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Space data and information transfer systems — CCSDS file delivery protocol

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National foreword

This British Standard is the UK implementation of ISO 17355:2007. It supersedes BS ISO 17355:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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INTERNATIONAL STANDARD

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Third edition
2007-05-15

Space data and information transfer systems — CCSDS file delivery protocol

Systèmes de transfert des informations et données spatiales — Protocole CCSDS de livraison de fichiers

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17355 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 727.0-B-3, June 2005) and was adopted (without modifications except those stated in Clause 2 of this International Standard) by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 13, *Space data and information transfer systems*.

This third edition cancels and replaces the second edition (ISO 17355:2004), which has been technically revised.

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Space data and information transfer systems — CCSDS file delivery protocol

1 Scope

This International Standard defines a CCSDS file delivery protocol (CFDP) and associated service for application in the space environment. It is intended for use over the current and envisaged packet delivery services used in the space environment, including

— CCSDS conventional packet telecommand;

— CCSDS conventional packet telemetry;

— CCSDS advanced orbiting systems (AOS) path service.

It may also operate over a wide variety of ground network services, including those specified by the CCSDS for cross-support purposes. The protocol operates in the space-to-ground, ground-to-space, and space-to-space directions of transfer. It may be initiated by the file sending or receiving entity. In the interests of interoperability, protocol elements are included for generalized forms of standard file manipulation operations based on assumptions of a common model for a 'filestore', or medium used to store files. It is recognized, however, that the precise nature and capabilities of filestore management systems are operating-system dependent and, for that reason, the protocol assumes a virtual filestore and associated services that an implementation must map to the capabilities of the actual filestore used.

The scope and field of application are furthermore detailed in subclauses 1.2 and 1.3 of the enclosed CCSDS publication.

2 Requirements

Requirements are the technical recommendations made in the following publication (reproduced on the following pages), which is adopted as an International Standard:

CCSDS 727.0-B-3, June 2005, *CCSDS file delivery protocol (CFDP).*

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 727.0-B-3.

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This part is information which is relevant to the CCSDS publication only.

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Add the following information to the reference indicated:

[1] Document CCSDS 732.0-B-1, September 2003, is equivalent to ISO 22666:2005.

[2] Document CCSDS 132.0-B-1, September 2003, is equivalent to ISO 22645:2005.

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[3] Document CCSDS 133.0-B-1, September 2003, is equivalent to ISO 22646:2005.

[4] Document CCSDS 232.0-B-1, September 2003, is equivalent to ISO 22664:2005.

3 Revision of publication CCSDS 727.0-B-3

It has been agreed with the Consultative Committee for Space Data Systems that Subcommittee ISO/TC 20/SC 13 will be consulted in the event of any revision or amendment of publication CCSDS 727.0-B-3. To this end, NASA will act as a liaison body between CCSDS and ISO.

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The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

CCSDS FILE DELIVERY PROTOCOL (CFDP)

RECOMMENDED STANDARD

CCSDS 727.0-B-3

BLUE BOOK

June 2005

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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 Recommendations is detailed in the reference [A1], 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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STATEMENT OF INTENT

The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of its members. The Committee meets periodically to address data systems problems that are common to all participants, and to formulate sound technical solutions to these problems. Inasmuch as participation in the CCSDS is completely voluntary, the results of Committee actions are termed **Recommended Standards** and are not considered binding on any Agency.

This **Recommended Standard** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommendation** is entirely voluntary. Endorsement, however, indicates the following understandings:

- Whenever a member establishes a CCSDS-related **standard**, this **standard** will be in accord with the relevant **Recommended Standard**. Establishing such a **standard** does not preclude other provisions which a member may develop.
- Whenever a member establishes a CCSDS-related **standard**, that member will provide other CCSDS members with the following information:
  - The **standard** itself.
  - The anticipated date of initial operational capability.
  - The anticipated duration of operational service.
- Specific service arrangements shall be made via memoranda of agreement. Neither this **Recommended Standard** nor any ensuing **standard** is a substitute for a memorandum of agreement.

No later than five years from its date of issuance, this **Recommended Standard** will be reviewed by the CCSDS to determine whether it should: (1) remain in effect without change; (2) be changed to reflect the impact of new technologies, new requirements, or new directions; or (3) be retired or canceled.

In those instances when a new version of a **Recommended Standard** is issued, existing CCSDS-related member standards and implementations are not negated or deemed to be non-CCSDS compatible. It is the responsibility of each member to determine when such standards or implementations are to be modified. Each member is, however, strongly encouraged to direct planning for its new standards and implementations towards the later version of the Recommended Standard.

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FOREWORD

Until relatively recently the typical storage medium for spacecraft has been the tape recorder, a complex device offering limited data storage and data access. The use of this type of storage has typically been limited to the recording and subsequent dump to the ground of telemetry data. Manipulation from the ground has required significant human intervention and used ad hoc, privately developed protocols.

The introduction of solid state mass memory providing gigabytes of storage with random access opens up a whole new ethos of spacecraft operation where much of the routine traffic to and from the spacecraft will be in the form of files. Furthermore, because of the random access nature of the onboard storage medium, it becomes possible to repeat transmission of data lost on the link and thus guarantee delivery of critical information.

To exploit the potential advantages of onboard mass memory, protocol support is required to provide a standard means to move data to and from the onboard storage medium in the form of files.

While the onboard storage medium has rapidly evolved, the essential constraints of space missions remain:

- limited systems resources in terms of computational power and memory capacities;
- environmental restrictions including noisy, bandwidth limited, asymmetrical, and interrupted communications links, some with very long propagation delay;
- varying user needs including a requirement for early access to transferred data regardless of its quality.

In view of these constraints, it is clear that there is a need for a file delivery service capable of transferring files to and from mass memory located in the space segment. Such a capability must not only operate under the constraints associated with space data communication, but it must also be applicable to the diverse range of mission configurations ranging from single low earth orbiting spacecraft to complex networks of relays, orbiters, and landers.

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommendation is therefore subject to CCSDS document management and change control procedures which are defined in reference [A1]. Current versions of CCSDS documents are maintained at the CCSDS Web site:

http://www.ccsds.org/

Questions relating to the contents or status of this document should be addressed to the CCSDS Secretariat at the address indicated on page i.

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- Belgian Federal Science Policy Office (BFSPO)/Belgium.
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- Swedish Space Corporation (SSC)/Sweden.
- United States Geological Survey (USGS)/USA.

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DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 727.0-B-1	CCSDS File Delivery Protocol, Issue 1	January 2002	Original Issue (superseded)
CCSDS 727.0-B-2	CCSDS File Delivery Protocol, Issue 2	October 2002	Issue 2 (superseded)
CCSDS 727.0-B-3	CCSDS File Delivery Protocol, Issue 3	June 2005	Current Issue: adds procedures for unacknowledged-mode handling of metadata and file data received after the arrival of the EOF PDU for the same transaction.

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This document defines a CCSDS File Delivery Protocol (CFDP) and associated service for application in the space environment. It is intended for use over the current and envisaged packet delivery services used in the space environment including:

- CCSDS conventional packet telecommand;
- CCSDS conventional packet telemetry;
- CCSDS Advanced Orbiting Systems (AOS) Path service.

In may also operate over a wide variety of ground network services including those specified by the CCSDS for cross-support purposes.

The protocol operates in the space-to-ground, ground-to-space, and space-to-space directions of transfer. It may be initiated by the file sending or receiving entity.

In the interests of interoperability, protocol elements are included for generalized forms of standard file manipulation operations based on assumptions of a common model for a 'filestore', or medium used to store files. It is recognized, however, that the precise nature and capabilities of filestore management systems are operating-system dependent and, for that reason, the protocol assumes a virtual filestore and associated services that an implementation must map to the capabilities of the actual filestore used.

1.2 APPLICABILITY

This Recommendation specifies a protocol and associated services that are applicable to space missions with continuous duplex contact, intermittent duplex contact, asymmetrical time-disjunct contact, and simplex contact.

1.3 CONVENTIONS AND DEFINITIONS

1.3.1 BIT NUMBERING CONVENTION AND NOMENCLATURE

In this document, the following convention is used to identify each bit in an *N*-bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be 'Bit 0'; the following bit is defined to be 'Bit 1' and so on up to 'Bit *N*–1'. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., 'Bit 0'.

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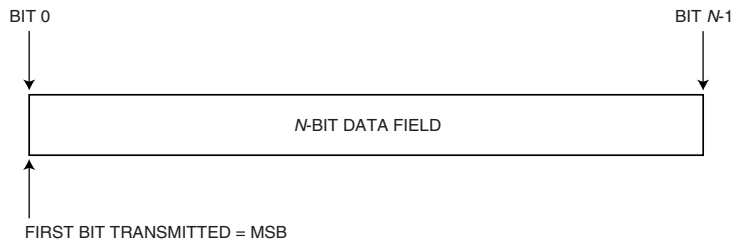

Figure 1-1: Bit Numbering Convention

In accordance with modern data communications practice, spacecraft data fields are often grouped into 8-bit 'words' which conform to the above convention. Throughout this Recommendation, the following nomenclature is used to describe this grouping:

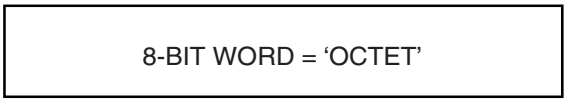

Figure 1-2: Octet Convention

By CCSDS convention, all 'spare' bits shall be permanently set to value 'zero'.

1.3.2 ORGANIZATION OF THE RECOMMENDATION

This Recommendation is organized as follows:

- Section 2 provides an overview of the protocol, its intended use, and a description of the main interactions involved in a file transfer.
- Section 3 defines the services provided by the protocol along with the associated primitives and parameters.
- Section 4 is the main body of the protocol specification.
- Section 5 defines the formats for the PDUs.
- Section 6 defines proxy and directory operations.
- Section 7 defines a number of classes of operation designed to meet the most typical operating scenarios.
- Section 8 describes the Management Information Base (MIB).
- Annex A provides a list of informative references.
- Annex B provides a list of acronyms and definitions.
- Annex C provides an example of file checksum calculation.

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1.3.3 DEFINITIONS

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

This Recommendation makes use of a number of terms defined in reference [5]. The use of those terms in this Recommendation shall be understood in a generic sense, i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

- entity;
- Protocol Data Unit (PDU);
- service;
- Service Access Point (SAP);
- Service Data Unit (SDU).

1.3.3.2 Definitions from OSI Service Definition Conventions

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

- Indication;
- Primitive;
- Request;
- Response.

1.3.3.3 Terms Defined in This Recommendation

Within the context of this document the following definitions apply:

A *CFDP protocol entity* (or *CFDP entity*) is a functioning instance of an implementation of the CFDP protocol, roughly analogous to an Internet protocol 'host'.

The functional concatenation of a file and related *metadata* transmitted between two CFDP entities is termed a *File Delivery Unit* (FDU); in this context the term 'metadata' is used to refer to any data exchanged between CFDP protocol entities in addition to file content, typically either additional application data (such as a 'message to user') or data that aid the recipient entity in effectively utilizing the file (such as file name). Note that an FDU may consist of metadata only. Note also that the term 'file' is frequently used in this specification as an abbreviation for 'file delivery unit'; only when the context clearly indicates that only

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actual files are being discussed, for example, in the explanation of the segmentation control parameter or the source and destination file name parameters of the CFDP Service Definition, should the term 'file' not be read as 'file delivery unit'.

The individual, bounded, self-identifying items of CFDP data transmitted between CFDP entities are termed *CFDP Protocol Data Units* or *CFDP PDU*s. Unless otherwise noted, in this document the term 'PDU' always means 'CFDP PDU'. CFDP PDUs are of two general types: *File Data PDUs* convey the contents of the files being delivered, while *File Directive PDUs* convey only metadata and other non-file information that advances the operation of the protocol.

A *transaction* is the end-to-end transmission of a single FDU between two CFDP entities. A single transaction normally entails the transmission and reception of multiple PDUs. Each transaction is identified by a unique transaction ID; all elements of any single FDU, both file content and metadata, are tagged with the same CFDP transaction ID.

Any single end-to-end file transmission task has two associated entities: the entity that has the file at the beginning of the task (the *source*) and the entity that has a copy of the file when the task is completed (the *destination*).

Each end-to-end file transmission task comprises one or more point-to-point file copy operations. A file copy operation has two associated entities: the entity that has a copy of the file at the beginning of the operation (the *sender* or *sending entity*) and the entity that has a copy of the file when the operation is completed (the *receiver* or *receiving entity*). In the simplest case, the only sender of the file is the source and the only receiver is the destination. In more complex cases (the general case) there are additional '*waypoint*' entities that receive and send copies of the file; the source is the first sender and the destination is the last receiver.

Filestore is a generic term referring to the medium used to store files.

The term *offset* is used in a familiar way: the offset of a given octet of file data is the number of data octets that precede this octet in the file.

The file delivery *progress* represented by a given file data PDU is the sum of the offset of the PDU's file data content (the offset of the content's first octet) and the length of that file data content.

The *transmission progress* for a given transaction, delivering some file, is the maximum progress value over all file data PDUs sent so far in the course of this transaction.

Similarly the *reception progress* for a given transaction is the maximum progress value over all file data PDUs received so far in the course of this transaction. If and only if no data are lost in transmission, reception progress is equal to the number of file data octets received.

The term *CFDP user* is used to refer to the software task that causes the local entity to initiate a transaction or the software task that is notified by the local entity of the progress or

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completion of a transaction. The CFDP user local to the source entity is referred to as the *source CFDP user*. The CFDP user local to the destination entity is referred to as the *destination CFDP user*. The CFDP user may be operated by a human or by another software process. Unless otherwise noted the term *user* always refers to the CFDP user.

1.4 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommendation are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommendations.

[1] *AOS Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 732.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

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

[3] *Space Packet Protocol*. Recommendation for Space Data System Standards, CCSDS 133.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

[4] *TC Space Data Link Protocol*. Recommendation for Space Data System Standards, CCSDS 232.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.

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

[6] *Information Technology—Open Systems Interconnection—Basic Reference Model—Conventions for the Definition of OSI Services*. International Standard, ISO/IEC 10731:1994. Geneva: ISO, 1994.

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2 OVERVIEW

2.1 GENERAL

This Recommendation defines a protocol suitable for the transmission of files to and from spacecraft data storage. In addition to the purely file delivery related functions, the protocol also includes file management services to allow control over the storage medium.

The protocol is capable of operating in a wide variety of mission configurations, from relatively simple low earth orbit spacecraft to complex arrangements of orbiters and landers supported by multiple ground facilities and transmission links. In its simplest form, the protocol provides a *Core* file delivery capability operating across a single link. For more complex mission scenarios, the protocol offers *Extended* operation providing store-and-forward functionality across an arbitrary network containing multiple links with disparate availability.

The protocol is independent of the technology used to implement data storage and requires only a few fundamental filestore capabilities in order to operate. It assumes two filestores, one within the spacecraft and one on the ground, and operates by copying data between the two filestore locations.

The protocol makes no assumptions about the information being transferred and can be utilized for a wide range of applications involving the loading, dumping, and control of spacecraft storage.

The protocol has been specifically designed to minimize the resources required for operation. It is also scaleable, so that only those elements required to fulfill the selected options are required to be implemented.

Although the protocol can operate over a wide range of underlying communication services, this Recommendation assumes the use of CCSDS packet services as defined in references [1] through [4].

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2.2 ARCHITECTURE ELEMENTS

2.2.1 GENERAL

The architectural elements involved in the file delivery protocol are depicted in figure 2-1 and described below.

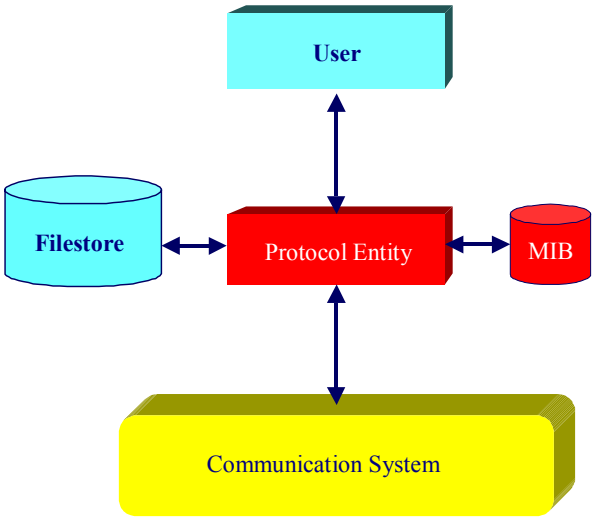

Figure 2-1: Architectural Elements of the File Delivery Protocol

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2.2.2 USER

The protocol operates at the request of the CFDP user. The user interacts with the protocol using the service primitives defined in section 3.

A CFDP user is always a software task, which may or may not be operated by a human.

Each CFDP protocol entity has at most one user. In some instances a user may not be present; in particular, any entity which always functions solely as an Extended Procedures waypoint (performing store and forward operations) need not have a user.

2.2.3 PROTOCOL ENTITY

The protocol **entity** consists of implementations of the *Core delivery procedures*, which allow immediate file delivery and manipulation over a single network hop, and optionally the *Extended procedures*, which allow for time-disjunct or immediate delivery over a number of network hops with appropriate facilities for onward routing. A single service interface is presented to the user; the operation of the Extended procedures is evident in the quality of service and the multi-hop capability.

2.2.4 FILESTORE

The protocol operates by copying files from storage medium to storage medium, and it is therefore assumed that all CFDP entities have access to a local storage capability. As the ways in which the storage capability is provided will vary, the protocol is built on the premise that any file or organized set of files (i.e., a filestore) can be described in terms of a single standard representation. This representation, called a '**virtual filestore**' is assigned a standard set of attributes which are then used by the protocol to manage the file delivery process. In an implementation, the virtual filestore must be mapped to and from actual hardware and software which constitute the real filestore. This approach allows complete independence from the technology used to implement the filestore.

2.2.5 UNDERLYING COMMUNICATION SYSTEM

The protocol assumes the availability of a single conceptual underlying communication system, referred to as the '**Unitdata Transfer (UT) layer**', to which all CFDP entities in a given CFDP addressing domain have access. In order that the protocol may operate over a wide range of implementations, the services required of the UT layer have intentionally been kept as simple as possible; those services are assumed to be made available to any single CFDP entity at only a single conceptual service access point.

Because of the potential diversity of physical underlying services in use, no reuse of underlying protocol features is utilized beyond the addressing required to identify localities within the domain of the underlying communication system ('**UT addresses**', to which CFDP entities' names may be mapped using information contained in the management information base) and the delimitation of the CFDP Protocol Data Unit (CFDP PDU).

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The relative independence of the CFDP protocol specifically implies that all multiplexing to support multiple file delivery transactions occurs internally in the CFDP protocol entity and that sequence auditing and error detection is provided by CFDP. PDU length information is incorporated in the CFDP PDU header to give independence from the underlying protocol and to simplify protocol processing.

It should be noted that although the CFDP protocol can operate over a service where data errors, data loss, and out-of-sequence delivery occur, it is not intended to compensate for networks where these effects are prevalent. Severe performance reductions will result if such an approach is taken. A simplified analysis of CFDP performance is detailed in the CFDP Green Book (CCSDS 720.1-G-1). This analysis will allow implementers to gauge likely performance based on file size, file segment size and bit error probability.

2.2.6 MANAGEMENT INFORMATION BASE

To perform a file delivery, a significant amount of information must be passed by the local user to its local CFDP entity and by the local CFDP entity to the remote CFDP entity. Typically, this data is static and may be stored within the CFDP entities as system tables, referred to as the *Management Information Base* (*MIB*). The MIB contains such information as default values for user communications requirements, e.g., for address mapping, and for communication timer settings. The MIB is formally defined as part of the protocol specification in section 8.

2.3 GENERAL CHARACTERISTICS

2.3.1 GENERAL

The CFDP enables the moving of a file from one filestore to another, where the two filestores are in general resident in separate data systems and often with an intervening space link. Functionally attached to each such file may be metadata of variable size, format, and semantics. The metadata consists of information associated with the file or the file transfer such as file names, filestore requests, or messages to the CFDP user. The functional concatenation of a file and all relevant metadata is termed an FDU, but it is also permissible for an FDU to consist of metadata only.

FDU transmission is accomplished by CFDP entities, each of which has access to exactly one filestore. A transaction is the end-to-end transmission of a single FDU between two CFDP entities. The initiation of the transaction causes a file copy operation to occur between two entities, the sender and the receiver.

As depicted in figure 2-2, the protocol procedures constitute the interaction between two protocol entities. The sending entity is the entity from which the file is copied in a file copy operation. The receiving entity is the entity to which the file is copied in a file copy operation. Where direct connectivity between the source and destination is impossible, the Extended procedures automatically execute multiple file copy operations: one file copy

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operation between the source and the first waypoint; others between successive waypoints as necessary; and a final file copy operation between the last waypoint and the destination. Each of these is simply another instance of the Core file copy operation.

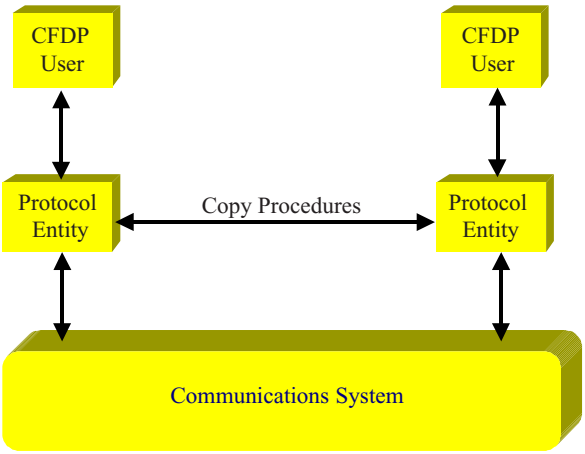

Figure 2-2: CFDP Procedures

The reliability of a transaction is determined by whether the transaction is chosen to operate in unacknowledged mode or one of the acknowledged modes. In unacknowledged mode, data delivery failures are not reported to the sender and therefore cannot be repaired. Reception of the complete file is therefore not guaranteed. In acknowledged mode, the receiver informs the sender of any undelivered file segments or ancillary data. These are then retransmitted, guaranteeing complete file delivery.

Each transaction results in the copying of a single FDU from source to destination. Within any single transaction, the subsidiary actions cancel, suspend, resume, and report may be performed.

The transaction is terminated when one of the following conditions applies:

- the file has been successfully transferred;
- a sending or receiving entity has disallowed the transaction;
- the transaction has been canceled because a fault was detected;
- the source or destination CFDP user has canceled the transaction.

2.3.2 USER OPERATIONS

The term ‘user operations’ refers to the use of the CFDP services offered by the local CFDP entity to cause the CFDP user of a remote CFDP entity to initiate additional CFDP transactions. User operations are implemented using the ‘Message to User’ capability of the

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protocol to forward an 'order' to the remote CFDP user which will in turn initiate a transaction with its local CFDP entity.

Five standard user operations are defined: proxy operations, remote status report operations, remote suspend and resume operations, and directory operations. Directory operations are used to request a listing of the contents of a specified directory in the remote user's local filestore. Remote status report operations are used to request a report of the status of a specified CFDP transaction at the remote entity. Remote suspend and resume operations are used to request the suspension and resumption of a specified CFDP transaction at the remote entity. Proxy operations are used to initiate the delivery of a file from a remote CFDP entity to some other user, either to the local user itself (in which case the proxy operation functions as a 'Get') or to the user of some third CFDP entity. The FDU transmitted in a proxy operation normally contains a file but may contain only metadata, such as filestore directives or a Message to User containing an order to another remote CFDP user.

User operations are described in section 6.

2.3.3 ADDRESSING

Within any single CFDP network (i.e., any set of CFDP entities that is closed under communication), each CFDP entity is assigned a unique name. As each CFDP entity has access to exactly one filestore, identification of a CFDP entity implicitly identifies the associated filestore. At each CFDP entity location, address look-up capabilities are provided using information contained in the associated MIB. This look-up capability provides translation between the network-unique name of a CFDP entity and the corresponding UT address, which may in reality be an Internet address, radio device buffer, APID, virtual channel number, or other implementation-specific mechanism.

The names, or 'entity IDs', that uniquely identify the source CFDP entity and the destination CFDP entity must be included in the header of each PDU in order for an FDU to be successfully transmitted through a series of waypoint CFDP entities.

2.3.4 STORE AND FORWARD CONSIDERATIONS

When the Extended procedures are operating, the sender and/or receiver of a given PDU may be a 'waypoint' CFDP entity. Extended procedures are used when the original source of the PDU has no direct connectivity to the PDU's final destination, but only to some intermediate entity. That waypoint entity in turn may have direct connectivity either to the PDU's final destination or only to some further intermediate entity; the last waypoint entity in such a chain must have direct connectivity to the final destination of the PDU.

The determination of how and when a waypoint entity forwards a PDU toward its target entity is an implementation matter. In general it is desirable to forward each PDU as soon as possible, rather than wait until custody of an entire FDU has been taken before forwarding any part of it; this approach minimizes the time required for complete end-to-end transmission of the data. In practice, however, immediate forwarding will frequently be

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impossible, because radio contact among CFDP entities is typically discontinuous. The waypoint entity in such cases must store PDUs in some persistent medium, such as an intermediate copy of the transmitted file, until forwarding is practical.

The end-to-end execution of a transaction may therefore comprise multiple successive executions of Core procedures between adjacent entities, some of which may be initiated by the Extended procedures themselves rather than by a CFDP user's invocation of services; when this is the case, the Extended procedures essentially take on the role of the CFDP user. However, this variation is invisible to the Core procedures, which operate in the same way at all times.

When the sender for a Copy File procedure is the file's source entity but the receiver is a waypoint rather than the file's destination entity, the sender issues a `Transfer-Consigned.indication` primitive (rather than a `Transaction-Finished.indication` primitive) when it receives notification from the receiver that the file has been successfully copied. This notifies the sending application that custody of the file has been transferred to the first waypoint; if the original file itself is being used as the sender's retransmission buffer, and is therefore protected from deletion or modification, it is now safe to end that protection.

As noted earlier, when the receiver for a Copy File procedure is a waypoint, it may or may not wait until the entire procedure is complete before beginning to copy the file to the destination (or next waypoint). Immediate (incremental) forwarding of the file has the desirable effect of minimizing delay in getting at least part of the file to the destination.

The precise order in which stored PDUs are forwarded when connectivity is established is another implementation matter. Optional 'flow labels' may be associated with transmitted data to aid implementations of CFDP in determining how and when to issue the data.

2.3.5 RETRANSMISSION STRATEGIES

The quality of service offered by the protocol is selectable, according to mission requirements and transmission capability, and ranges from an unacknowledged option, whereby a file is transmitted with no attempt at completeness should errors occur (errors will be detected and data discarded), to a fully acknowledged option providing error recovery through retransmission. For the acknowledged modes of operation, several sub-options may be selected by the receiver. These sub-options relate to release time of any Negative Acknowledgments (NAKs) and range from immediate release to deferred release (whereby any NAKs are stored until the assumed end of the transmission). The extent of available retransmission strategies is more completely described in section 4.

2.3.6 VIRTUAL FILESTORE

The virtual filestore concept provides for a mapping of protocol filestore directives to actual filestore manipulation. The way in which this mapping is performed in an implementation is

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a local matter. Allowances are made in the protocol for inclusion of additional filestore directives using the Type-Length-Value (TLV) capability of the Metadata PDU.

To enable interoperability, this Recommendation assumes a minimum set of capabilities from the virtual filestore as follows:

- create file;
- delete file;
- rename file;
- append file;
- replace file;
- create directory;
- remove directory;
- list directory.

In some circumstances, it is advantageous for the CFDP protocol to be able to recognize record boundaries within the file. If this option is to be used, the filestore must have the capability to make the distinction between such files and those which are to be treated as a stream of octets.

2.4 OVERVIEW OF INTERACTIONS

Figure 2-3 shows the details of a Copy operation. (In all following figures in this section, dashed lines denote optional actions.)

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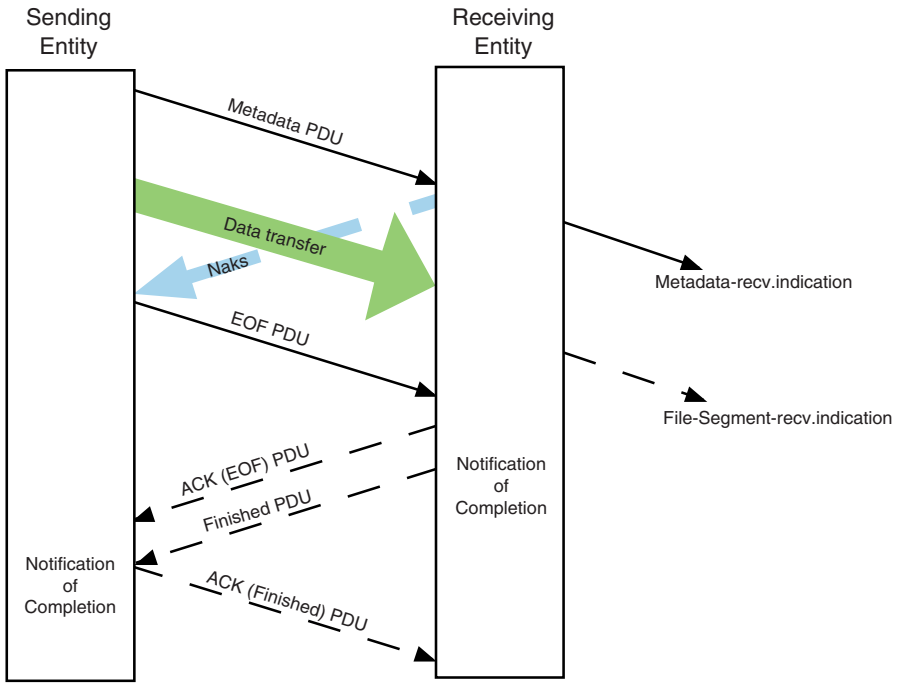

Figure 2-3: Copy Operations, Sequence of Events

All copy operations start with transmission of the Metadata, followed by transmission of the file segments and a PDU to indicate the End of File (EOF). Optional service primitives may be issued at the receiving entity to announce receipt of individual file segments; notification of receipt of Metadata is mandatory.

For reliable transactions, a number of features are added. NAKs are used to request retransmission of lost data. Receipt of the EOF PDU is ensured via an EOF acknowledgement. Since lost data may still be outstanding after the EOF sequence, a Finished PDU is sent when all file data has been successfully assembled. Delivery of this PDU is ensured through use of the Finished acknowledgement.

When the file transmission task is completed the sending and receiving entities issue Notices of Completion. These Notices of Completion are abstract internal events which are not exposed to the CFDP user. They are used to inform the Put procedures (described later in this section) of completion of the file transmission task.

The Put transaction is initiated by a `Put.request` from a CFDP user to the source entity. The `Put.request` results in initiation of the FDU transmission procedure and also of the first (possibly only) copy operation. The `Put.request` also results in the notification of a Transaction identifier to the application so that the transaction may subsequently be unambiguously identified. A Notice of Completion at the source entity causes it to issue a `Transaction-Finished.indication`. This process is optional at the destination entity. The Put transaction is illustrated in figure 2-4.

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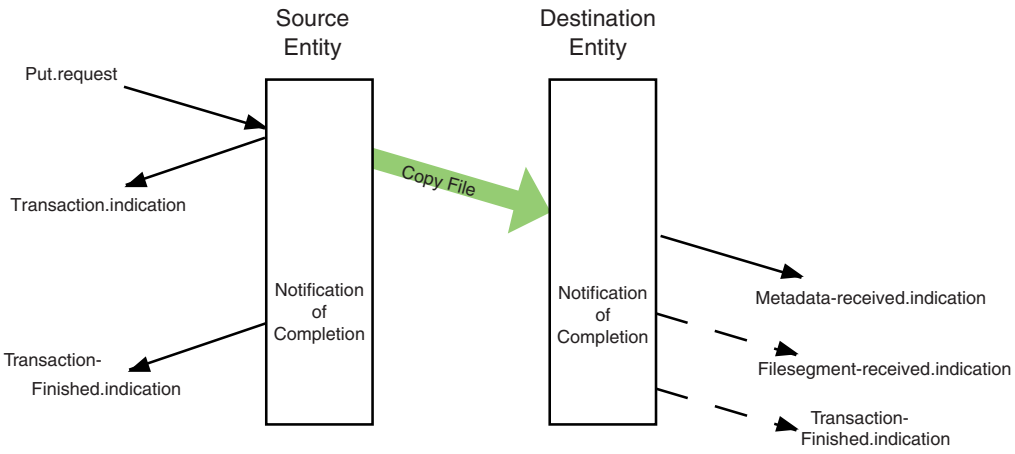

Figure 2-4: Put Operations, Sequence of Events

It is possible for the source and destination CFDP entities of a transaction to be unable to communicate directly; in this case the transaction may entail a series of point-to-point (sender-to-receiver) PDU exchange sessions between the source and destination CFDP entities and one or more waypoint CFDP entities, as shown in figure 2-5.

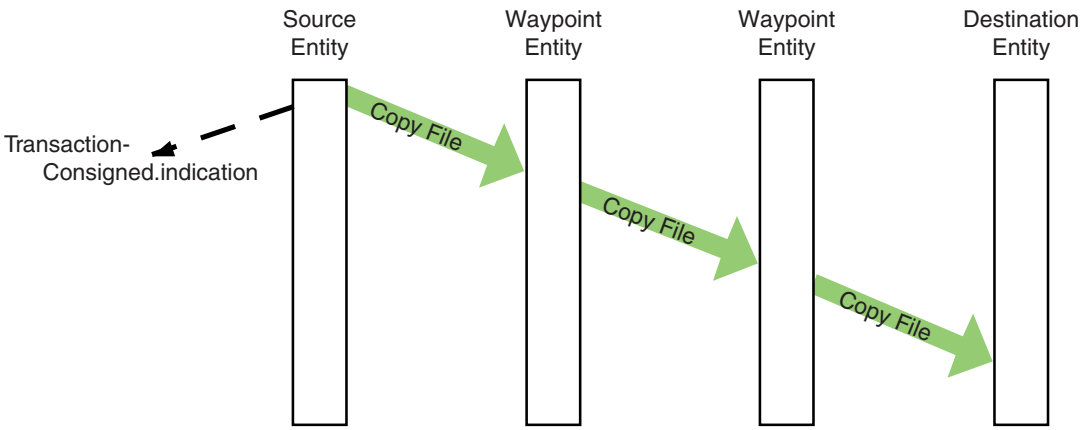

Figure 2-5: File Custody Transfer Operations, Sequence of Events

When the source of the file to be transferred is other than the local filestore, the requesting user must initiate a Put transaction containing a message to the user of the remote CFDP entity, the 'proxy user'. This message requests that the proxy user in turn submit a `Put.request` to that entity. The destination of the requested Put transaction may be the original requesting user (in which case the proxy operation functions as a 'Get') or some third CFDP user. On completion of the second transaction, the proxy user initiates a third transaction to notify the original requesting user of the completion of the proxy operation. A proxy put operation is illustrated in figure 2-6.

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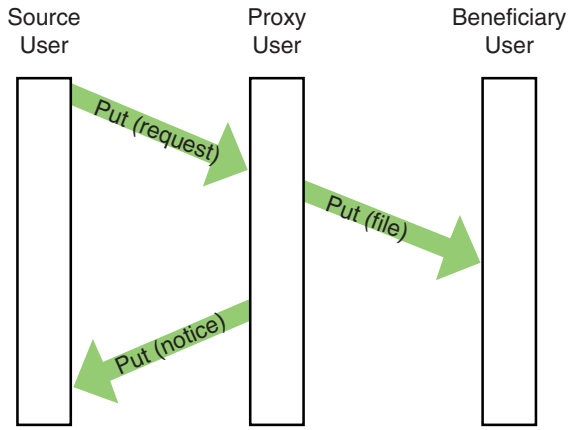

Figure 2-6: Proxy Put Operations, Sequence of Events

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3 SERVICE DESCRIPTION

3.1 SERVICES AT THE USER INTERFACE

3.1.1 The services provided by the protocol shall be made available to the CFDP user and shall include the following:

a) initiating the transmission of files between filestores;

b) initiating filestore operations on remote filestores;

c) receiving events related to the operation of current transactions;

d) requesting status information related to the current transactions;

e) sending or receiving messages associated with the current transactions;

f) suspending, resuming, or canceling the transmission of a current transaction.

3.1.2 The CFDP entity shall be implemented such that virtually any number of transactions may be concurrently in various stages of transmission or reception at a single CFDP entity.

NOTE – To clarify: the implementation must be able to accept a `Put.request` primitive, and thereupon initiate a new transaction, prior to the completion of previously initiated transactions. The completion of a transaction encompasses the initial transmission of file data by the source entity, the reception of some or all of that data by the destination entity, and any consequent acknowledgment and retransmission data exchange that may be necessary between the two entities. The requirement for concurrent transaction support therefore does not necessarily imply that the implementation must be able to begin initial transmission of file data for one transaction while initial transmission of file data for one or more other transactions is still in progress. (But neither is support for this functional model precluded.)

3.2 SUMMARY OF PRIMITIVES

3.2.1 The CFDP service shall consume the following request primitives:

a) `Put.request`;

b) `Report.request`;

c) `Cancel.request`;

d) `Suspend.request`;

e) `Resume.request`.

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3.2.2 The CFDP service shall deliver the following indication primitives:

a) `Transaction.indication`;

b) `EOF-Sent.indication`;

c) `Transaction-Finished.indication`;

d) `Metadata-Recv.indication`;

e) `File-Segment-Recv.indication`;

f) `Report.indication`;

g) `Suspended.indication`;

h) `Resumed.indication`;

i) `Fault.indication`;

j) `Abandoned.indication`;

k) `EOF-Recv.indication`.

3.2.3 When the Extended procedures are implemented, the CFDP service shall also deliver the following indication primitive: `Transfer-Consigned.indication`.

3.3 SUMMARY OF PARAMETERS

NOTE – The availability and use of parameters for each primitive are indicated in 3.5, where parameters that are optional are identified with square brackets [thus]. The following definitions apply.

3.3.1 The *destination CFDP entity ID* parameter shall uniquely identify the CFDP entity **to** which the FDU is to be sent.

3.3.2 The *source CFDP entity ID* parameter shall uniquely identify the CFDP entity **from** which the FDU is to be sent.

3.3.3 The *source file name* parameter

a) shall contain the full path name at which the file to be copied is located at the filestore associated with the source entity;

b) shall be omitted when the FDU to be Put contains only metadata, such as a message to a user or a standalone filestore request.

3.3.4 The *destination file name* parameter

a) shall contain the full path name to which the file to be copied will be placed at the filestore associated with the destination entity;

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b) shall be omitted when the FDU to be Put contains only metadata, such as a message to a user or a standalone filestore request.

3.3.5 The *segmentation control* parameter

a) shall indicate whether the file being delivered is to be segmented as an array of octets or as an array of variable-length records;

b) shall be omitted when local and remote file names are omitted.

3.3.6 The *Transaction ID* parameter shall uniquely identify a single instance of FDU delivery and shall contain the ID of the source CFDP entity together with a sequence number that is specific to that entity.

NOTES

1 At any moment, any given transaction ID is unique within the CFDP addressing domain that encompasses the source CFDP entity.

2 The entity ID and transaction sequence number are variable in length to accommodate differing mission requirements. A common parsing scheme is defined to allow full interoperability despite differing parameter lengths.

3.3.7 The *Condition code* parameter shall provide additional information on some change in transaction status.

3.3.8 The *Status report* parameter shall indicate the status of the indicated file delivery transaction. The format and scope of the *status report* parameter are specific to the implementation. It could contain information such as:

a) whether the transaction is finished, canceled, suspended, or active;

b) what extents of the FDU are known to have been successfully received by the receiving CFDP entity;

c) what extents of the FDU are known to have been transmitted by the sending CFDP entity.

3.3.9 *Fault handler overrides*:

a) If included, the optional *fault handler overrides* shall indicate the actions to be taken upon detection of one or more types of fault condition. Each fault handler override shall identify both a type of fault condition to be handled and the action to be taken in the event that a fault of this type is detected; each such action shall be one of the following:

– cancel the file delivery transaction,

– suspend the transaction,

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– ignore the fault but issue a `Fault.indication` primitive to the local CFDP user, or

– abandon the transaction and issue an `Abandoned.indication` primitive to the local CFDP user.

b) The fault conditions for which handler overrides may be specified are a subset of the conditions listed in table 5-5, later in this specification. The listed conditions that are *not* fault conditions are 'No error', 'Suspend request received', and 'Cancel request received'.

c) For each type of fault condition for which no *fault handler override* is included among the service request parameters, a default handler shall be selected according to the contents of the MIB.

3.3.10 If included, the optional *transmission mode* parameter shall override the default transmission mode. The values of the transmission mode parameter are 'acknowledged' or 'unacknowledged'.

3.3.11 If included, the optional *Messages to User* parameter shall be transmitted at the beginning of the transaction and delivered to the destination CFDP user upon receipt. Certain messages are defined in the Proxy, Remote Status Report, and Directory Operations section to allow remote initiation of CFDP transactions.

3.3.12 *Filestore Requests*:

a) if included, the optional *filestore requests* shall be transmitted at the beginning of the transaction and shall be acted upon by the destination entity when all data transfer activities of the transaction are completed;

b) to indicate the action to be taken, each *filestore request* shall include sub-parameters as follows:

– *action*,

– *file name 1*,

– *file name 2* (present for certain values of the *action* parameter);

c) the *action* sub-parameter may take the values of:

– *create file*,

– *delete file*,

– *rename file (file name 2* present*)*,

– *append file* (*file name 2* present),

– *replace file* (*file name 2* present),

– *create directory*,

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– *remove directory*,

– *'deny' file* (like *delete*, but does not fail if file does not exist),

– *'deny' directory* (like *remove*, but does not fail if directory does not exist);

d) when the value of the *file name 1* or *file name 2* sub-parameter is equal to the value of the *destination file name* parameter, the file to which the filestore request pertains shall be the newly delivered file;

e) in the case of multiple *filestore requests* in the same transaction, the source entity shall preserve the order in which the requests were submitted and the destination entity shall execute them in this same order.

3.3.13 The *Filestore Responses* parameter shall indicate whether the indicated *filestore requests* in the indicated transaction succeeded or failed and shall include the following additional information for each filestore request:

– if it failed, an explanation;

– if it succeeded, a report in action-specific format (if relevant).

3.3.14 The *Filestore Responses* parameter shall not be used to convey directory listing information; the transfer of directory listing information is achieved via Directory Operations transactions.

3.3.15 The *flow label* parameter may optionally be used to support prioritization and preemption schemes.

NOTE – The *flow label* parameter should be taken as a hint to the order in which PDUs should be transmitted when the opportunity arises, but the manner in which flow labels are used is strictly an implementation matter.

3.3.16 The *offset* parameter shall indicate a displacement from the beginning of the file.

3.3.17 The *length* parameter shall indicate the number of octets of file data received.

3.3.18 The *progress* parameter shall report on current file transmission or reception progress, as defined earlier.

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3.4 SERVICES REQUIRED OF THE UNDERLYING COMMUNICATION SYSTEM

The service primitives and parameters required to access the services of the Unitdata Transfer (UT) layer are:

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

NOTES

1 The service assumed of the underlying layer is as simple as possible to allow CFDP to be as generally applicable as possible. For the purposes of this specification the service is referred to as the UT service and the delimited data unit it transfers is the UT Service Data Unit (UT_SDU). Although the UT layer is conceptually a single service, in practice CFDP might use several different physical underlying communication systems at different times, or even concurrently, depending on the remote entities with which it is in communication. In a purely CCSDS network the sole service could be the CCSDS Path or Packet service, and the UT_SDU would be the data field of a CCSDS packet.

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

3 The CFDP protocol operates over a single conceptual UT service access point. In practice, the implementation of the UT layer is not constrained to provide all services through a single physical service access point. Different physical service access points would necessarily be provided if different physical underlying communication systems were in use concurrently. A given implementation might even maintain a different physical service access point for each remote entity with which CFDP is currently (at any moment) in direct communication.

4 The above list of mandatory UT layer service primitives does not imply that the UT layer is prohibited from supporting additional services for the convenience of the CFDP implementation. Possible additional primitives that might prove valuable include:

- An indication whenever the UT layer is prepared to accept another PDU for transmission to the UT layer instance at an identified UT address. (This indication could be used to implement data flow control. Destination UT address might be needed in the indication because the UT layer might be transmitting concurrently to multiple UT addresses.)
- An indication whenever the UT layer completes transmission of a UT_SDU whose content is a CFDP PDU to which Positive Acknowledgment procedures apply. (This indication could be used to start positive acknowledgment timers.)

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5 The assumed minimum underlying quality of service is:

– with possible errors in the delivered UT_SDUs;

– incomplete, with some UT_SDUs missing;

– in sequence; i.e., the delivered UT_SDUs are delivered in the order in which they were transmitted. (In-sequence arrival is specifically assumed in the design of the immediate, asynchronous, and prompted lost segment detection modes and the Keep Alive mechanism.)

The CFDP protocol can operate over a service where data errors and data loss occur; and when no incremental lost segment detection procedures are in effect, even out-of-sequence data arrival can be tolerated. However, the protocol is not intended to compensate for networks where these effects are prevalent. Severe performance reductions will result if such an approach is taken.

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3.5 CFDP SERVICE PRIMITIVES

3.5.1 `Put.request`

3.5.1.1 Function

The `Put.request` primitive shall be used by the application to request delivery of a file from the source filestore to a destination filestore.

3.5.1.2 Semantics

`Put.request` shall provide parameters as follows:

```
Put.request   (destination CFDP entity ID,
               [source file name],
               [destination file name],
               [segmentation control],
               [fault handler overrides],
               [flow label],
               [transmission mode],
               [messages to user],
               [filestore requests])
```

3.5.1.3 When Generated

`Put.request` is generated by the source CFDP user at any time.

3.5.1.4 Effect on Receipt

Receipt of `Put.request` shall cause the CFDP entity to initiate source entity put procedures.

3.5.1.5 Additional Comments

None.

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3.5.2 `Cancel.request`

3.5.2.1 Function

The `Cancel.request` primitive shall be used to request that a transaction be canceled.

3.5.2.2 Semantics

`Cancel.request` shall provide parameters as follows:

`Cancel.request` (transaction ID)

3.5.2.3 When Generated

`Cancel.request` is generated by any CFDP user at any time during the lifetime of any transaction.

3.5.2.4 Effect on Receipt

Receipt of `Cancel.request` shall cause a Notice of Cancellation at the local entity.

3.5.2.5 Additional Comments

None.

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3.5.3 `Suspend.request`

3.5.3.1 Function

The `Suspend.request` primitive shall be used to request that a transaction be suspended.

3.5.3.2 Semantics

`Suspend.request` shall provide parameters as follows:

`Suspend.request` (transaction ID)

3.5.3.3 When Generated

`Suspend.request` is generated by any CFDP user at any time during the lifetime of any transaction, except that for a transaction sent in unacknowledged mode it can only be generated by the transaction's source user.

3.5.3.4 Effect on Receipt

Receipt of `Suspend.request` shall cause a Notice of Suspension at the local entity.

3.5.3.5 Additional Comments

None.

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