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Space data and information transfer systems — Advanced orbiting systems — Networks and data links — Architectural specification

*Systèmes de transfert des informations et données spatiales — Systèmes
perfectionnés sur orbite — Réseaux et liaisons de données —
Spécification de l'architecture*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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Space data and information transfer systems — Advanced orbiting systems — Networks and data links — Architectural specification

1 Scope

This International Standard specifies the requirements for the architecture of the networks and data links of advanced orbiting systems.

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 701.0-B-2, November 1992, *Recommendation for space data system standards — Advanced orbiting systems, networks and data links: Architectural specification*.

For the purposes of international standardization, the modifications outlined below shall apply to the following pages of publication CCSDS 701.0-B-2.

Pages i to iii

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

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Add the following information to the references indicated:

[2] Document CCSDS 102.0-B-3, November 1992 is equivalent to ISO 13419:—¹⁾

[3] Document CCSDS 101.0-B-3, May 1992 is equivalent to ISO 11754:1994.

[4] Document CCSDS 203.0-B-1, January 1987 is equivalent to ISO 12174:—¹⁾.

[6] Document CCSDS 201.0-B-1, January 1987 is equivalent to ISO 12171:—¹⁾.

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Since the issue of Recommendation CCSDS 701.2-B-2 in November 1992, certain ISO documents (references [15] through [19]) have been updated. In view of this, the possibility of referring to the following up-to-date International Standards will be considered on the occasion of the next revision of publication CCSDS 701.2-B-2.

[15] ISO/IEC 7498-1:1994, *Information technology — Open Systems Interconnection — Basic Reference Model: The Basic Model*.

¹⁾ To be published.

ISO 7498-2:1989, *Information processing systems — Open Systems Interconnection — Basic Reference Model — Part 2: Security Architecture.*

ISO 7498-3:1989, *Information processing systems — Open Systems Interconnection — Basic Reference Model — Part 3: Naming and addressing.*

ISO/IEC 7498-4:1989, *Information processing systems — Open Systems Interconnection — Basic Reference Model — Part 4: Management framework.*

- [16] ISO/IEC 8473-1:1994, *Information technology — Protocol for providing the connectionless-mode network service — Part 1: Protocol specification.*

ISO/IEC 8473-2:1996, *Information technology — Protocol for providing the connectionless-mode network service — Part 2: Provision of the underlying service by an ISO/IEC 8802 subnetwork.*

ISO/IEC 8473-3:1995, *Information technology — Protocol for providing the connectionless-mode network service — Part 3: Provision of the underlying service by an X.25 subnetwork.*

ISO/IEC 8473-4:1995, *Information technology — Protocol for providing the connectionless-mode network service — Part 4: Provision of the underlying service by a subnetwork that provides the OSI data link service.*

ISO/IEC 8473-5:1997, *Information technology — Protocol for providing the connectionless-mode network service — Part 5: Provision of the underlying service by ISDN circuit-switched B-channels.*

- [17] ISO/IEC 8348:1996, *Information technology — Open Systems Interconnection — Network Service Definition.*

- [18] ISO 8348 Addendum 1:1987 was included in ISO/IEC 8348:1993 (see clause 3).

- [19] ISO 8348 Addendum 3:1989 was replaced by ISO 8348-4:1995.

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Add the following information to reference [20]:

Document CCSDS 301.0-B-2, April 1990 is equivalent to ISO 11104:1991.

3 Revision of publication CCSDS 701.0-B-2

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 701.0-B-2. To this end, NASA will act as a liaison body between CCSDS and ISO.

Consultative Committee for Space Data Systems

RECOMMENDATION FOR SPACE
DATA SYSTEMS STANDARDS

ADVANCED ORBITING SYSTEMS, NETWORKS AND DATA LINKS:

ARCHITECTURAL SPECIFICATION

CCSDS 701.0-B-2

BLUE BOOK

November 1992



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CCSDS RECOMMENDATION FOR ADVANCED ORBITING SYSTEMS

AUTHORITY

Issue:	Blue Book, Issue 2
Date:	November 1992
Location:	Annapolis, Maryland, USA

This Recommendation reflects the consensus technical agreement of the following member Agencies of the Consultative Committee for Space Data Systems (CCSDS):

- o British National Space Centre (BNSC)/United Kingdom.
- o Canadian Space Agency (CSA)/Canada.
- o Central Research Institute of Machine Building (TsNIIMash)/ Russian Federation.
- o Centre National D'Etudes Spatiales (CNES)/France.
- o Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V.(DLR)/Germany.
- o European Space Agency (ESA)/Europe.
- o Instituto de Pesquisas Espaciais (INPE)/Brazil.
- o National Aeronautics and Space Administration (NASA)/USA.
- o National Space Development Agency of Japan (NASDA)/Japan.

The following observer Agencies also concur with this Recommendation:

- o Chinese Academy of Space Technology (CAST)/People's Republic of China.
- o Central Research Institute of Physics (CRIP)/Hungary.
- o Department of Communications, Communications Research Centre (DOC-CRC)/Canada.
- o Institute of Space and Astronautical Science (ISAS)/Japan.

This Recommendation is published and maintained by:

CCSDS Secretariat
 Program Integration Division (Code-OI)
 National Aeronautics and Space Administration
 Washington, DC 20546, USA

STATEMENT OF INTENT

The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of member space Agencies. 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 RECOMMENDATIONS and are not considered binding on any Agency.

This RECOMMENDATION is issued by, and represents the consensus of, the CCSDS Plenary body. Agency endorsement of this RECOMMENDATION is entirely voluntary. Endorsement, however, indicates the following understandings:

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

No later than five years from its date of issuance, this Recommendation 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 cancelled.

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

CCSDS RECOMMENDATION FOR ADVANCED ORBITING SYSTEMS

FOREWORD

This document, which is a technical Recommendation prepared by the Consultative Committee for Space Data Systems (CCSDS), is intended for use by participating space Agencies in their development of "Advanced Orbiting Systems".

The CCSDS has previously developed a set of layered Telemetry and Telecommand Recommendations which meet the common requirements of conventional missions, as characterized by the bidirectional (but asymmetric) transfer of data between moderately complex space and ground systems, serving a moderate number of users, at low-to-medium data rates.

This document extends the previous set of CCSDS Recommendations for conventional missions, to accommodate extra services needed by Advanced Orbiting Systems. Target Advanced Orbiting Systems include manned and man-tended space stations, unmanned space platforms, free-flying spacecraft, and new space transportation systems, many of which require a richer repertoire of data handling services than are provided by the conventional Recommendations.

This Recommendation allows the implementing organizations within each Agency to proceed coherently with the development of compatible Standards for the flight and ground elements associated with Advanced Orbiting Systems that are within their cognizance. Agency Standards derived from this Recommendation may implement only a subset of the optional features allowed herein, or may incorporate features not addressed by the Recommendation.

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 [1].

CCSDS RECOMMENDATION FOR ADVANCED ORBITING SYSTEMS

DOCUMENT CONTROL

Document/Title	Date	Status and Substantive Changes
CCSDS 701.0-B-1, Recommendation for Space Data Systems Standards: Advanced Orbiting Systems, Networks and Data Links: Architectural Specification, Issue 1	October 1989	Original Issue
CCSDS 701.0-B-2, Recommendation for Space Data Systems Standards: Advanced Orbiting Systems, Networks and Data Links: Architectural Specification, Issue 2	November 1992	- Supersedes Issue-1 - No substantive technical changes - primarily incorporates numerous small clarifications resulting from formal protocol validation and early implementation experience: - refines Insert service addressing by introducing a "LinkID"; - adds the APID as a mandatory parameter for Path service; - adds the PCID as a mandatory parameter for Multiplexing service; - adds the VCDU Loss Flag as a mandatory parameter for the VCA service; - describes operation of the Bitstream Data Loss Flag; - corrects editorial errors in Figures 5-9 and 5-15; - provides clearer discussion of the Bit Transition Generator; - defines SCID naming domain conventions. - Adds a more complete specification of the VCDU Header Error Control. - Adds a new Annex on Packet Timetagging. - Deletes references to undeveloped documentation (SLAP, Management and Signalling).

NOTE: All text changes from the previous issue are flagged with change bars in the margin. Deleted text is indicated by a single short dash ("—") in the margin.

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REFERENCES

- [1] "Procedures Manual for the Consultative Committee for Space Data Systems", CCSDS A00.0-Y-5, Yellow Book, Issue 5 (Washington, D.C.: CCSDS, May 1992 or later issue).
- [2] "Packet Telemetry", Recommendation for Space Data Systems Standards, CCSDS 102.0-B-3, Blue Book, Issue 3 (Washington, D.C.: CCSDS, November 1992 or later issue).
- [3] "Telemetry Channel Coding", Recommendation for Space Data Systems Standards, CCSDS 101.0-B-3, Blue Book, Issue 3 (Washington, D.C.: CCSDS, May 1992 or later issue).
- [4] "Telecommand Part 3—Data Management Service", Recommendation for Space Data Systems Standards, CCSDS 203.0-B-1, Blue Book, Issue 1 (Washington, D.C.: CCSDS, January 1987 or later issue).
- [5] "Telecommand Part 2—Data Routing Service", Recommendation for Space Data Systems Standards, CCSDS 202.0-B-2, Blue Book, Issue 2 (Washington, D.C.: CCSDS, November 1992 or later issue).
- [6] "Telecommand Part 1—Channel Service", Recommendation for Space Data Systems Standards, CCSDS 201.0-B-1, Blue Book, Issue 1 (Washington, D.C.: CCSDS, January 1987 or later issue).
- [7] "Audio, Video and Still-Image Communications Services", Recommendation for Space Data Systems Standards, CCSDS 704.0-R-2, Red Book, Issue 2 (Washington, D.C.: CCSDS, May 1993 or later issue).
- [8] "Advanced Orbiting Systems, Networks and Data Links: Summary of Concept, Rationale and Performance", Report Concerning Space Data Systems Standards, CCSDS 700.0-G-3, Green Book, Issue 3 (Washington, D.C.: CCSDS, November 1992 or later issue).
- [9] "Advanced Orbiting Systems, Networks and Data Links: Formal Definition of CPN Protocols, Methodology and Approach", Report Concerning Space Data Systems Standards, CCSDS 705.0-G-2, Green Book, Issue 2 (Washington, D.C.: CCSDS, May 1993 or later issue).
- [10] "Advanced Orbiting Systems, Networks and Data Links: Abstract Data Type Library", Recommendation for Space Data Systems Standards, CCSDS 705.1-R-2, Red Book, Issue 2 (Washington, D.C.: CCSDS, May 1993 or later issue).

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- [11] “Advanced Orbiting Systems, Networks and Data Links: Formal Specification of the Path Service and Protocol”, Recommendation for Space Data Systems Standards, CCSDS 705.2-R-2, Red Book, Issue 2 (Washington, D.C.: CCSDS, May 1993 or later issue).
- [12] “Advanced Orbiting Systems, Networks and Data Links: Formal Specification of the VCLC Service and Protocol”, Recommendation for Space Data Systems Standards, CCSDS 705.3-R-2, Red Book, Issue 2 (Washington, D.C.: CCSDS, May 1993 or later issue).
- [13] “Advanced Orbiting Systems, Networks and Data Links: Formal Specification of the VCA Service and Protocol”, Recommendation for Space Data Systems Standards, CCSDS 705.4-R-2, Red Book, Issue 2 (Washington, D.C.: CCSDS, May 1993 or later issue).
- [14] “Radio Frequency and Modulation Systems; Part 1: Earth Stations and Spacecraft”, Recommendation for Space Data Systems Standards, CCSDS 401.0-B, Blue Book (Washington, D.C.: CCSDS, September 1989 or later issue). Note: Since this Reference does not currently cover data relay satellites, the following document shall be substituted for Reference [14]: STDN 101.2, “Space Network (SN) Users’ Guide” [formerly titled “Tracking and Data Relay Satellite System (TDRSS) Users’ Guide”], Revision 6, (Greenbelt, Maryland: NASA Goddard Space Flight Center, September 1988 or later issue).
- [15] “Information Processing Systems—Open Systems Interconnection—Basic Reference Model”, ISO 7498 (Geneva: ISO, 1984).
- [16] “Information Processing Systems—Data Communications—Protocol for Providing the Connectionless-Mode Network Service”, ISO 8473 (Geneva: ISO, 1988).
- [17] “Information Technology—Telecommunications and Information Exchange Between Systems—Network Service Definition for Open Systems Interconnection”, ISO 8348 (Geneva: ISO, 1992).
- [18] “Information Processing Systems—Data Communications—Network Service Definition—Addendum 1: Connectionless Mode Transmission”, ISO 8348 AD1 (Geneva: ISO, 1987).
- [19] “Information Processing Systems—Data Communications—Protocol for Providing the Connectionless-Mode Network Service—Addendum 3: Provision of the Underlying Service Assumed by ISO 8473 over Subnetworks which Provide the OSI Data Link Service”, ISO 8473 AD3 (Geneva: ISO, 1989).
- [20] “Time Code Formats”, Recommendation for Space Data Systems Standards, CCSDS 301.0-B-2, Blue Book, Issue 2 (Washington, D.C.: CCSDS, April 1990 or later issue).

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CCSDS RECOMMENDATION FOR ADVANCED ORBITING SYSTEMS

1 INTRODUCTION

- 1.a This document is a Recommendation of the Consultative Committee for Space Data Systems (CCSDS). The CCSDS is an international standardization body which is chartered with developing standard solutions to data handling problems that are common to many types of space missions; its operating principles and procedures are defined in Reference [1].

1.1 PURPOSE OF THIS DOCUMENT

- 1.1.a The purpose of this document is to establish a CCSDS Recommendation for the architecture of the space/ground and space/space data handling systems which are embedded within a category of complex, networked space missions called "Advanced Orbiting Systems".
- 1.1.b This document specifies an architectural framework within which the Agencies participating in the CCSDS may implement compatible space mission data handling systems, so that opportunities for inter-Agency cross support and cooperation are maximized. It defines the top-level characteristics of the systems architecture, but not necessarily all of the detailed specifications that would be required to implement a concrete system. Where appropriate, the CCSDS may extend or supplement this document with more detailed specifications as the need is identified.
- 1.1.c This Recommendation primarily addresses those data handling operations which are unique to space missions. It therefore focuses on data transmission through special-purpose space data links, and their associated interface networks. Wherever possible and technically appropriate, interfaces with the commercial networking environment are provided so that the emerging infrastructure of commercial Open Systems Interconnection (OSI) may be exploited.

1.2 SCOPE OF THIS DOCUMENT

- 1.2.a Between 1982 and 1986, in response to the mission requirements of that era, CCSDS developed a series of technical Recommendations (References [2] through [6]) for the standardization of common data-system functions across a spectrum of "Conventional" missions.
- 1.2.b To meet the needs of the "Advanced Orbiting Systems" of the 1990s and beyond, CCSDS is extending its previous Recommendations to provide a more diverse and flexible set of data handling services. Advanced Orbiting Systems include manned and man-tended space stations, unmanned space platforms, free-flying spacecraft and new space transportation systems, many of which need services to concurrently transmit multiple digital data types (including audio and video) through space/ground and ground/space data channels.

- 1.2.c This Recommendation specifies the architecture, services and protocols to be used within a "CCSDS Principal Network" (CPN) that supports CCSDS Advanced Orbiting Systems. The scope of the CPN is addressed in section 2.

1.3 APPLICABILITY OF THIS DOCUMENT

- 1.3.a This Recommendation serves as a guideline for the development of compatible internal Agency standards for advanced orbiting data systems. Systems embraced by this Recommendation are foreseen to enter development during the 1990s and include: manned and man-tended space stations; unmanned space platforms; free-flying spacecraft; and new space transportation systems.
- 1.3.b This Recommendation is not retroactive, nor does it commit any Agency to implement the recommended concepts at any future time. Nevertheless, all CCSDS Agencies accept the principle that all future implementations of advanced orbiting data systems which are used in inter-Agency cross support situations will be based on this Recommendation.
- 1.3.c The recommendations in this document are to be invoked through the normal standards programs of each member Agency, and are applicable to those missions for which cross support based on capabilities described in this Recommendation is anticipated. Where mandatory capabilities are clearly indicated in sections of the Recommendation, they must be implemented when this document is used as a basis for cross support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross support agreements between the Agencies involved.

1.4 INTERFACES WITH CONVENTIONAL SYSTEMS

- 1.4.a This Recommendation draws heavily upon previous CCSDS Recommendations for the asymmetric flow of Telemetry and Telecommand data within Conventional space systems, as defined in References [2] through [6]. Where feasible, appropriate elements of the previous Recommendations are used directly. In other cases, upward-compatible extensions of the previous Recommendations are defined to satisfy new requirements, such as the integration of digitized audio and video (Reference [7]) into space data streams.
- 1.4.b By virtue of this upward compatibility, it should be noted that this Recommendation does not preclude "mixed" mission configurations whereby Conventional space systems are operated in conjunction with Advanced Orbiting Systems. For example:
- 1.4.c the space-located elements of CCSDS Advanced Orbiting Systems may interface with independent free-flying spacecraft whose data-communications systems conform to Conventional CCSDS Recommendations. These interfaces are

CCSDS RECOMMENDATION FOR ADVANCED ORBITING SYSTEMS

technically supported via the various Service Access Points identified in Section 2, but may not be specifically addressed within this Recommendation;

- 1.4.d some missions may wish to operate hybrid configurations; e.g., a Conventional CCSDS Telecommand uplink as described in References [4], [5], and [6] may be paired with an Advanced Orbiting Systems downlink. (Note that this configuration would not satisfy the integration of digitized audio and video into the uplink data stream.) Such hybrid configurations are technically supported by the data structures defined in Section 5 of this Recommendation, but they are the subject of detailed negotiations between Projects and CCSDS cross support organizations. A discussion of hybrid Telecommand operations is contained in Reference [8].

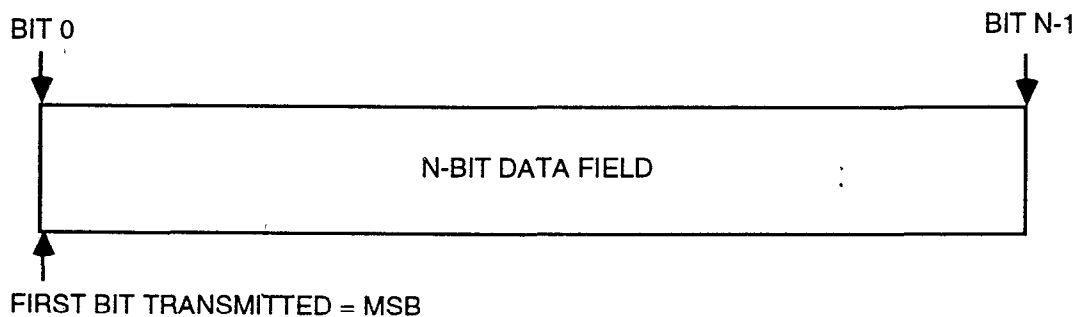
1.5 ORGANIZATION AND STATUS OF THIS DOCUMENT

- 1.5.a This document, which is the main Recommendation for CCSDS Advanced Orbiting Systems, contains a definition of the CCSDS Principal Network and specifications of its associated services and protocols. It is supplemented by CCSDS Reports (References [8] and [9]), which are not part of the Recommendation, and by implementation-oriented service and protocol definitions (References [10] through [13]), which are written in a formal specification language.
- 1.5.b The main Recommendation contains this introduction (Section 1) plus six technical sections and two Annexes as follows:
- 1.5.c Section 2 contains a description of the CCSDS Principal Network (CPN), including a broad definition of the services it provides. In case of conflict, the specifications contained in Sections 3 through 7 shall take precedence over the descriptive material in Section 2.
- 1.5.d Section 3 contains the controlling technical specification for a CCSDS "Path service", and its associated protocol, which supports one method for transferring user data through the CPN. A formal definition of the Path protocol is contained in Reference [11].
- 1.5.e Section 4 contains the controlling technical specification for a CCSDS "Internet Service", and its associated protocol, which supports another method for transferring user data through the CPN.
- 1.5.f Section 5 contains the controlling technical specification for a CCSDS "Space Link Subnetwork", and its associated services and protocols, which supports a variety of methods for transferring data through space/space and space/ground channels. A formal definition of the Space Link Subnet protocol is contained in References [12] and [13].

- 1.5.g Section 6 contains an architectural overview of a space link retransmission protocol, which supports the reliable transfer of data through space channels. (The CCSDS Secretariat should be consulted for information concerning the detailed service and protocol specifications for this "Space Link ARQ Procedure".)
- 1.5.h Section 7 contains a summary of the requirements which a Project must satisfy in order to be compatible with this Recommendation for the purpose of obtaining cross support from other organizations.
- 1.5.i Annex A contains a definition of the mechanisms to be used for CCSDS packet timetagging.
- 1.5.j Annex B contains a list of the acronyms and terminology used throughout the main Recommendation. First-time readers are strongly urged to become familiar with the contents of this Annex, which is augmented by the index.
- 1.5.k A supporting CCSDS Report, Reference [8], summarizes key operational concepts of the CCSDS Principal Network. It provides general rationale and tutorial information, and presents supporting analysis of space data channel performance implications. First-time readers are strongly urged to become familiar with the contents of this Report.

1.6 BIT NUMBERING CONVENTION AND NOMENCLATURE

- 1.6.a 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".
- 1.6.b In accordance with standard data-communications practice, data fields are often grouped into 8-bit "words" which conform to the above convention. Throughout this Recommendation, such an 8-bit word is called an "octet".
- 1.6.c By CCSDS convention, all "spare" bits shall be permanently set to value "zero".

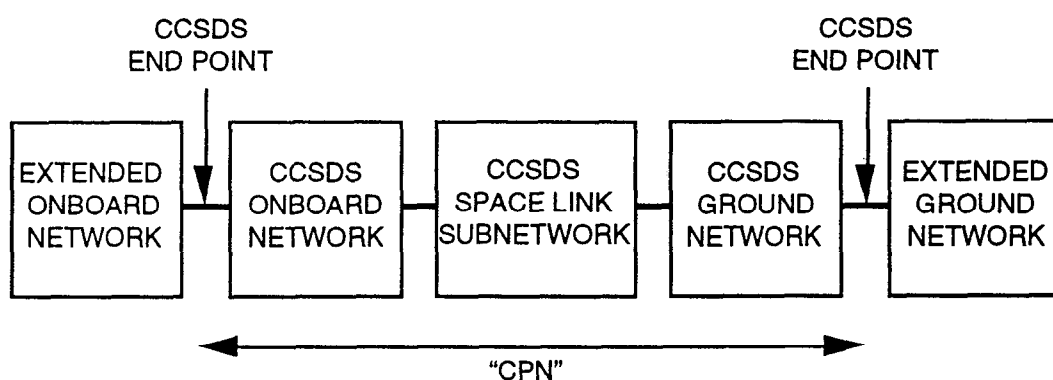


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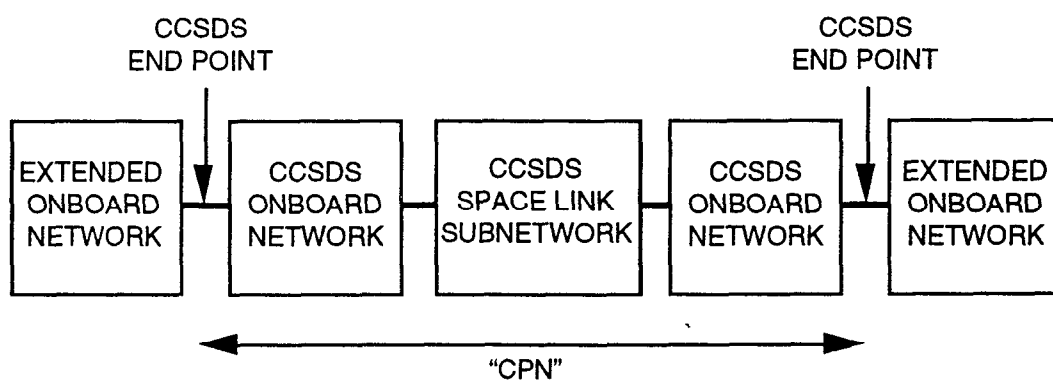
2 SYSTEM OVERVIEW

2.1 SCOPE OF THE CCSDS PRINCIPAL NETWORK

- 2.1.a This Recommendation defines a conceptual model for a CCSDS Principal Network (CPN). A CPN serves as, or is embedded within, the Project data handling networks which provide end-to-end data flow in support of space mission users. A CPN consists of an "Onboard Network" in an orbiting segment connected via a CCSDS "Space Link Subnetwork" either to a "Ground Network", or to an Onboard Network in another orbiting segment. The conceptual context of a CPN is shown in Figure 2-1 in both a space/ground and a space/space configuration.



(A) SPACE/GROUND CONFIGURATION



(B) SPACE/SPACE CONFIGURATION

Figure 2-1: CCSDS Principal Network Elements

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- 2.1.b Recognizing the uniqueness of data transfer through special-purpose space data channels, this Recommendation specifies the full suite of services and protocols operating within the Space Link Subnetwork (SLS). It also specifies the end-to-end services and protocols required for the transfer of user data across the entire CPN. It does not make recommendations regarding the internal protocols operating within the Onboard and Ground Networks, nor does it define or make recommendations concerning extended services beyond the conceptual bounds of the CPN.
- 2.1.c Within the SLS, this Recommendation assumes the use of space/ground data channels as defined in Reference [14]. Although it is possible that many space/space data channels may also be embraced by this Recommendation, its applicability to general space/space communications has not been determined.
- 2.1.d Two end-to-end service options are offered to users for the packetized transfer of data across the CPN: "Path" service and "Internet" service. The CPN extends to the points at which the Path or Internet data-transfer protocols are terminated, and, as such, locations of the end points of the CPN are not explicitly defined by CCSDS. Note that this does not preclude the use of CCSDS data transfer protocols as extended end-to-end protocols outside the bounds of the CPN, in which case Project organizations may use them within "extended" Onboard or Ground Networks.
- 2.1.e As far as the scope of the CCSDS Onboard or Ground Networks is concerned, they may consist of:
 - 2.1.f multiple interconnected subnetworks traversed by Internet and/or Path protocol data units; or
 - 2.1.g a single subnetwork traversed by Internet and/or Path protocol data units; or
 - 2.1.h a data link traversed by Internet and/or Path protocol data units; or
 - 2.1.i an internal communication within a data system using Internet and/or Path protocol data units.

2.2 CROSS SUPPORT

- 2.2.a CCSDS seeks to provide a communication systems architecture that facilitates opportunities for inter-Agency "cross support", which is defined as the capability for one space Agency to bidirectionally transfer another Agency's data between ground and space systems, using its own transmission resources. Cross support takes place at the level of data structures that are created by one Agency and handed over to another Agency for transmission. This is achieved by exposing standard service interfaces to the (otherwise private) communications infrastructure which is provided by the cooperating Agencies. The addresses of such service interfaces on the CPN are called "Service Access Points" (SAPs).

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- 2.2.b The cross support concept for CCSDS Advanced Orbiting Systems is based upon the following precepts:
- 2.2.c each Agency has its own private network implementation;
- 2.2.d the cross support services that are provided must be independent of the physical implementation of an Agency's network;
- 2.2.e the cross support services should be arranged so as to support the transfer of data structures created at different layers of the CPN protocol architecture; i.e., flexible service interfaces should be offered;
- 2.2.f incomplete data structures, or data structures containing detected but uncorrectable errors, are not required to be delivered in cross support situations (though in case of nondelivery, error reports may be provided using optional service parameters).
- 2.2.g To realize this concept, CCSDS specifies the exposed service interfaces at which the various services can be obtained, the corresponding interface primitives to be implemented to access them, and their associated data structures.
- 2.2.h The requirements which a Project organization must satisfy in order to be compatible with this Recommendation, and their cross support implications, are defined in Section 7.
- 2.2.i The service interfaces defined in this Recommendation are abstract service interfaces: a specific implementation is not intended, and therefore such an implementation is the subject of local Agency or Project agreements.

2.3 OVERVIEW OF SERVICES WITHIN THE CCSDS PRINCIPAL NETWORK

- 2.3.a A conceptual model of a typical space mission CPN data-flow configuration is shown in Figure 2-2. Here, examples of the various user services offered by the Onboard and Ground Networks, and the Space Link Subnetwork, are indicated. Note that data may flow in either direction (from space to ground, or from ground to space) in association with any of the services. Also note that, although Figure 2-2 does not depict the space-to-space configuration, the concept is identical.
- 2.3.b The CPN model is layered, showing its general correspondence to the Open Systems Interconnection (OSI) model which is maintained by the International Organization for Standardization (ISO), Reference [15]. The CPN model, in addition to clearly indicating the nature and number of services provided by the CPN, also allows the systems implementers to better understand the complexities involved in providing the services.

- 2.3.c Since the whole CPN is conceptually composed of two architecturally symmetric halves, the services associated with the model may be made simpler to understand by concentrating on only one of the halves, as shown in Figure 2-3. It should be noted that in a physical implementation the two halves are not necessarily identical owing to operational factors which are discussed in more detail in Reference [8]; however, in this conceptual discussion the differences are put aside.
- 2.3.d Eight separate services are provided within a CPN. Two of these services ("Internet" and "Path") operate in an asynchronous mode across the entire CPN. The remaining six services ("Encapsulation", "Multiplexing", "Bitstream", "Virtual Channel Access", "Insert", and "Virtual Channel Data Unit") are provided in either an asynchronous or isochronous mode by the Space Link Subnetwork.

2.3.1 CCSDS PRINCIPAL NETWORK END-TO-END DATA TRANSFER SERVICES

- 2.3.1.a Two services, the Internet service and the Path service, operate end-to-end across a CPN. Project-defined "application services" may exist above these services to provide higher layer functions such as data-base access and file transfer, but CCSDS does not define their characteristics. For instance, while a Project-defined "stack" (OSI Layers 4-7) of protocols may exist above the CCSDS Internet service to support application services, these protocols are not specified by CCSDS: the shaded areas in Figure 2-2 and 2-3 specifically indicate the services which ARE NOT discussed within this Recommendation.
- 2.3.1.b Since both the Internet and Path services rely on underlying subnetworks which may not preserve sequence, end-to-end data transfer using these services is defined to be non-sequence preserving; the SLS, however, does preserve sequence.

2.3.1.1 INTERNET SERVICE

- 2.3.1.1.a The Internet service routes variable-length network service data units end-to-end across the CPN, from a sending Network layer SAP to a receiving Network layer SAP. Each network service data unit contains a delimited string of octets representing higher-layer user data. The transfer is asynchronous, non-sequence preserving, and with lifetime control.
- 2.3.1.1.b This service is expected to be used primarily for intermittently transferring, at relatively low data rates, low to moderate volumes of structured, delimited data from a single source end point to a single destination end point. Such uses may require access to upper-layer ISO protocol services, or may require communication through space links with applications that are accessible through ISO ground networks. This service could be used to support, for example, realtime interactive command and control operations, file transfer, and interactive operations such as electronic mail and remote terminal access.

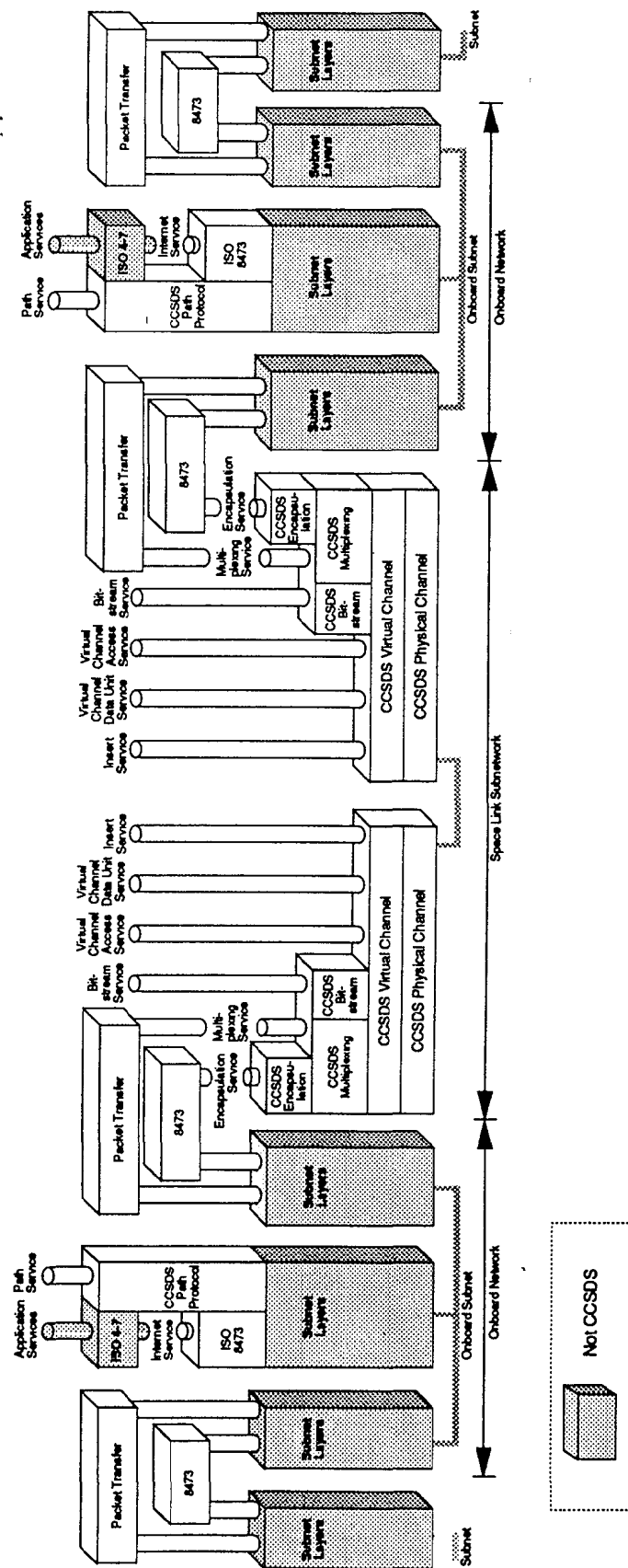


Figure 2-2: CCSDS Principal Network Service Model

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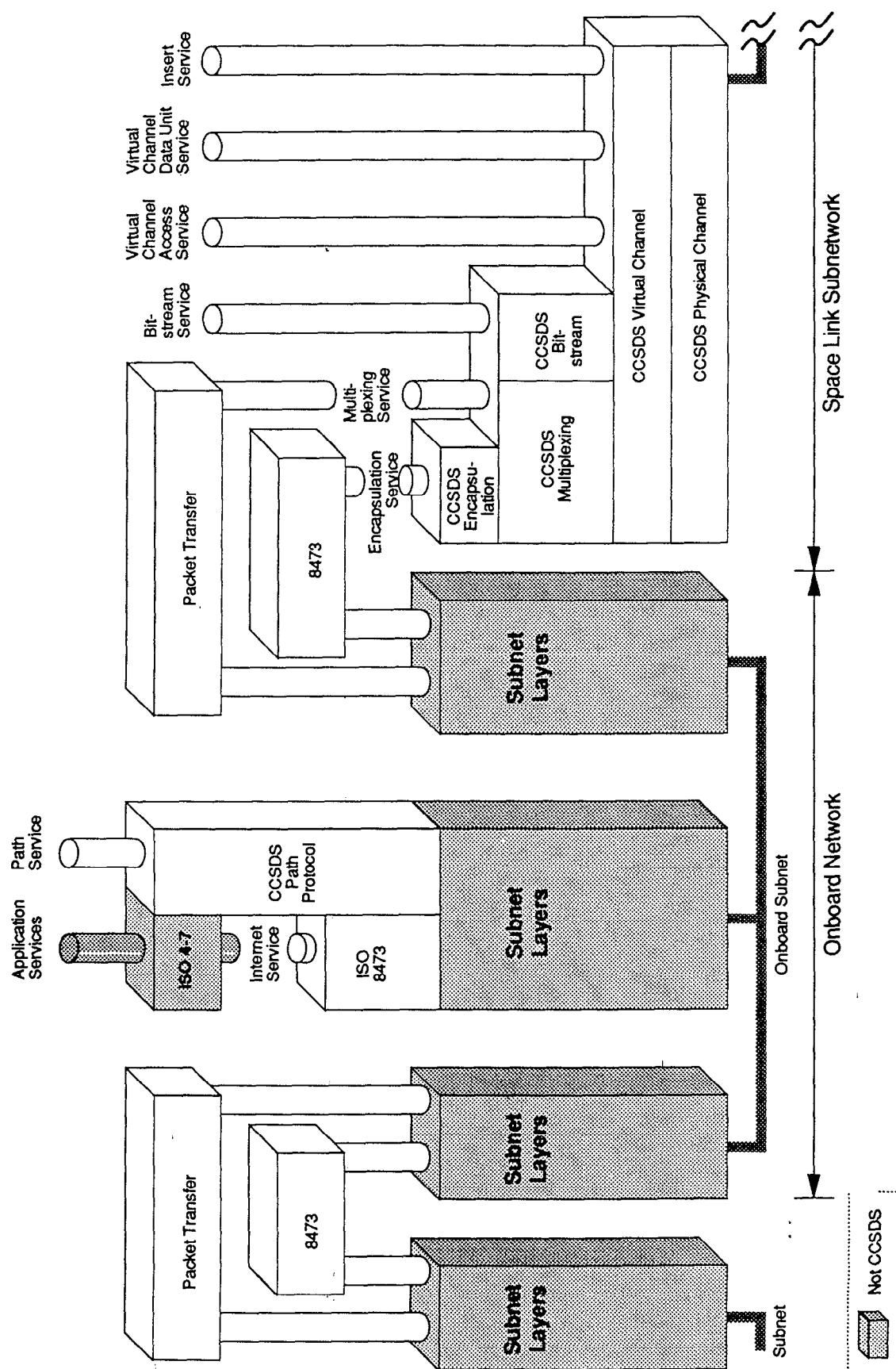


Figure 2-3: Simplified CCSDS Principal Network Service Model

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- 2.3.1.1.c The CCSDS Internet service conforms with the ISO 8473 Connectionless Network Protocol Specification, Reference [16]. To provide flexibility, the ISO 8473 packet features full addressing of the source and destination network SAPs, and the possibility of partial or full source routing, at the expense of a larger and more complex communications header than is provided within the Path service.

2.3.1.2 PATH SERVICE

- 2.3.1.2.a The Path service transfers variable-length application-layer service data units end-to-end across the CPN, from an application-accessible source SAP to one or more application-accessible destination SAPs. Each service data unit contains a delimited string of octets of user application data. The Path service is asynchronous and non-sequence preserving.
- 2.3.1.2.b The Path service is expected to be used primarily for transferring, at moderate to very-high data rates, large volumes of structured, delimited data units between fairly static source and destination associations. It is the service most likely to be used, for example, for the transfer of measurement data (i.e., telemetry) from payload instruments.
- 2.3.1.2.c The transfer is designed to use a lean and efficient protocol, by exploiting the fact that in many space mission operations the association between the source and destination of user messages is known *a priori*. These pre-established associations, known as CCSDS “Logical Data Paths” (LDPs), are configured by management. Instead of providing full endpoint addressing, the protocol data unit of the Path service contains a “Path Identifier” which identifies the LDP.
- 2.3.1.2.d The protocol data unit of the Path service is the Version-1 CCSDS Packet. The Path service offers two service options:
- 2.3.1.2.e a “Packet” service transfers CCSDS Packets, preformatted by the user, intact across the CPN;
- 2.3.1.2.f an “Octet String” service transfers delimited strings of user octets across the CPN, by building them into Version-1 CCSDS Packets on the user’s behalf.
- 2.3.1.2.g The Path service does not have an underlying segmentation function and does not include a protocol mechanism for end-to-end flow control.

2.3.2 SPACE LINK SUBNETWORK DATA TRANSFER SERVICES

- 2.3.2.a The SLS, which forms the core of the CCSDS Principal Network, supports the bidirectional transmission of Path and Internet service data units through the space/ground and space/space channels that interconnect the distributed elements of the CCSDS Advanced Orbiting Systems. It also provides SLS data-transfer services which do not extend further through the CPN. Within the SLS, CCSDS defines the full protocol suite required to achieve cross support.
- 2.3.2.b A key feature of the CCSDS protocol provided for the SLS is the concept of “Virtual Channels”. The Virtual Channel facility allows one physical space channel to be shared among multiple higher-layer traffic streams, each of which may have different service requirements. A single physical space channel may therefore be divided into several separate logical data channels, each known as a “Virtual Channel” (VC). Each VC is individually identified and supports a single “Grade of Service”.
- 2.3.2.c To facilitate simple, reliable, and robust synchronization procedures, fixed-length protocol data units are used to transmit data through the weak-signal, noisy space channels: their length is established for a particular link during a particular mission phase by management, and they are delimited by placing Synchronization Markers between their boundaries. These protocol data units are each associated with one particular Virtual Channel, and are known as “Virtual Channel Data Units” or VCDUs. A service option internal to the VCDU can also produce a protocol data unit known as a “Coded Virtual Channel Data Unit”, or CVCDU. Each VCDU and CVCDU contains a header and trailer which provide space link protocol control information, and a fixed-length data field within which higher-layer service data units are carried.
- 2.3.2.d The SLS supports six different types of services: Encapsulation; Multiplexing; Bitstream; Virtual Channel Access; Virtual Channel Data Unit; and Insert.

2.3.2.1 ENCAPSULATION SERVICE

- 2.3.2.1.a The Encapsulation service provides a facility whereby variable-length, octet-aligned service data units that are not formatted as CCSDS Packets may be transferred across the SLS. The transfer is asynchronous and sequence preserving.
- 2.3.2.1.b The service is accomplished by locally encapsulating the “foreign” data structure within a CCSDS controlled data structure that is part of the suite of cross supported protocols defined for the SLS. The Encapsulation service is provided using the Version-1 CCSDS Packet as its protocol data unit.

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2.3.2.2 MULTIPLEXING SERVICE

- 2.3.2.2.a The Multiplexing service provides a facility whereby variable-length, delimited, octet-aligned service data units, which conform to the Version-1 CCSDS Packet format, may be multiplexed together for transfer across the SLS on the same Virtual Channel. The transfer is asynchronous and sequence preserving.
- 2.3.2.2.b The Multiplexing service concatenates different CCSDS Packets together and formats them into blocks which are sized to exactly load the fixed-length data field of one Virtual Channel Data Unit. The Multiplexing service is provided using the Version-1 CCSDS Packet as its service data unit. The Multiplexing service can therefore accept both Encapsulation service and Path service data units, and concatenate them within one Virtual Channel.

2.3.2.3 BITSTREAM SERVICE

- 2.3.2.3.a The Bitstream service provides a facility whereby serial strings of bits, whose internal structure and boundaries are unknown to the CPN, may be transferred across the SLS. The transfer is sequence preserving and may be either “asynchronous” or “isochronous”. Isochronous transfer from service interface to service interface is provided with a specified maximum delay and a specified maximum jitter at the service interface. High-rate video data (Reference [7]) may use the isochronous Bitstream service.
- 2.3.2.3.b The Bitstream service breaks the stream of bits from each SLS user into blocks which are sized to exactly load the fixed-length data field of one dedicated Virtual Channel Data Unit. Fill data may be transparently added and removed as necessary to match the bitstream to the fixed-length data field. Bitstreams from different SLS users may not be multiplexed together within one Virtual Channel by the Bitstream service.

2.3.2.4 VIRTUAL CHANNEL ACCESS SERVICE

- 2.3.2.4.a The Virtual Channel Access service provides a facility whereby a Project organization may transfer private service data units (which are sized to exactly load the fixed-length data field of one dedicated Virtual Channel Data Unit and whose internal structure is unknown to the CPN) across the SLS. The transfer can be either asynchronous or isochronous, and is sequence preserving.

2.3.2.5 VIRTUAL CHANNEL DATA UNIT SERVICE

- 2.3.2.5.a The Virtual Channel Data Unit service provides a facility whereby a fixed-length, octet-aligned VCDU or CVCDU, created by an independent SLS entity, may be transferred across the SLS. The transfer is sequence preserving and is performed either asynchronously or isochronously and in accordance with a prespecified priority.

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- 2.3.2.5.b Internal to the SLS, the Virtual Channel Data Unit service transfers the independently created VCDUs/CVCDUs through the space channel, together with VCDUs/CVCDUs created by the SLS itself. This service is made available to trusted users who are certified during the design process to ensure that the independently created protocol data units do not violate the operational integrity of the SLS. Necessarily, the independent VCDUs/CVCDUs must have the same length as those generated by the SLS.

2.3.2.6 INSERT SERVICE

- 2.3.2.6.a The Insert service provides a facility whereby private, octet-aligned service data units may be transferred isochronously across the SLS in a mode which efficiently utilizes the space channel transmission resources at relatively low data rates (Reference [8]). When activated, the Insert service is implemented by establishing an "Insert Zone" in every Virtual Channel Data Unit that is transmitted on a particular Physical Channel, and by placing the Insert service data units into this Zone. The Insert Zone shares the fixed-length data field of the VCDUs and/or CVCDUs with other types of service.
- 2.3.2.6.b As noted in Reference [8], when the aggregate transmitted data rate across the Physical Channel is less than 10Mb/s, the Insert Zone should be used for isochronous data transfer; however, at rates greater than 10Mb/s the isochronous data should be transmitted using the Bitstream service on a dedicated Virtual Channel. To avoid operational complexity, CCSDS recommends that the Insert service should not exist simultaneously with the Virtual Channel Data Unit service on one Physical Channel.
- 2.3.2.6.c The Insert service is sequence preserving and is provided with a specified maximum delay and a specified maximum jitter at the service interface. Typical isochronous applications using the Insert service include moderate-rate processes such as audio (Reference [7]) and teleoperations control, operating in low-bandwidth environments where the overall transmitted data rate on the Physical Channel is constrained. The size of the Insert Zone and the sample rate of the Insert service data units must be carefully tuned in concert with the available data transmission resources. Note that it is unlikely that the aggregate Insert service data rate will exactly match the generated data rate of the user source; provision must therefore be made to compensate for any difference by the Insert service user.
- 2.3.2.6.d When the Insert service is used, the Insert Zone must be present in all Virtual Channels that share the same Physical Channel, and its length is established by management.

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2.3.3 SLS GRADES OF SERVICE

- 2.3.3.a Three “Grades of Service” are offered within the Space Link Subnet. A Project organization must implement at least one of these Grades of Service in order to be compatible with this Recommendation.
- 2.3.3.b **Grade-1** service: SLS service data units are delivered through the SLS complete, with their sequence preserved, and with a very high probability of containing no errors induced by the SLS.
- 2.3.3.c **Grade-2** service: SLS service data units are delivered through the SLS possibly incomplete, but with their sequence preserved and with a very high probability of containing no errors induced by the SLS.
- 2.3.3.d **Grade-3** service: SLS service data units are delivered through the SLS possibly incomplete and with a moderate probability that they contain errors induced by the SLS, but with their sequence preserved.
- 2.3.3.e It should be noted that:
- 2.3.3.f not all Grades of Service are offered for each SLS service;
- 2.3.3.g the Grades of Service are only offered during periods when space/ground or space/space data channels are scheduled and available. Higher-layer CPN processes are required to reconstitute and deliver service data units which are buffered during periodic space channel outages;
- 2.3.3.h the Grades of Service are ONLY defined by CCSDS across the Space Link Subnet; it is necessarily a Project responsibility to extend them into end-to-end Grades of Service, if desired;
- 2.3.3.i the Grades of Service are not explicitly signalled by protocol, but are set up by management;
- 2.3.3.j service data units which contain detected SLS-induced errors are not required to be delivered in CCSDS cross support configurations.

2.4 ARCHITECTURE OF THE SPACE LINK SUBNET

- 2.4.a The purpose of this section is to present a top level overview of the key functions and data structures which support the operation and services of the SLS. All of the operations which are described must be understood to be independent of the direction of data flow through the SLS. The controlling specification for the SLS service and protocol is contained in Section 5 of this Recommendation.

2.4.1 FUNCTIONS PERFORMED BY THE SLS

- 2.4.1.a Figure 2-4 shows all possible data flows through the SLS: data flow from top to bottom of the figure on the sending side, and from bottom to top on the receiving side. The physical space medium (a space/ground or space/space data-transmission path) interconnects the sending and receiving sides of the SLS. The figure identifies the data-handling and formatting functions that are involved. These functions are discussed in the following paragraphs.

2.4.1.1 PHYSICAL CHANNEL FUNCTION

- 2.4.1.1.a The Physical Channel function creates one dedicated space data transmission path. A continuous stream of data bits is accepted at the sending side, modulated, serially transmitted through the physical space medium, demodulated, bit synchronized, and delivered through the receiving interface. The CCSDS Recommendation for the Physical Channel function is contained in Reference [14] and is not specified herein. While direct access to the Physical Channel is permissible, definition of such a service is not within the scope of this Recommendation.

2.4.1.2 VIRTUAL CHANNEL FUNCTION

- 2.4.1.2.a At the sending side, the Virtual Channel function accepts service data units from higher-layer functions, builds them into the space link protocol data units (VCDUs or CVCDUs) that are required to identify and operate the Virtual Channels, applies the error control required by different Grades of Service, commutates the VCDUs/CVCDUs into an appropriate sequence, and submits them as a serial stream to the Physical Channel function for transmission through one Physical Channel. At the receiving side the serial stream is synchronized to find the boundaries between VCDUs/CVCDUs, which are then passed through error control procedures and decommutated. The higher-layer service data units are then extracted and passed back through the receiving service interface.
- 2.4.1.2.b During transmission through the Physical Channel, each VCDU or CVCDU is carried synchronously within one "Channel Access Data Unit" (CADU). The CADUs provide fixed-length "channel access slots" which occur at precise time intervals that are synchronized with the transmitted bit rate, and whose boundaries are delimited using "Synchronization Markers". The commutated sequence of VCDUs/CVCDUs is transmitted so that all of the synchronous channel access slots are occupied. In situations where no valid higher-layer data are ready for release, a VCDU/CVCDU containing "Fill" data is commutated into the transmitted sequence. The continuous and contiguous stream of CADUs, known as a "Physical Channel Access Protocol Data Unit", is transferred through the Physical Channel.

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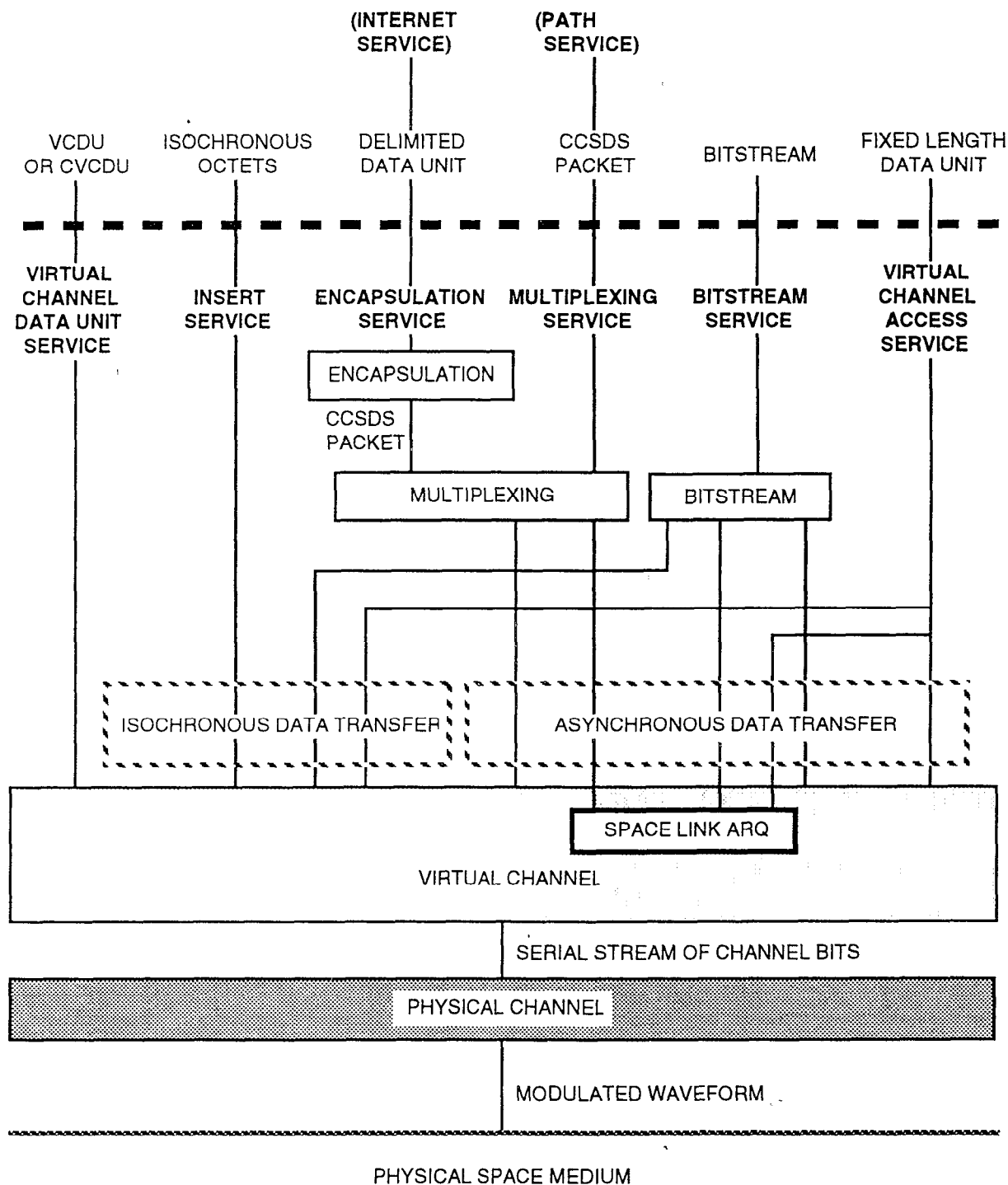


Figure 2-4: Space Link Subnet Data Flow

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- 2.4.1.2.c Service data units associated with the Encapsulation, Multiplexing, Bitstream or Virtual Channel Access services are placed into a “Data Unit Zone” within the data field of the VCDU or CVCDU. At low transmitted data rates, the Insert Zone facility may be activated to allow isochronous data samples associated with the Insert service to share the VCDU/CVCDU data field with the other types of service data units.
- 2.4.1.2.d The Grades of Service are supported as follows:
- 2.4.1.2.e Grade-3 service is provided by constructing VCDUs for direct transmission through the underlying dedicated Physical Channel;
- 2.4.1.2.f Grade-2 service is provided by adding an error-correcting code to the constructed VCDUs to form CVCDUs. The recommended code appends a block of error-correcting Reed-Solomon check symbols to the VCDU in order to provide virtually “error-free” transmission;
- 2.4.1.2.g Grade-1 service is provided within CVCDUs on certain Virtual Channels by a “Space Link ARQ” function that supports the transfer of asynchronous Multiplexing, Bitstream or Virtual Channel Access service data units through the space link using a retransmission control (“ARQ”) procedure to protect against momentary channel outages. The function is implemented by a “Space Link ARQ Procedure” (SLAP). Grade-1 service is defined only for full-duplex operation, i.e., two dedicated Virtual Channels, one in each direction, must be paired by management for Grade-1 service to be provided.
- 2.4.1.2.h (Note: some Projects may be constrained to operate only with a unidirectional retransmission procedure; i.e., full-duplex operation may not be possible. Such Projects have the option of implementing a hybrid configuration with a Conventional CCSDS “Command Operation Procedure” providing retransmission control for the uplink, as described in References [4], [5] and [6]. While technically supported, hybrid configurations are the subject of detailed Project implementations; such configurations are discussed in Reference [8].)
- 2.4.1.2.i If Grades-1/2 operate in conjunction with Grade-3 on the same Physical Channel, the stream of protocol data units observed at the receiving side of the Physical Channel may therefore contain VCDUs and CVCDUs which are serially interleaved in a nondeterministic order.
- 2.4.1.2.j The demultiplexing and delivery of VCDUs and CVCDUs is achieved by using a Spacecraft Identifier concatenated with a Virtual Channel Identifier, both of which are contained in the VCDU header. Error-control mechanisms are provided to protect these key header routing fields.

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- 2.4.1.2.k Independently created VCDUs/CVCDUs associated with the Virtual Channel Data Unit service flow through the Virtual Channel function, potentially interfacing only with the error-control mechanisms.

2.4.1.3 ASYNCHRONOUS DATA TRANSFER

- 2.4.1.3.a The normal “asynchronous” mode of SLS data transfer associated with the Multiplexing, Encapsulation, Bitstream or Virtual Channel Access service is for incoming service data units to asynchronously fill up the Data Unit Zone of the VCDU or CVCDU before being released for transmission. The incoming service data units must be preformatted into fixed-length blocks in order to be placed within the Data Unit Zone.

2.4.1.4. ISOCHRONOUS DATA TRANSFER

- 2.4.1.4.a Some types of “isochronous” service data units require transfer through the SLS in a manner which preserves timing relationships that are important to users. This is achieved by defining a fixed time delay with specified jitter between transmissions.
- 2.4.1.4.b High-rate isochronous data streams (e.g., video data) may be blocked using Bitstream procedures and an entire Virtual Channel may be dedicated for their isochronous transmission.
- 2.4.1.4.c For low- or medium-rate user applications such as audio or teleoperations control data, situations may arise where the maximum transmitted data rate of the CADUs is constrained by channel bandwidth considerations. In this case, since the combination of maximum allowable time delay and CADU length lead to an inefficient utilization of the space channel if dedicated Virtual Channels are used, it may be necessary to share the VC with other data. The Insert Zone facility is provided within the VCDU/CVCDU data structures to carry the isochronous data samples; it is present in every transmitted CADU and hence provides a fixed, synchronous time slot for the isochronous data.

2.4.1.5 MULTIPLEXING FUNCTION

- 2.4.1.5.a To efficiently utilize the space channel, variable-length service data units must be packed together so that they fully occupy the fixed-length Data Unit Zone of the CVCDU. This is accomplished by a multiplexing, delimiting and blocking function. The Version-1 CCSDS Packet provides the only cross supported data structure that is recognized for use within this function.

- 2.4.1.5.b Individual CCSDS Packets from multiple sources are concatenated together into a contiguous string of Packets, which is then broken into blocks whose length is arranged such that they may be loaded exactly into the fixed-length CVCDU Data Unit Zone. Several individual "Packet Channels" may thus concurrently share one VC using the Multiplexing functions. Each Packet Channel is locally identified using the "Application Process ID" (APID) field contained in the CCSDS Packet header.
- 2.4.1.5.c The demultiplexing and delivery of CCSDS Packets on individual Packet Channels is achieved by examining the APID and "Packet Length" fields in the Packet header: since these fields are not protected against errors, the demultiplexing and delivery functions can only be reliably accomplished if the headers are known to be correct. Consequently, cross support can only be provided if the multiplexed data are placed within Reed-Solomon-protected CVCDUs.
- 2.4.1.5.d In the event that a CVCDU has to be released before its Data Unit Zone is full, an "idle" CCSDS Packet, containing Fill data, is inserted.

2.4.1.6 BITSTREAM FUNCTION

- 2.4.1.6.a The Bitstream function breaks each incoming stream of bits into blocks whose lengths are arranged so that they may be exactly loaded into the fixed-length Data Unit Zone of a VCDU on a dedicated VC. Reassembly of the contiguous stream of bits at the receiving service interface is performed. If fill data are inserted during the transfer, they are removed prior to delivery. The Bitstream data may be transferred either asynchronously or isochronously.

2.4.1.7 ENCAPSULATION FUNCTION

- 2.4.1.7.a Since the asynchronous Multiplexing function only recognizes the Version-1 CCSDS Packet data structure, an Encapsulation function is provided which wraps "other" delimited data units into Version-1 CCSDS Packets.
- 2.4.1.7.b The CCSDS Path service, by virtue of its use of Version-1 CCSDS Packets as its protocol data unit, is directly compatible with the Multiplexing function and therefore bypasses the Encapsulation function. However, the CCSDS Internet service uses the ISO 8473 packet format, and from an evolutionary viewpoint it is desirable to provide the flexibility to handle other delimited, octet-aligned data units should the future need arise to support different network layer services across the CPN. The Encapsulation function provides this flexibility.

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- 2.4.1.7.c The Encapsulation function takes any delimited service data unit which is presented to the SLS at a requesting service interface in non-CCSDS Packet format (e.g., the 8473 Internet packet) and encapsulates it within a special CCSDS “carrier” Packet during its transfer through the SLS. The carrier Packet may then be multiplexed onto an appropriate Packet Channel within one VC, along with Packet Channels containing other carrier Packets or Path service data units. At the receiving service interface of the SLS, the carrier Packet is stripped and the original delimited service data unit is reconstituted to continue its passage through the CPN.

2.5 ARCHITECTURE OF THE CCSDS PATH SERVICE

- 2.5.a The CCSDS Path service, using the Version-1 CCSDS Packet, provides an optimized connectionless data transfer service between a single source user Application and one or more destination Applications. Since the Version-1 CCSDS Packet is a user data structure which is also standardized across CCSDS “Conventional” missions, the CCSDS “Advanced Orbiting Systems” Path service presents a compatible user interface across the entire spectrum of space applications.
- 2.5.b This section contains a descriptive overview and definition of the Path service; the full service and protocol specification is contained in Section 3. Reference [8] contains a more general discussion of Path service characteristics.
- 2.5.c The architecture of the CCSDS Path service is illustrated in Figure 2-5. The Path layer provides an enhanced performance service which exposes a Path SAP to the user Application at its upper side, and interfaces directly to the underlying local subnetwork on its lower side, thus bypassing all intermediate layers of protocol.
- 2.5.d Although the service may operate in either direction through the CPN, one major requirement for the Path service is the need to transfer high rates and volumes of telemetry data from space to ground. The Path service architecture is shown to be symmetrical in Figures 2-2, 2-3, and 2-5; however, at the ground end of a telemetry data transfer system, additional higher-layer processes may be provided to remove transmission artifacts induced by the SLS (such as filling data gaps when Path data are retrieved from onboard storage), and also to buffer the Path data for delivery on a user-convenient timescale. These services are discussed in Reference [8].

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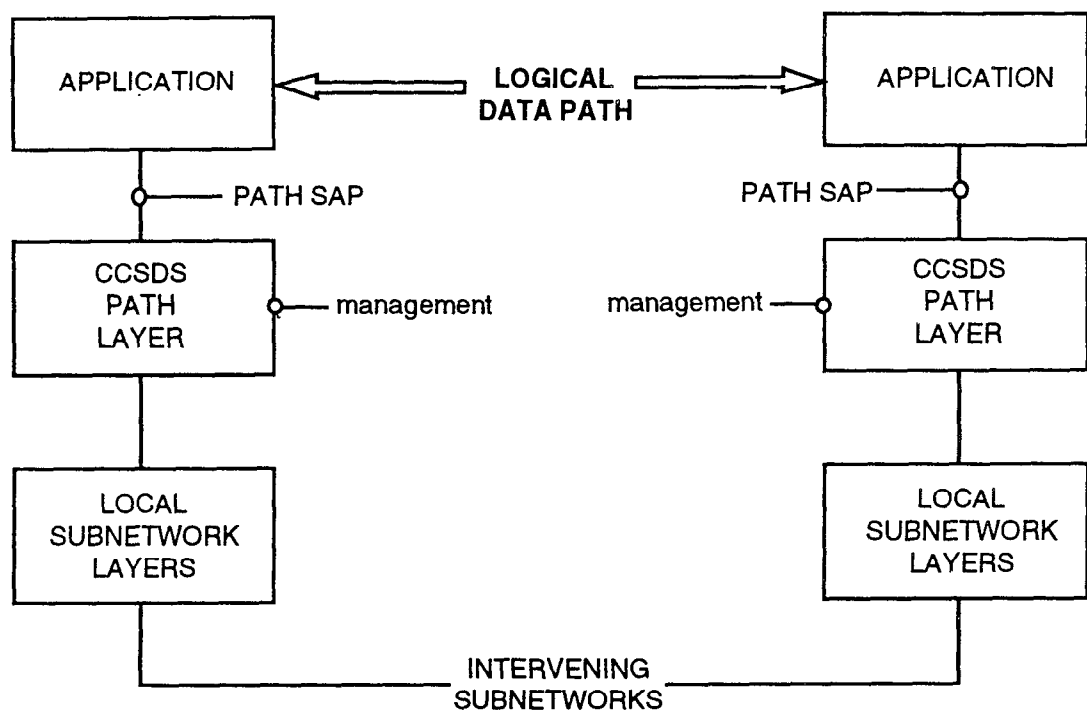


Figure 2-5: CCSDS Path Service Architecture

2.5.1 LOGICAL DATA PATHS

- 2.5.1.a The Path service relies on the use of a managed association between two or more application end-points, i.e., a Logical Data Path (LDP). The LDP association is preconfigured by CPN management for subsequent use by the Path service. Each Logical Data Path is referenced by a "Path ID".
- 2.5.1.b As the CCSDS Packets traverse the local subnetworks of the CPN, they are carried and routed by subnet-specific mechanisms (e.g., local area networks). At relay points between different subnetwork routing mechanisms, the CCSDS Packet header itself may be used in a routing and relay role, in which case the LDP interpretation and mapping to the next subnetwork address is performed using tables that are configured through prior interaction between the relay points and management: in this case the "Application Process Identifier" (APID) field in the Version-1 CCSDS Packet header is used to provide the reference to the Path ID.

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2.5.2 PATH ID MANAGEMENT

- 2.5.2.a Reflecting the need to use a lean and compact protocol to achieve fast and efficient space communications, the APID field in the Version-1 CCSDS Packet is limited in length to eleven bits, thus giving the possibility to reference 2048 different LDPs. For complex international constellations of space vehicles, APIDs must be shared between space Agencies. To facilitate cross support, it is therefore necessary to identify a strategy for APID assignment which, while enabling the sharing of APIDs, avoids any APID ambiguity.
- 2.5.2.b Within the onboard systems of a CPN, it is the responsibility of individual Projects to define a local assignment strategy for the available APIDs. Within the ground systems of a CPN (which must support Path service associated with multiple spacecraft) it is necessary to globally identify each LDP. This may be accomplished by concatenating the APID in the CCSDS Packet with an “APID Qualifier” that is associated with the Packet throughout its ground transfer to and from user applications. A “Spacecraft Identifier” (SCID) may be used within the ground systems to provide this APID Qualifier. The SCID is carried as an 8-bit field within the header of the space link protocol data unit, i.e., the VCDU/CVCDU. Each of the 256 SCIDs associated with the VCDU Version Number “01” may potentially provide an individual naming domain for 2048 APIDs.
- 2.5.2.c The APID Qualifier may also be required in some space-to-space applications of the Path service.

2.5.3 PATH SERVICE INFORMATION FLOW

- 2.5.3.a The flow of information from the user application to the local subnetwork interface, for a typical Path service transmission, is as follows:
- 2.5.3.b the Path layer receives either a delimited string of user octets, together with the parameters necessary for the construction of the Path protocol data unit (CCSDS Packet), or a complete user-formatted CCSDS Packet;
- 2.5.3.c the Path layer either constructs a CCSDS Packet or validates a user-formatted Packet;
- 2.5.3.d the Path layer cooperates with locally supplied communication mechanisms to deliver the CCSDS Packet to its intended destination.

2.6 ARCHITECTURE OF THE CCSDS INTERNET SERVICE

- 2.6.a The CCSDS Internet service supports interactive operations (of the type represented by activities such as file transfer, electronic mail, and remote terminal access) between end systems located on the Onboard and Ground Networks of the CPN. The Internet service is associated with the Network layer of the ISO Reference Model of Open Systems Interconnection, Reference [15], and operates in connectionless mode.
- 2.6.b This section contains a descriptive overview and definition of the Internet service; the full service and protocol specification is contained in Section 4, which references the appropriate ISO documentation. Reference [8] contains a more general discussion of Internet service characteristics.
- 2.6.c The CPN comprises a series of interconnected, dissimilar subnetworks through which data are conveyed. Each subnetwork may have different ways of addressing the destination, different protocol data unit sizes, different time delays and bandwidths, and different status and monitoring capabilities. The CCSDS Internet service resolves these subnetwork differences by providing global inline protocol mechanisms, which are contained in the Internet protocol data unit and mapped down to the subnet layer as the Internet data unit is transported through the CPN.
- 2.6.d Since standard techniques already exist to solve problems of global internetworking, CCSDS has adopted existing international standards for both the Internet service definition and the protocol specification, i.e., the ISO connectionless mode network service (ISO 8348/AD1) and the associated protocol (ISO 8473) as defined in References [16] through [19].
- 2.6.e The ISO 8473 Internet protocol data unit carries along in its packet header full endpoint addresses, security, priority, quality of service, and routing capabilities which minimize (but do not eliminate) network management responsibility. This generality comes at the expense of a large communications header.
- 2.6.f The Internet service differs from the Path service in several respects:
- 2.6.g the number and location of the application endpoints may change relatively rapidly;
- 2.6.h the data rates and volumes associated with this type of traffic are relatively low, and the duty cycle of individual users is more intermittent, so that the communications efficiency and throughput penalties of comprehensive inline protocol are not so important;
- 2.6.i the service may support a suite of higher-layer OSI-compatible services, for those users who need them;

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- 2.6.j the service provides a richer Internet addressing capability which conforms to ISO international address partitioning standards, with a proportionally longer and more complex header to carry the address;
- 2.6.k the service provides for a set of additional options, such as segmenting and route reporting, which may be needed by specific Projects.

2.7 MANAGEMENT OF THE CCSDS PRINCIPAL NETWORK

- 2.7.a Many of the CPN protocols defined in this Recommendation have been designed to enable fast processing and to conserve bandwidth during space data transfer; therefore, some parameters associated with their operation are handled by management rather than by inline protocol. Management of the CPN consists of the set of functions and services which are provided to supervise, schedule and control the CPN resources. To perform their coordinating functions, management systems exchange information using signalling mechanisms.
- 2.7.b Insofar as these management functions are not associated with cross support, their implementation is a local matter which is not embraced by this CCSDS Recommendation. The management and signalling aspects of cross support configurations are the subject of separate CCSDS Recommendations; the CCSDS Secretariat should be consulted for information relative to their status.

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3 PATH SERVICE AND PROTOCOL SPECIFICATION

3.1 INTRODUCTION

- 3.1.a The CCSDS Path service provides efficient, high throughput, unidirectional data transfer between a single source User Application and one or more destination User Applications. The organization of the Path service is reviewed in Figure 3-1.

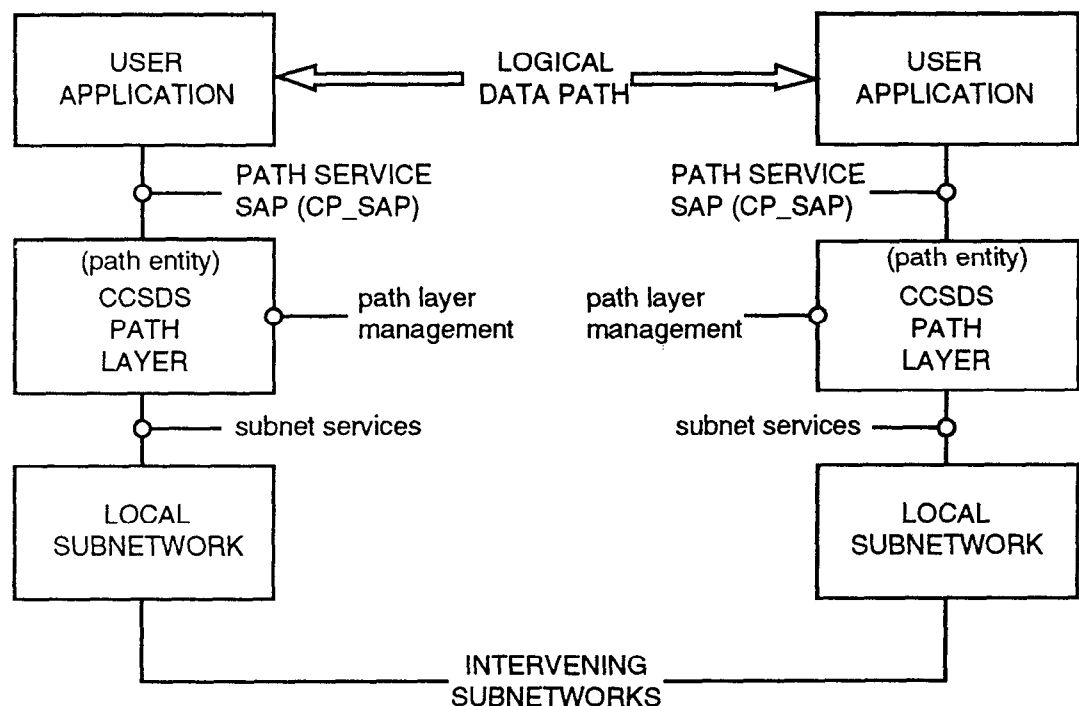


Figure 3-1: Path Service Architecture

- 3.1.b A CCSDS “Path Entity” provides Path service to a User Application. The Path layer protocol transfers variable-length CCSDS Path Service Data Units (CP_SDUs) from end to end across the CPN, from a source Path Entity to one or more destination Path Entities. The Path layer interfaces with management services that configure and control the Path service, and draws upon local subnetwork services for the transfer of the CCSDS Path Protocol Data Units (CP_PDUs). The CP_PDU is the Version-1 CCSDS Packet.

- 3.1.c The route through the subnets of the CPN, known as a Logical Data Path (LDP), is established by Path layer management and is constant for the lifetime of the association between User Applications. The LDP is identified by a Path ID. At any point in the LDP, the CP_PDU may be routed from subnetwork to subnetwork by examining its Path ID. Alternatively, at any point in the LDP, routing may be accomplished between cooperating subnetworks by use of an agreed mapping between subnetwork addresses. (Note, however, that at the exiting gateway of the Space Link Subnet the Path ID must be employed for routing, since there is no alternative mechanism available in the SLS protocol stack.)
- 3.1.d The Path service is provided in two ways:
- 3.1.e a “Packet service” option transfers “Packet Service Data Units” (P_SDUs), which are preformatted by the user as Version-1 CCSDS Packets, intact across the CPN. Thus the user-formatted P_SDU is used as the CP_PDU, and can be transferred without further formatting by the Path procedures; or
- 3.1.f an “Octet String service” option transfers “Octet Service Data Units” (O_SDUs), which consist of delimited strings of user octets, across the CPN by formatting them into CP_PDUs. This service may reduce the complexity of data transfer for the users, since the CCSDS Packets are created by the service.
- 3.1.g Note that the O_SDU and the P_SDU are both instances of CCSDS Path Service Data Units (CP_SDUs).
- 3.1.h Each LDP terminating in a source end system of the CPN has an associated type of service, either Packet or Octet String. The service type need not be preserved from end to end of the LDP; i.e., asymmetric services may be provided. For instance, an invocation of the Octet String service at the source end system may (at the user’s request) result in an instance of the Packet service at the destination end system(s). Once selected, the type of service (symmetric or asymmetric) provided at the ends of an LDP shall be fixed for its lifetime.
- 3.1.i The Path service does not provide inline protocol mechanisms for flow control or segmentation.
- 3.1.j The end-to-end Quality of Service provided to Path service users will vary according to the individual qualities of service provided by the various subnetworks along the Logical Data Path. The Path service does not provide any mechanisms for guaranteeing a particular quality of service; it is the responsibility of implementing organizations to ensure that the end-to-end performance of a particular instance of the Path service meets the requirements of its users.

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3.1.1 ORGANIZATION OF THE PATH LAYER

3.1.1.a The composition and service interfaces of the Path layer are shown in Figure 3-2.

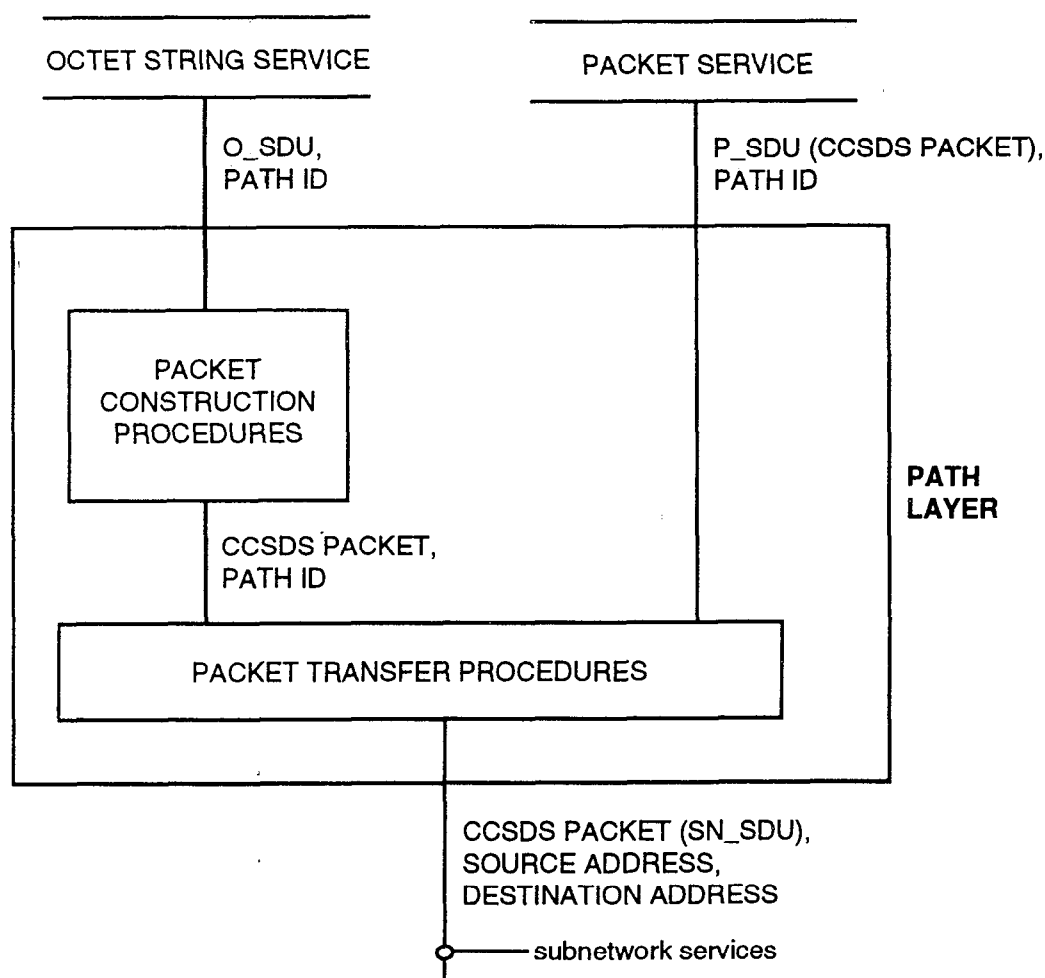


Figure 3-2: Path Layer Organization

- 3.1.1.b The parameters passed to the Octet String service by the Path service user (along with information supplied by Path layer management) are used by the “Packet Construction Procedures” to build the Primary Header of the CP_PDU (the CCSDS Packet).
- 3.1.1.c A Version-1 CCSDS Packet passed to the Packet service by the Path service user is used as the CP_PDU, so it is unchanged by the Path procedures.

3.1.2 PATH LAYER ADDRESSING

- 3.1.2.a The Path service relies on the use of a preconfigured route (the Logical Data Path) between a single source User Application and one or more destination User Applications. The LDPs are configured by Path layer management for subsequent use by the Path service. Every LDP is uniquely identified by a Path ID.
- 3.1.2.b Each LDP consists of the source end system, the destination end system(s), and the intermediate subnetworks on the LDP. An LDP need not include intermediate subnetworks if the source and destination end systems are on the same subnetwork.
- 3.1.2.c “Packet Transfer Procedures”, used to forward the CP_PDU through the CPN, are performed by Path Entities located in either a source end system or an intermediate system.
- 3.1.2.d Figure 3-3 shows an example of a single LDP crossing an intermediate subnetwork to a single destination User Application.

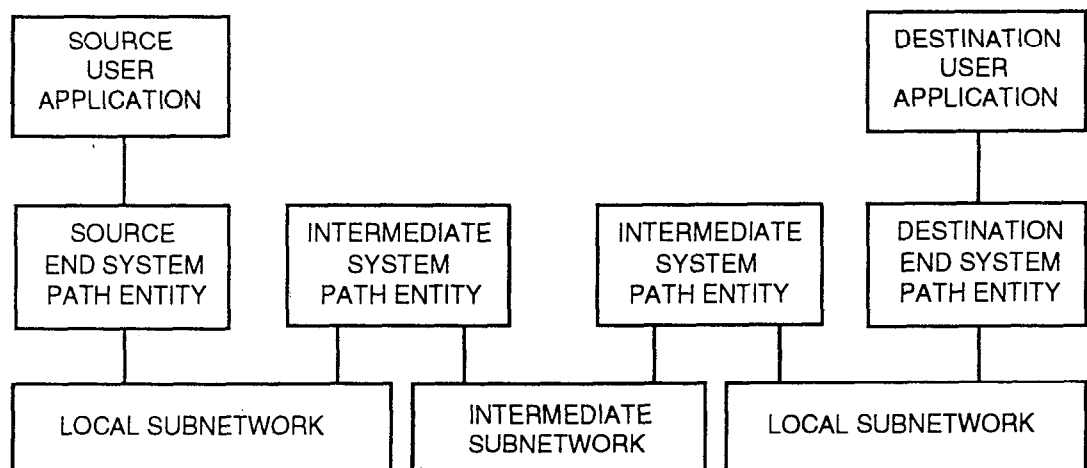


Figure 3-3: Example of a Logical Data Path

- 3.1.2.e Note that multi-addressing may be performed at any of the intermediate system Path Entities or at the source end system Path Entity. Multi-addressing may be performed from a single source end system Path Entity to multiple destination end system Path Entities on the same subnetwork, or on several subnetworks. A “multidrop” architecture is permitted where the CP_SDU is delivered to a user in a data system and the CP_PDU is also forwarded to other data systems.
- 3.1.2.f In simple mission configurations, the Path ID of the LDP may be fully represented by the “Application Process ID” (APID) contained in the header of the Version-1 CCSDS Packet; up to 2048 different APIDs may be supported.

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- 3.1.2.g Since complex Path service cross support configurations may exist and LDPs must be uniquely identified, an extension of the Path addressing mechanism (known as an APID Qualifier) may be required within some of the subnetworks traversed by the LDP. If needed, the APID Qualifier is locally associated with the APID in the CCSDS Packet but is not explicitly represented in the CP_PDU. In such configurations, the Path ID is represented by the APID plus the APID Qualifier.
- 3.1.2.h The APID Qualifier uniquely identifies a naming domain which “owns” an APID address space, and hence the 2048 Path IDs. The naming domain may be one spacecraft or, if a complex orbiting constellation of spacecraft elements exists, each of the individual elements may be its own naming domain. In this Recommendation it is assumed that (at least as far as the flight systems are concerned) all of the available APIDs are locally assigned by a Project organization across the communicating set of spacecraft elements which are under the control of that Project.
- 3.1.2.i However, within the ground system (which may have to concurrently support multiple spacecraft) the APID Qualifier may be needed to maintain global uniqueness of Path IDs. The 8-bit Spacecraft Identifier (SCID), contained within the headers of VCDU/CVCDUs and concatenated with the Version Number “01”, provides the APID Qualifier within the SLS. The SCID may therefore be used at the ground gateways with the SLS to map into appropriate ground network addressing mechanisms, so that partitioning of APIDs from different naming domains is preserved. Within the ground networks local subnetwork addressing information (i.e., “SN_SAPs”) may be used to represent the APID Qualifier.
- 3.1.2.j Note that some complex orbiting spacecraft may have multiple SCIDs assigned to them while implementing a common onboard APID address space. In this case all of the SCIDs are treated as a unified APID naming domain as far as the APID Qualifier is concerned.
- 3.1.2.k If a constellation of cooperating but separate spacecraft (each implementing its own internal APID naming domain without sharing APID address space across the orbiting systems) transmit their data through a common Physical Channel, then each of the SCIDs provides a separate APID Qualifier.
- 3.1.2.l The convention for the APID naming domains is as follows:
- 3.1.2.m for space-to-ground communication the naming domain is the source naming domain (the spacecraft or spacecraft element);
- 3.1.2.n for ground-to-space communication the naming domain is the destination naming domain (the spacecraft or spacecraft element);

- 3.1.2.o for space-to-space communication the naming domain is the source naming domain (the source spacecraft or spacecraft element). In this case, the destination spacecraft may need to use the APID Qualifier in a manner similar to the ground system.

3.1.3 SUBNETWORK SERVICES ASSUMED BY THE PATH LAYER

- 3.1.3.a It is intended that the Path layer be capable of operating over connectionless-mode services derived from a wide variety of real subnetworks and data links. Therefore, in order to simplify the specifications of the protocol, its operation is defined with respect to an abstract "underlying service" rather than any particular real subnetwork (SN) service. This underlying service consists of a single "SN_UNITDATA" primitive which conveys the source and destination subnetwork point of attachment addresses and a minimum number of octets of user data.

- 3.1.3.b The service primitives required are:

SN_UNITDATA.request (SN_SDU,
Source Address,
Destination Address)

SN_UNITDATA.indication (SN_SDU,
Source Address,
Destination Address)

- 3.1.3.c Real subnetworks and data links may not conform to the SN_UNITDATA service interface defined in 3.1.3.b. Use of the Path service over such a subnetwork or data link requires that a convergence function be performed between the SN_UNITDATA primitives specified for the Path protocol and the service primitives specified for that subnetwork or data link.

3.1.4 SERVICES ASSUMED FROM THE LOCAL ENVIRONMENT

- 3.1.4.a The services assumed by the Path layer from the local environment are unspecified.

3.2 SERVICE INTERFACE SPECIFICATION

- 3.2.a All of the service interface specifications in this Recommendation generally follow conventions used by ISO. Accordingly, the specifications are given in the form of primitives, which present an abstract model of the logical exchange of information between the Path layer and the user of the Path service. The primitives are specified to be independent of any particular implementation approach.

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3.2.1 OVERVIEW OF INTERACTIONS**3.2.1.1 PACKET SERVICE**

3.2.1.1.a The service primitives associated with the Packet service are:

PACKET.request
PACKET.indication

3.2.1.1.b The PACKET.request primitive is passed to the CCSDS Path layer to request that a P_SDU be sent.

3.2.1.1.c The PACKET.indication primitive is passed from the CCSDS Path layer to indicate the arrival of a P_SDU.

3.2.1.2 OCTET STRING SERVICE

3.2.1.2.a The service primitives associated with the Octet String service are:

OCTET_STRING.request
OCTET_STRING.indication

3.2.1.2.b The OCTET_STRING.request primitive is passed to the CCSDS Path layer to request that an O_SDU be sent.

3.2.1.2.c The OCTET_STRING.indication primitive is passed from the CCSDS Path layer to indicate the arrival of an O_SDU.

3.2.2 SERVICE PRIMITIVE PARAMETERS

3.2.2.a The parameters for the Path service primitives are:

3.2.2.b **O_SDU** The Octet Service Data Unit. The O_SDU is a delimited, octet-oriented data unit whose content and format are unknown to the Path layer. The maximum length of the O_SDU is defined by individual Project organizations, taking into account the maximum SDU size in all subnets traversed by the LDP.

3.2.2.c **APID** The APID is a mandatory parameter and is used in conjunction with the APID qualifier (if present) to uniquely identify the Logical Data Path to be used in conjunction with the PACKET.request and PACKET.indication primitives.

3.2.2.d **P_SDU** The Packet Service Data Unit. The P_SDU is a Version-1 CCSDS Packet that has been created by the service user. The maximum length of the P_SDU is defined by individual Project organizations, taking

into account the maximum SDU size in all subnets traversed by the LDP.

- 3.2.2.e **APID Qualifier** The APID Qualifier is an optional parameter which is associated with the APID in the CCSDS Packet in order to maintain global uniqueness of APIDs. In this Recommendation, it is assumed that the APID Qualifier is only used within the ground network, and that the Spacecraft ID (SCID), concatenated with the Version Number "01", may be used to provide this parameter.
- 3.2.2.f **Secondary Header Indicator** The Secondary Header is a feature of the CCSDS Packet which allows additional types of information that may be useful to the User Application (e.g., a time code) to be included. The CP_PDU Primary Header contains a "Secondary Header Flag" which indicates the presence or absence of a Secondary Header. Within the Packet service, a user of the service in a source end system may signal the presence or absence of a Secondary Header by passing the Secondary Header Indicator parameter in the form of the Secondary Header Flag. Within the Octet String service, the Secondary Header Indicator parameter signals the presence of a Secondary Header at the start of the O_SDU.
- 3.2.2.g **Path ID** The Path ID, which uniquely identifies the LDP, consists of the APID plus the optional APID Qualifier.
- 3.2.2.h **Data Loss Indicator** The Data Loss Indicator is used to alert the user of the Octet String service in a destination end system that one or more O_SDUs have been lost during transmission, as evidenced by a discontinuity in the CP_PDU Sequence Count. This is an optional parameter, the presence or absence of which is implementation-specific. If Data Loss Indicators are to be generated by a particular implementation then they must be declared at design time and be used consistently by all parties involved in the implementation.

3.2.3 DETAILED PATH SERVICE SPECIFICATION

- 3.2.3.a This section describes in detail the primitives and parameters associated with the identified services. Note that the parameters, which specify the information to be made available to the receiving entity, are specified in an abstract sense: a specific implementation is not constrained in the method of making this information available.