offers different qualities of service ranging from best effort to fully reliable and has been specifically optimized for long delay, noisy, and disjoint links. CFDP requires a simple minimum service from the underlying protocols, operating over any link providing a packet communication service.

The purpose of this document is to specify how to operate CFDP over the CCSDS Encapsulation Service (reference [2]) as provided for Earth-to-spacecraft, spacecraft-to-Earth, and spacecraft-to-spacecraft communications. It sets out the communications architecture for CFDP operating over the Encapsulation Service. It describes the service expected by CFDP of the underlying layers and reconciles this with the service provided by the Encapsulation Service.

1.2 APPLICABILITY

This document applies to any mission or equipment claiming to provide a CCSDS-compliant CFDP capability between two endpoints operating over a single CCSDS space link.

1.3 RATIONALE

This document is needed to clarify how CFDP should be used with the CCSDS Encapsulation Service.

1.4 DOCUMENT STRUCTURE

The document has three major sections and four annexes:

- this section, containing administrative information, definitions, and references;
- section 2, describing the communications architecture of CFDP operating over an underlying transport protocol;
- section 3, reconciling the service required of the underlying layer by CFDP with the service provided by the underlying Encapsulation Service;
- annex A, listing informative references;
- annex B, discussing the operation of CFDP over long-haul and planetary CCSDS space links;
- annex C, discussing options for deployment into ground station networks;
- annex D, expanding abbreviations used in the document.

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 DEFINITIONS

1.5.1.1 General

For the purpose of this document the following definitions apply.

1.5.1.2 Definitions from the Open Systems Interconnection (OSI) Basic Reference Model

This document is defined using the style established by the Open Systems Interconnection (OSI) Basic Reference Model (reference [A1]). This model provides a common framework for the development of standards in the field of systems interconnection.

The following terms, used in this Recommended Practice, are adapted from definitions given in reference [A1]**:**

layer: Subdivision of the architecture, constituted by subsystems of the same rank.

protocol data unit: Unit of data specified in a protocol and consisting of protocol-control information and possibly user data.

protocol ID: Identifier that specifies the layer-(*N+1*) protocol (type of service data unit) encapsulated within a protocol data unit at layer *N*.

service: Capability of a layer (service provider) together with the layers beneath it, provided to the service users.

service data unit, SDU: Set of data that is sent by a user of the services of a given layer and is transmitted to a peer service user semantically unchanged.

1.5.1.3 Definitions of Terms as Used in this Recommended Practice

packet: Delimited, octet-aligned data unit.

1.6 NOMENCLATURE

1.6.1 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.

1.6.2 INFORMATIVE TEXT

In the normative section of this document (section 3), informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

– Overview;

– Background;

– Rationale;

– Discussion.

1.7 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. All publications are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS publications.

[1] *CCSDS File Delivery Protocol (CFDP)*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 727.0-B-4. Washington, D.C.: CCSDS, January 2007.

[2] *Encapsulation Service*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.1-B-2. Washington, D.C.: CCSDS, October 2009.

[3] *Proximity-1 Space Link Protocol—Data Link Layer*. Issue 5. Recommendation for Space Data System Standards (Blue Book), CCSDS 211.0-B-5. Washington, D.C.: CCSDS, December 2013.

[4] *TC Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 232.0-B-2. Washington, D.C.: CCSDS, September 2010.

[5] *TM Space Data Link Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 132.0-B-1. Washington, D.C.: CCSDS, September 2003.

[6] *AOS Space Data Link Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 732.0-B-2. Washington, D.C.: CCSDS, July 2006.

2 OVERVIEW

2.1 GENERAL

The specification of CFDP is provided by reference [1]. The standard is supplemented by three informational reports, references [A2], [A3], and [A4], and the reader is directed to these for a more detailed explanation of the protocol and its intended targets.

CFDP is designed to run over an Underlying Transport (UT) service that provides to CFDP the following primitives:

`UNITDATA.request` (UT_SDU, UT Address)
`UNITDATA.indication` (UT_SDU, UT Address)

This document maps the primitives that CFDP requires onto those provided by the Encapsulation Service (section 3).

2.2 CONTEXT AND GUIDELINES

The protocol configuration for CFDP communication over a CCSDS space link when using the Encapsulation Service is shown in figure 2-1.

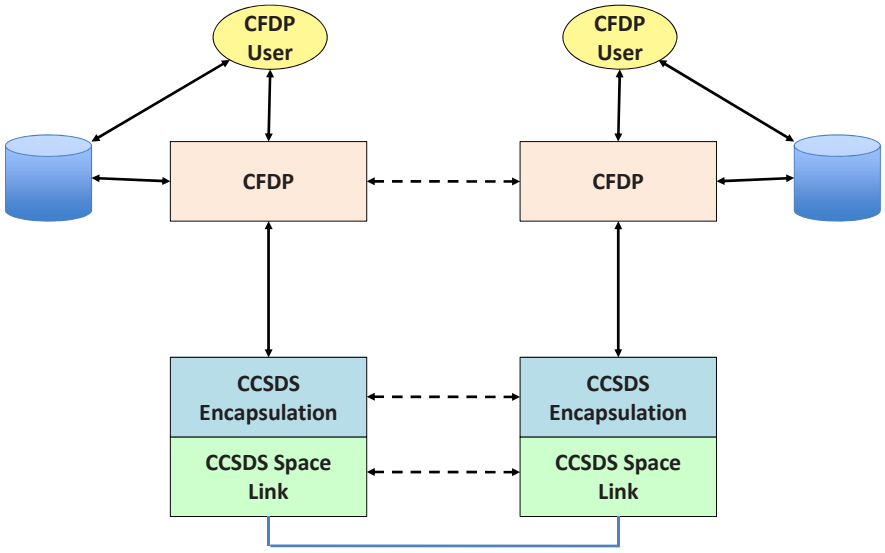

Figure 2-1: CFDP Communication over Encapsulation

In figure 2-1, operation of the CFDP entities is shown over the CCSDS Encapsulation Service (reference [2]).

3 CFDP-OVER-ENCAPSULATION

3.1 GENERAL

3.1.1 CFDP shall operate, via the CCSDS Encapsulation Service, defined in reference [2], over CCSDS space links (references [3], [4], [5], and [6]).

3.1.2 CCSDS space links shall support the Encapsulation Service via the primitives defined in reference [2].

3.2 DISCUSSION—CFDP REQUIRED SERVICE

CFDP defines the service primitives and parameters required to be provided by the underlying layer as:

`UNITDATA.request` (UT_SDU, UT Address)
`UNITDATA.indication` (UT_SDU, UT Address)

NOTES:

1 The format and contents of the UT Address parameter depend on the addressing capabilities and conventions of the underlying service. Information in the Management Information Base (MIB) must enable translation between CFDP entity names and the corresponding UT addresses.

2 The assumed minimum underlying quality of service is:

- with possible errors in the delivered UT_SDUs;
- incomplete, with some UT_SDUs missing;

3.3 DISCUSSION—ENCAPSULATION SERVICE

The Encapsulation Service (reference [2]) provides the following service primitives and parameters:

`ENCAPSULATION.request` (Data Unit, SDLP_Channel, PVN, EPI)
`ENCAPSULATION.indication` (Data Unit, SDLP_Channel, PVN, EPI,
Data Unit Loss Flag (optional))

Where:

- Data Unit is the SDU to be transferred.
- SDLP_Channel is part of the SAP address of the Encapsulation Service. It uniquely identifies the channel of the underlying Space Data Link Protocol (SDLP) through which the Data Unit is to be transferred. Reference [2] describes the SDLP_Channel semantics; the exact semantics depend on the underlying SDLP services.

– PVN is part of the SAP address of the Encapsulation Service and is the Packet Version Number (of the Encapsulation Service, either Encapsulation or CCSDS Packet).

– EPI is part of the SAP address of the Encapsulation Service; depending on the protocol used to implement the encapsulation service, the EPI is either an Application Process Identifier (APID) or the Protocol Identifier.

– The Data Unit Loss Flag is an optional parameter that may be used to notify the user at the receiving end of the Encapsulation Service that a sequence discontinuity has been detected and that one or more Data Units have been lost. This flag may be used only if the Space Packet is used for encapsulation. This parameter, if present, is ignored by implementations of this specification.

3.4 EQUIVALENCIES

3.4.1 To reconcile the service required by CFDP and the service provided by the Encapsulation service the following equivalences shall be used:

– CFDP UT_SDU = Encapsulation Data Unit;

– CFDP UT Address = Encapsulation SAP Address
= Encapsulation SDLP_Channel + PVN + EPI.

3.4.2 A CFDP UNITDATA.request shall generate an ENCAPSULATION.request where:

– The CFDP protocol data unit UT_SDU to be transferred shall be the Encapsulation Data Unit.

– The CFDP UT Address shall contain SDLP_Channel, PVN, and EPI.

3.4.3 A ENCAPSULATION.indication shall generate a CFDP UNITDATA.indication where:

– The CFDP protocol data unit UT_SDU shall contain the received Encapsulation Data Unit.

– The CFDP UT Address shall contain the SDLP_Channel, PVN, and EPI.

3.4.4 The EPI value shall be either an APID (if the Space Packet is used) or a Protocol ID (if the Encapsulation Packet is used).

3.4.4.1 The EPI value shall be set to the CCSDS APID for CFDP when the Encapsulation Service uses CCSDS Packets.

3.4.4.2 The EPI value shall be set to the CCSDS Encapsulation Protocol Identifier for CFDP when the Encapsulation Service uses Encapsulation Packets.

3.4.4.3 If Space Packets are used by the Encapsulation Service used by this specification, the optional Data Loss Flag shall be ignored by implementations of this specification.

NOTE – The SDLP_Channel, PVN, and EPI fields used by CFDP for encapsulation are configured as part of the CFDP Remote Entity Configuration Information.

ANNEX A

INFORMATIVE REFERENCES

(INFORMATIVE)

[A1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[A2] *CCSDS File Delivery Protocol (CFDP)—Part 1: Introduction and Overview*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 720.1-G-3. Washington, D.C.: CCSDS, April 2007.

[A3] *CCSDS File Delivery Protocol (CFDP)—Part 2: Implementers Guide*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 720.2-G-3. Washington, D.C.: CCSDS, April 2007.

[A4] *CCSDS File Delivery Protocol (CFDP)—Part 3: Interoperability Testing Final Report*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 720.3-G-1. Washington, D.C.: CCSDS, September 2007.

ANNEX B

CFDP OPERATION OVER CCSDS SPACE LINKS

(INFORMATIVE)

Figure B-1 shows an example of the CFDP Earth/spacecraft scenario.

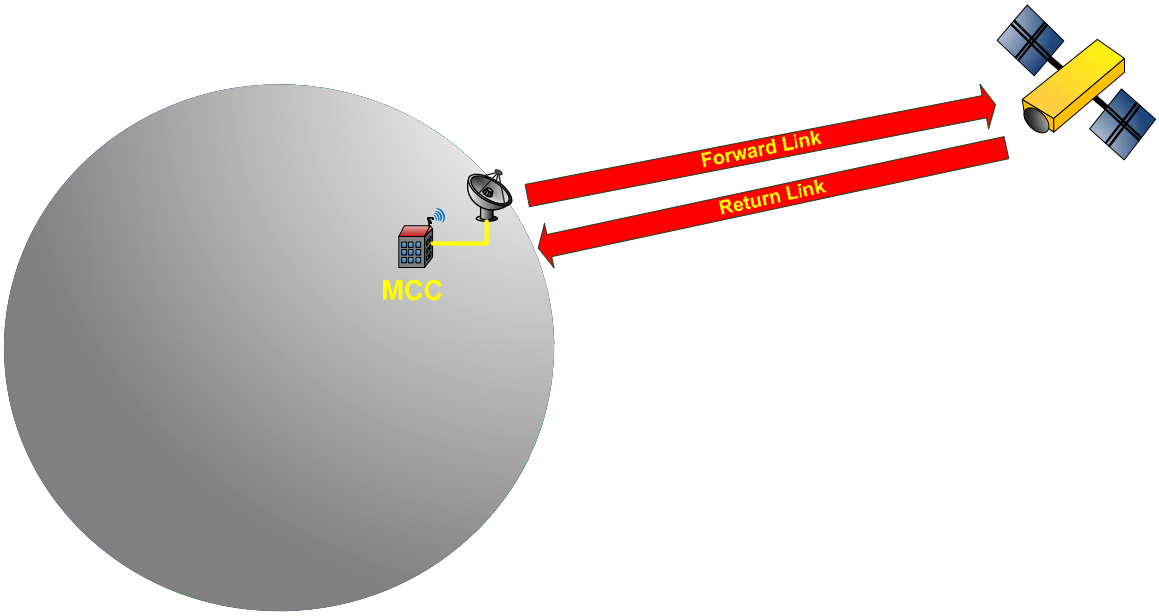

Figure B-1: CFDP Earth/Spacecraft Architecture Example

The scenario includes two elements:

– the ground segment;

– a spacecraft such as a LEO or geostationary Earth orbiter or a planetary orbiter.

Although the ground segment is more complex than a single control center, it is sufficient for the purposes of this document to assume that the ground station network is transparent to the link services, probably operating at the Space Link Extension (SLE) frame level, and that the Mission Control Centre (MCC) is transparent or it assumes the role of the CFDP end point.

The space data links are designated as in table B-1.

Table B-1: Link Designations

Name	Source	Destination	CCSDS Recommended Standards
Forward Link	Earth	Spacecraft	Telecommand, AOS
Return Link	Orbiter	Earth	Telemetry, AOS

The protocol configuration for direct CFDP transfer between Earth and a spacecraft is shown in figure B-2.

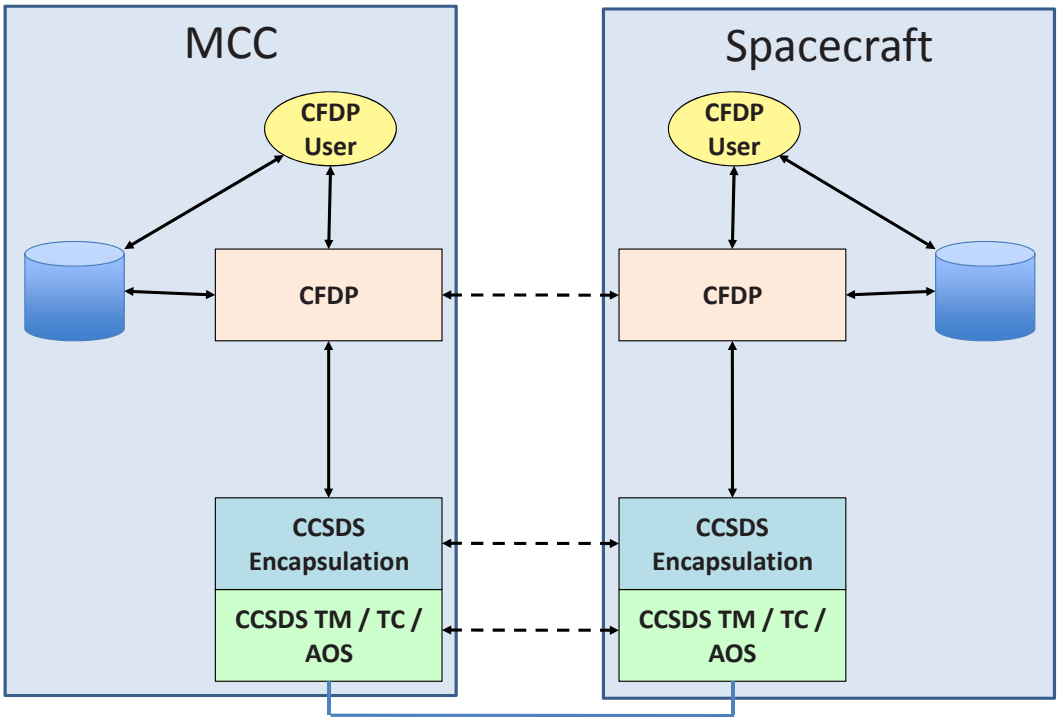

Figure B-2: CFDP Communication between Earth and a Spacecraft

In figure B-2, operation of the CFDP entities is shown over CCSDS TC, TM, and AOS (references [4], [5], and [6], respectively). CCSDS standard architecture mandates that CCSDS standard Network Layer (and above) protocols operate over CCSDS space links via the CCSDS Encapsulation Service (reference [2]), which defines protocol identifiers and standard data structures to identify the user protocols and to transfer their protocol data units.

CFDP will operate, via the CCSDS Encapsulation Service, in the Earth-spacecraft link over TC (forward link) and over TM or AOS (return link).

In the forward direction, CFDP Class-2 is more optimized for reliable data transfer over long-delay links than is CCSDS Telecommand COP-1, primarily because of:

– the use of a negative rather than positive acknowledgement;

– the ability to concatenate multiple fragments of lost data into one retransmission requiring only one retransmission request.

For these reasons it is recommended that CFDP class 2 be used for reliable file transfer in long-haul forward links.

The same advantages apply in the return direction. Furthermore, TM and AOS have no inherent reliability mechanism, and CFDP is easily optimized to operate over unbalanced (high-rate return, low-rate forward) channels.

There is still a case for operating unreliable CFDP in certain circumstances. For instance, for the transmission of highly ephemeral emergency commands in the forward direction and for return of highly redundant data in the return direction.

Figure B-3 shows an example of the CFDP proximity scenario.

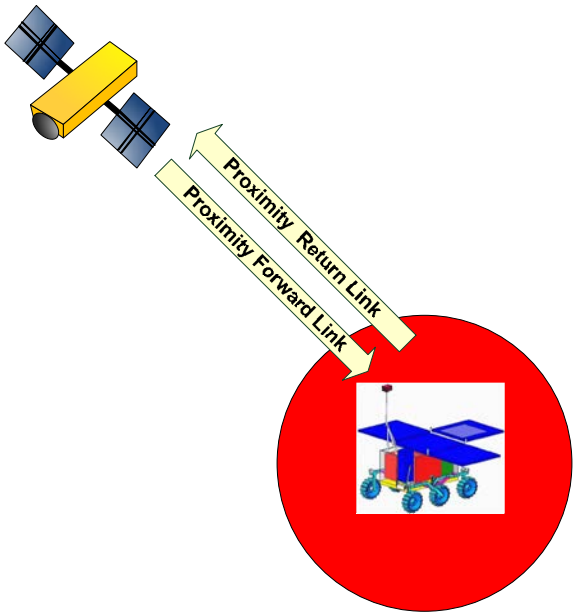

Figure B-3: CFDP Proximity Physical Architecture Example

The scenario includes two elements:

– the landed segment;

– a planetary orbiter or free-flying spacecraft.

The proximity space data links are designated as in table B-2.

Table B-2: Link Designations

Name	Source	Destination	CCSDS Recommended Standards
Forward Link	Orbiter	Lander	Proximity-1
Return Link	Lander	Orbiter	Proximity-1

The protocol configuration for the proximity scenario is shown in figure B-4.

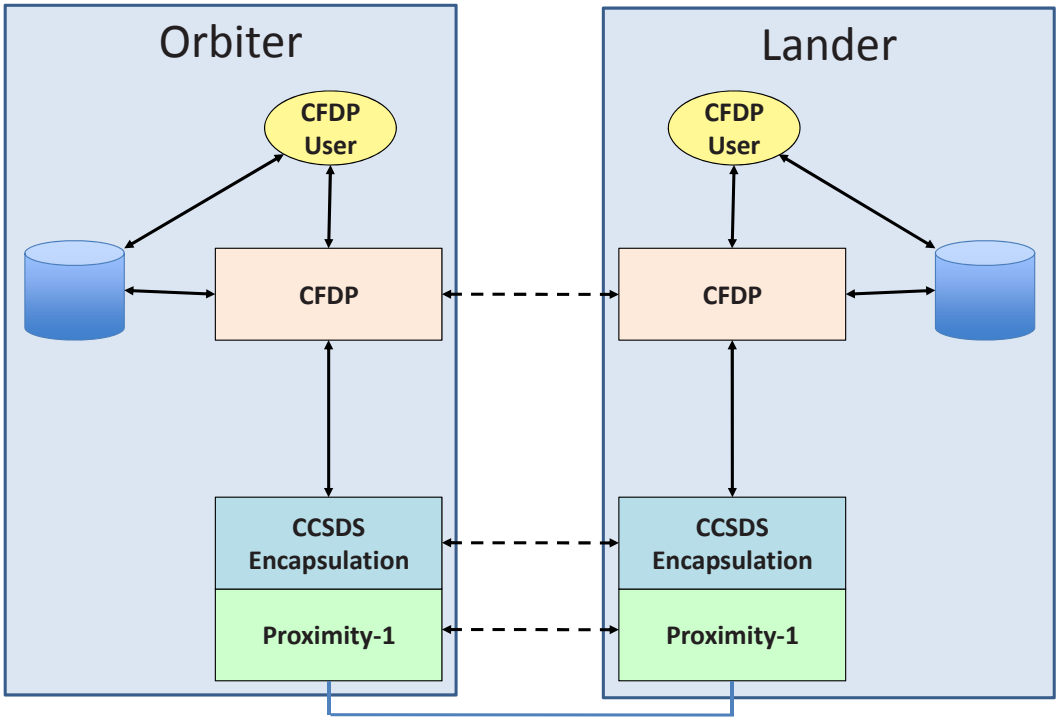

Figure B-4: CFDP Communication with Landed Element

In figure B-4, operation of the CFDP entities is shown over CCSDS Proximity-1 (reference [3]) and using the Proximity-1 reliable data transfer (sequence-controlled) service. CCSDS standard architecture mandates that CCSDS standard Network Layer (and above) protocols operate over CCSDS space links via the CCSDS Encapsulation Service (reference [2]), which defines protocol identifiers and standard data structures to identify the user protocols and to transfer their protocol data units.

Proximity-1 is optimized for reliable data transfer over Proximity links. It is therefore recommended that CFDP Class 1 in conjunction with Proximity-1 sequence-controlled service be used for reliable file transfer in Proximity links.

There may still a case for operating unreliable CFDP in certain circumstances. In these cases CFDP can use the Proximity-1 unreliable service.

ANNEX C

OPTIONS FOR DEPLOYMENT INTO GROUND STATION NETWORKS

(INFORMATIVE)

CCSDS makes no recommendations concerning the physical deployment of CFDP into the ground segment. It is recognized that there is debate as to whether the CFDP entity is best implemented in (possibly multiple) ground stations or in a centralized mission control facility. This annex describes an alternative approach to these two options.

Operating CFDP over high rate space data return links can be problematic where the link between mission control and ground station has limited bandwidth. In this case deploying CFDP at the ground station can solve this problem. However, it is often a mission requirement that the mission control center be in control of all traffic flowing to the spacecraft, and this policy does not tolerate the autonomous generation of retransmission requests by the ground station.

The deployment therefore consists of a CFDP engine (and underlying encapsulation and supporting space link protocols) being located in the ground station(s). The ground station receives the file segments and any retransmissions. Any outgoing Protocol Control Information (PCI) and retransmission requests are transferred to the mission control facility which can then merge the requests and PCI into the outgoing command stream.

This arrangement allows the file transfer to be performed by the ground station whilst putting the mission control center in control of all traffic to the spacecraft.

ANNEX D

ABBREVIATIONS

(INFORMATIVE)

AOS	Advanced Orbiting Systems
APID	Application Process Identifier
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
EPI	Encapsulated Protocol Identifier
ID	Identifier
IPE	Internet Protocol Extension
ISO	International Organization for Standardization
LEO	Low Earth Orbit
MCC	Mission Control Centre
MIB	Management Information Base
PCI	Protocol Control Information
PVN	Packet Version Number
SANA	Space Assigned Numbers Authority
SAP	service access point
SDLP	Space Data Link Protocol
SDU	service data unit
SLE	Space Link Extension
TC	Telecommand
TM	Telemetry
UT	Underlying Transport

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