

The Consultative Committee for Space Data Systems

Draft Recommendation for
Space Data System Standards

CCSDS BUNDLE PROTOCOL SPECIFICATION

PROPOSED DRAFT RECOMMENDED STANDARD

CCSDS 734.2-P-1.0

PROPOSED PINK BOOK

September 2022

DEDICATION

This book is dedicated to Adrian Hooke, whose end-to-end sensibilities and tireless advocacy for standardization of space data systems directly contributed to the formation of the Consultative Committee for Space Data Systems in 1982. His unique combination of technical skill, management abilities, and vision served CCSDS well for over 30 years. During that time CCSDS solidified the standardization of Physical and Data Link Layer protocols, and developed standards and technologies that had important and wide-ranging impacts in both the space and terrestrial communications industries. In the late 1990s, Adrian envisioned a new era for space communications leveraging a confluence of terrestrial internetworking and space-based data transport technologies. This led to the development of a concept that has come to be known as the Solar System Internetwork (SSI), of which the Bundle Protocol described here is a part.

Adrian will be missed, by CCSDS for the scope of his technical contributions and his leadership, and by his colleagues and friends for the greatness of his spirit and his wit. But his legacy to the space community remains. CCSDS will continue to provide useful and innovative solutions to space communication challenges so that Adrian's vision of an interoperable, standards-based communication system that reduces mission development time, cost, and risk will eventually be realized.

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FOREWORD

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PREFACE

This document is a draft CCSDS Recommended Standard. Its 'Pink Book' status indicates that the CCSDS believes the document to be technically mature and has released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process.

Implementers are cautioned **not** to fabricate any final equipment in accordance with this document's technical content.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 734.2-B-1	CCSDS Bundle Protocol Specification, Recommended Standard, Issue 1	September 2015	Original issue
CCSDS 734.2-P-1.0	CCSDS Bundle Protocol Specification, Proposed Draft Recommended Standard, Issue 1.0	September 2022	Current proposed draft update

NOTE – Changes from the original issue are too numerous to permit meaningful markup.

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to establish a CCSDS Recommended Standard for Bundle Protocol (BP), based on the bundle protocol of RFC 9171 (reference [1]), which defines the end-to-end protocol, bundle structure, naming schemes, and block types for the exchange of messages (bundles) that support Delay Tolerant Networking (DTN). This document includes abstract service descriptions for the application services provided by BP. This document does not describe how to route bundles in a DTN. It also does not address how BP can be used to provide data reliability and/or accountability.

1.2 SCOPE

This Recommended Standard is designed to be applicable to any space mission network infrastructure that might benefit from delay and/or disruption tolerance . It is intended that this Recommended Standard become a uniform standard among all CCSDS Agencies.

This Recommended Standard is intended to be applied to all systems that claim conformance to the CCSDS Bundle Protocol version 7.

BP is agnostic to the choice of underlying transmission protocol in that BP can function over TC, TM, AOS, USLP, Proximity-1 Space Link Protocol, Encapsulation Packet Protocol, Space Packet, and various Internet and ground-based protocols.

The CCSDS believes it is important to document the rationale underlying the recommendations chosen so that future evaluations of proposed changes or improvements will not lose sight of previous decisions. The concept and rationale for the use of bundle protocol in space links may be found in reference [F1].

1.3 ORGANIZATION OF THE RECOMMENDED STANDARD

This recommended Standard is organized as follows:

- Section 2 contains an overview of the Bundle Protocol and the references from which it is derived.
- Section 3 contains the CCSDS modification to RFC 9171.
- Section 4 contains the service descriptions.
- Section 5 contains services BP requires of the system.
- Section 6 contains conformance requirements.
- Annex A contains the Implementation Conformance Statement for the protocol.
- Annex B contains the Convergence Layer Adapters (CLAs).

- Annex C contains BP managed information.
- Annex D contains Security, Space Assigned Numbers Authority (SANA), and Patent considerations.
- Annex E contains BP Element Specification.
- Annex F contains Informative References.
- Annex G contains abbreviations and acronyms used in this document.

1.4 DEFINITIONS

1.4.1 DEFINITIONS FROM OPEN SYSTEMS INTERCONNECTION (OSI) SERVICE DEFINITION CONVENTIONS

This Recommended Standard makes use of a number of terms defined in reference [2]. As used in this Recommended Standard, those terms are to be interpreted in a generic sense, that is, 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.

1.4.2 DEFINITIONS FROM OSI BASIC REFERENCE MODEL

This Recommended Standard makes use of a number of terms defined in reference [3]. As used in this Recommended Standard, those terms are to be understood in a generic sense, that is, 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;

1.4.3 DEFINITIONS FROM RFC 9171

1.4.3.1 Overview

This Recommended Standard makes use of a number of terms defined in reference [1]. Some of the definitions needed for section 2 of this document are reproduced here for convenience.

A graphical representation of a bundle node is given in figure 11. A bundle node is any entity that can send and/or receive bundles.

Each bundle node has three conceptual components described in more detail below: a ‘bundle protocol agent’, a set of zero or more ‘convergence layer adapters’, and an ‘application agent’. The major components are illustrated in figure 11 (‘CLx PDUs’ are the PDUs of the convergence-layer protocols used in individual networks).

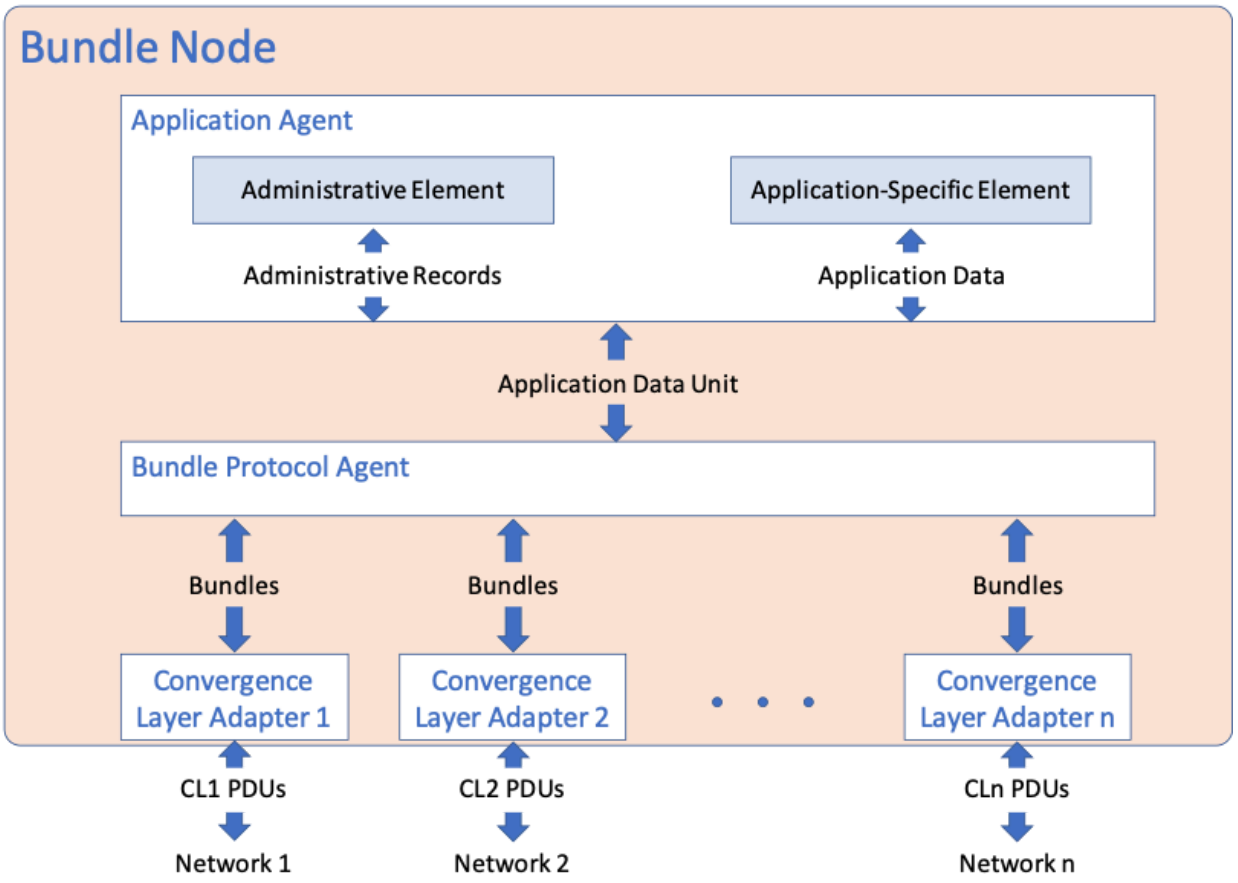


Figure 111-1 Graphical Representation of a Bundle Node": Graphical Representation of a Bundle Node

It should be noted that there is *one* application agent per conceptual bundle node. That Application Agent may provide communication services to multiple applications, and the node may register in multiple endpoints (may provide multiple endpoint identifiers to the bundle protocol agent, requesting delivery of bundles to any of those endpoints).

1.4.3.2 RFC 9171 Terms

bundle: A protocol data unit of BP, so named because negotiation of the parameters of a data exchange may be impractical in a delay-tolerant network: it is often better practice to ‘bundle’ with a unit of application data all metadata that might be needed in order to make the data

immediately usable when delivered to the application. Each bundle comprises a sequence of two or more ‘blocks’ of protocol data, which serve various purposes.

block: A Bundle Protocol block is one of the protocol data structures that together constitute a well-formed bundle.

bundle node, node: Any entity that can send and/or receive bundles. Each bundle node has three conceptual components: a ‘bundle protocol agent’, a set of zero or more ‘convergence layer adapters’, and an ‘application agent’.

bundle protocol agent, BPA: The Bundle Protocol Agent (BPA) of a node is the node component that offers the BP services and executes the procedures of the Bundle Protocol.

bundle endpoint: A bundle endpoint (or simply "endpoint") is a set of zero or more bundle nodes that all identify themselves for BP purposes by some common identifier, called a "bundle endpoint ID" (or, in this document, simply "endpoint ID"); endpoint IDs are described in detail in RFC9171 Section 4.2.5.1.

endpoint identifier (EID): The destinations of bundles are bundle endpoints, identified by text strings termed "endpoint IDs" (see RFC9171 Section 3.1). Each endpoint ID (EID) is a Uniform Resource Identifier [URI]. As such, each endpoint ID can be characterized as having this general structure:

< scheme name > : < scheme-specific part, or "SSP" >

application agent, AA: A node component that utilizes the BP services to effect communication for some user purpose. The application agent in turn has two elements, an administrative element and an application-specific element.

administrative element (AE): In the context of an application agent, the node component that constructs and requests transmission of administrative records (defined below), including status reports, and accepts delivery of and processes any administrative records that the node receives.

application-specific element (ASE): In the context of an application agent, the node component that constructs, requests transmission of, accepts delivery of, and processes units of user application data.

application data unit (ADU): The ADU is the application-specific data being transferred via the Bundle Protocol. The data in an ADU is carried in the payload block(s) of a bundle, and may be split among the payloads of multiple bundles if the original bundle is fragmented.

Fragment: A fragment, a.k.a. "fragmentary bundle", is a bundle whose payload block contains a partial payload.**convergence layer adapter, CLA**: A convergence-layer adapter (CLA) is a node component that sends and receives bundles on behalf of the BPA, utilizing the services of some "integrated" protocol stack that is supported in one of the networks within which the node is functionally located.

registration: A registration is the state machine characterizing a given node's membership in a given endpoint. Any single registration has an associated delivery failure action as defined in RFC9171 and must at any time be in one of two states: Active or Passive. Registrations are local; information about a node's registrations is not expected to be available at other nodes, and the Bundle Protocol does not include a mechanism for distributing information about registrations. An 'Active' registration is one where the Bundle Protocol Agent attempts immediate delivery of bundles to applications; a 'Passive' registration is one where the Bundle Protocol Agent will store bundles for delivery to the application until the application requests them.

1.5 REFERENCES

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

[1] S. Burleigh, K. Fall, and E. Birrane. *Bundle Protocol Version 7*. RFC 9171. Reston, Virginia: ISOC, January 2022.

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

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

[4] B. Sipos, et al. *Delay-Tolerant Networking TCP Convergence-Layer Protocol Version 4*. RFC 9174. Reston, Virginia: ISOC, January 2022.

[5] *Space Packet Protocol*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.0-B-2. Washington, D.C.: CCSDS, June 2020.

[6] *Encapsulation Packet Protocol*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.1-B-3. Washington, D.C.: CCSDS, May 2020.

[7] "Protocol Identifier for Encapsulation Service." Space Assigned Numbers Authority. https://sanaregistry.org/r/protocol_id.

[8] J. Postel. *User Datagram Protocol*. RFC 768. Reston, Virginia: ISOC, August 1980.

[9] *Licklider Transmission Protocol (LTP) for CCSDS*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 734.1-B-1. Washington, D.C.: CCSDS, May 2015.

2 OVERVIEW

2.1 GENERAL

Delay Tolerant Networking is an end-to-end network service providing communications in and/or through environments characterized by one or more of the following:

– Intermittent Connectivity

  • Link connectivity within an interplanetary environment can periodically experience Loss of Signal (LOS) due to a variety of factors, including solar conjunction, occultation, atmospheric signal dispersion, etc.

  • Link connectivity in a near-Earth environment may periodically experience loss of signal due to obstructions, atmospheric signal dispersion, etc.

– Variable Delays, Which May Be Large and Irregular

  • Delays in data transmission between nodes will occur in interplanetary (and larger) scale environments. This delay is caused mostly by the extreme distance data can be required to travel. Delay can also be caused by events like solar conjunction, in which a planetary body may inhibit signal transmission.

  • Delays may also occur in smaller scale (e.g., near-Earth) environments, for example, resulting from contention for scarce scheduled resources such as antenna transmission opportunities, power constraints on duty cycles, or transient loss of connectivity.

– Highly Variable Transmission Error Rates

  • Error characteristics may vary widely at different links along the end-to-end path and/or at different times because of external factors.

  • For near-Earth missions, error rates may be strongly affected by various factors such as elevation angle.

– Asymmetric and Simplex Links

  • Deep space missions often carry constraints regarding the amount of equipment they can support on the satellite. The uplink bandwidth capacity (and the hardware required to support it) can often be minimized in favor of supporting other functions that require more of the satellite's resources. The result of this constraint is an asymmetric, sometimes even simplex, link between the satellite and the receiver.

  • Asymmetries may occur in near-Earth missions as a result of asymmetric hardware.

– Disparate Data Rates

  Data rates may vary greatly at different links along the end-to-end path. Thus a very high rate link may impinge on a node with a low-rate output, requiring the node to buffer traffic for a significant period of time.

One core element of DTN is the Bundle Protocol. BP provides end-to-end network services, operating above the data transport services provided by links or networks, accessed via the CLAs, and forming a store-and-forward network. This concept is illustrated in figure <XXX> where BP is used to provide an end-to-end data delivery service over an internetwork (on the left) and a link-layer hop (on the right). Wherever the data path transits the Bundle layer in the diagram, data may be stored waiting for an outbound path to become available.

Key capabilities of the Bundle Protocol include:

- ability to use physical mobility to assist in the forwarding of data;
- ability to move the responsibility for error control from one node to another;
- ability to cope with intermittent connectivity, including cases where the sender and receiver are not concurrently present in the network;
- ability to take advantage of scheduled, predicted, and opportunistic connectivity, whether bidirectional or unidirectional, in addition to continuous connectivity;
- ability to use available bandwidth for a wide variety of services and functions;
- late binding of bundle protocol network endpoint identifiers to underlying network addresses.

Reference [1] contains descriptions of these capabilities and rationale for the DTN architecture.

BP uses underlying ‘native’ link layer, network and/or transport protocols for communications within a given network. The layer at which those underlying protocols lie is known as the ‘convergence layer’. The interface between the BP layer and the convergence layer is known as the ‘convergence layer adapter’. This concept is illustrated in figure 21. PDUs traveling from the application and bundle layer encounter a CLA, which is responsible for sending (and receiving) bundles according to the ‘native’ protocol that the convergence layer uses underneath it (as interpreted in a standard OSI model with BP additions). Typically, a specific CLA is created for each unique ‘native’ protocol. The CLA on the left (CL A) , for example, could represent an adapter specific to a TCP network. The CLA on the right (CL B) could represent an interface to the Licklider Transmission Protocol (LTP) (reference [9]), with ‘Link B1’ representing LTP running over a CCSDS Data Link Layer protocol. Alternatively, BP can be used to support a connection between two separate internets, for example, an on-orbit internet and a ground internet, terrestrial or otherwise.

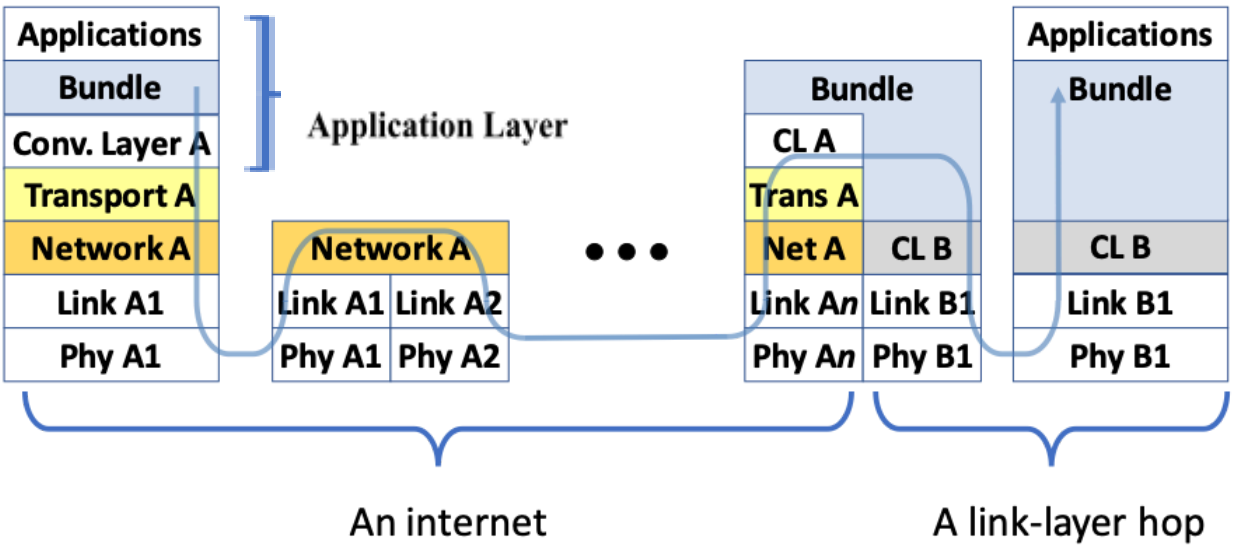


Figure 212-1 Bundle Protocol End-to-End Delivery Service": Bundle Protocol End-to-End Delivery Service

RFC 9171 describes the format of the messages (called bundles) passed between nodes participating in bundle transmission. Additionally, it addresses endpoint naming and describes how the protocol may be extended to support new capabilities while maintaining compatibility with the base protocol. Neither RFC 9171 nor this document address bundle routing algorithms (e.g., Schedule-Aware Bundle Routing [SABR]), mechanisms for populating the routing or forwarding information bases of bundle nodes, nor methods for scheduling bundle transmission (e.g., Contact Plan).

General refactoring of the bundle protocol has improved the protocol in terms of simplicity, power, and flexibility since the protocol was first released in CCSDS 734.2-B-1. These improvements make BPv7 incompatible with its previous iteration. Therefore this document, upon publication, will obsolete CCSDS 734.2-B-1.

Bundle protocol supports end-to-end communications that may include austere environments in which more commonly known communications protocols (e.g., TCP/IP) tend to break down and stop functioning. In scenarios like these, bundle protocol is an excellent technological innovation that allows multiple internetworking environments in previously unconnected locations to interact.

2.2 SERVICES PROVIDED BY BP

BP provides a data transmission service to move ‘bundles’ (contiguous groups of octets) of data from one BP node to another. The specific services provided at the service interface are:

a) initiating a registration (registering a node in an endpoint);

b) terminating a registration;

c) switching a registration between Active and Passive states;

d) transmitting a bundle to a bundle endpoint;

e) canceling a transmission that has been requested;

f) polling a registration that is in the Passive state;

g) delivering a received bundle;

h) reporting bundle status.

2.3 QUALITIES OF SERVICE NOT PROVIDED BY BP

The Bundle Protocol as specified in this document does not provide the following services:

a) in-order delivery of bundles;

b) guaranteed delivery of bundles;

c) broadcast, multicast, or anycast bundle delivery.

Custody transfer is omitted from the Bundle Protocol version 7 specification and may be standardized later via additional mechanisms, possibly supported by extension blocks. In the context of this specification, the recommended way to improve reliability is to use onlyreliable CLAs and/or an application-level reliability mechanism.

2.4 ONGOING AND FUTURE WORK

This specification covers the core Bundle Protocol functionality, and does not include specifications of security or network management.

2.4.1 SECURITY

The SIS-DTN WG is currently standardizing a set of security services based on IETF RFC 9172 (BPsec) [X - need informative reference]. BPsec provides per-block (or per-group-of-blocks) security services, including cryptographic integrity and confidentiality. With the ‘base’ BPv7 protocol, there is no mechanism to prevent a node ‘spoofing’ transmitted bundles by using the source EID of another node. While such attacks MIGHT be detectable by closely examining routing, there is no guarantee that such mechanisms would work or be sufficient.

In addition to the BPsec Blue Book in progress, the WG will, together with the SEA-SEC WG, develop a Blue or Magenta Book of CCSDS security contexts and recommended policies. The intent is to recommend that implementations use BPsec to provide integrity to at least the primary block of a bundle, and probably to (at least) the combination of the primary block and the payload block. Even without standardized key management / key distribution, users should be able to choose algorithms that provide the ability to cryptographically authenticate the primary block (which includes the source EID). For instance, a shared secret key between the sender and receiver would provide authentication of the sender, as would a public-private key

pair that includes a certificate that allows the receiver to verify the correctness of a signature generated by the source.

The goal is to eventually provide an automated, scalable key management system. Such a system is currently prototyped in the ION implementation (Delay-Tolerant Key Administration, DTKA). DTKA would need to be standardized and capabilities on which it relies, e.g. bundle multicast, which would need to be incorporated into the BPv7 specification suite if DTKA were to be widely deployed.

2.4.2 NETWORK MANAGEMENT

There will be many configuration parameters that need to be managed for each bundle node. There is ongoing work in the SIS-DTN WG and in the IETF to standardize a network management protocol that provides a level of autonomy in resource-constrained environments. The Asynchronous Management Protocol, AMP [X - need informative reference, maybe need to talk about and include AMA as well?] is the current draft specification. AMP is structured to provide an overall management protocol and set of encoding rules for a set of Asynchronous Data Models (ADMs). The community (both SIS-DTN and IETF) envisions a set of ADMs that includes both basic specification-level ADMs (e.g. an ADM that describes the configuration and monitoring of a ‘stock’ BPv7 bundle node) together with implementation-specific ADMs (e.g. an ADM that includes information specific to a particular BPv7 implementation).

The benefits of standardizing a network management protocol are (probably) largely more relevant to monitoring than they are to configuration. That is, while an agency might allow some other agency to monitor various configuration parameters of a bundle node, it seems unlikely that an agency would allow another agency to configure that node. That said, we do expect to include capabilities such as control / configuration of contact plan information (in either an ION-specific ADM or potentially in a ‘BP Nodes that use contact plans’ ADM).

Network Management, and particularly configuration changes, will probably need to be secured using the BP Security protocol above. This would allow a node to reject configuration changes that don’t pass cryptographic checks.

2.5 MECHANICS OF JOINING THE NETWORK

This section describes, at a high level, the mechanics of inserting a new node into an existing BPv7 network. While the network is still small, these manual procedures should suffice, though they are not expected to scale as the network grows. As the network grows, the procedures described here will likely shift to more automated, service-based solutions.

1) Determine the node number(s) to use for the nodes. Node nmbers are managed by SANA.

2) Determine the existing BP node(s) that the new node needs to connect to.

   The Service Site and Apertures (SS&A) SANA registry currently includes information about which sites provide DTN services. This document requests the extension of the

Service Site and Apertures SANA registry to include, with each site that provides DTN services, the node numbers of the DTN nodes at the site.

3) The Service Site and Apertures registry includes point-of-contact information for sites. Those people will be the initial points of contact to establish connectivity to the BP node(s) at the sites. Operators of new BP nodes will need to get with the site POCs or their designees to agree on convergence layers and contact plans and how to connect. Service sites may be at fixed locations (on Earth or other planetary bodies) or they may be hosted on spacecraft of different types.

4) Operators of new nodes will need to communicate with the operators of the nodes with which they wish to communicate (as destinations) to agree on security policies and other requirements. Those endpoints may or may not implement BPsec, or may have other implementation-specific mechanisms (e.g. some sort of firewall-like capabilities). Eventually nodes will start implementing the bundle security protocol, BPsec.

5) Users who wish to receive network monitoring information will need to work with the individual bp node managers to determine how to receive that information. Network management isn't standardized yet (anywhere, CCSDS *or* IETF) so it's likely that anything you'll be able to get is going to be custom.

6) Understand that connecting to a BP network means that anybody on that network can potentially send bundles to the new node. Users would be wise to consider implementing BPsec and establishing security policies to prevent unwanted traffic from being delivered to their applications.

3 CCSDS PROFILE OF RFC 9171

3.1 BUNDLE PROTOCOL FROM RFC 9171

This document adopts the Bundle Protocol as specified in Internet RFC 9171 (reference [1]), with the constraints and exceptions specified in section 3 of this document.

3.2 NAMING SCHEMES

3.2.1 Implementations of this specification shall support the ipn URI scheme as defined in section 4.2.5.1.2 of RFC 9171, *Bundle Protocol Version 7* (reference [1]).

NOTES

1 Node number 0 is reserved and is not a valid node number in the ipn URI scheme.

2 See Annex F for additional information on the ipn URI scheme.

3.2.2 Implementations of this specification are not required to deliver or forward bundles whose source, destination, or report-to endpoint identifiers use the dtn URI scheme in RFC 9171.

3.2.3 Implementations shall use IPN node numbers assigned by organizations that are documented in the SANA CCSDS CBHE Node Number Registry.

3.2.4 Implementations shall use service numbers assigned by IANA/SANA from either the IANA CBHE Service Numbers registry or the SANA CBHE Service Numbers Registry.

NOTES

1 The IANA registry includes a private address space of CBHE Service Numbers that can be used for mission-specific purposes.

2 The ‘CBHE’ label was adopted before BPv7 was standardized; the name was enshrined in registries and is therefore used here.

3.3 BUNDLE CREATION

3.3.1 Bundles shall be assigned source EID and creation timestamps when ADUs are accepted for transmission by the bundle protocol agent.

NOTE – The combination of source EID and creation timestamp is returned to the sending application in the bundle transmission request ID indication.

3.3.2 The source EIDs of all non-anonymous bundles sourced by a given bundle protocol agent shall have the same node number.

NOTE – Users may use different service numbers in the source EIDs of bundles sent.

3.3.3 Implementations are not required to be able to source bundles with sending EID dtn:none (anonymous bundles).

3.4 BUNDLE NODE REGISTRATION CONSTRAINTS

3.4.1 All endpoints in which a node is registered shall have the node number that is common to all the source node EIDs of non-anonymous bundles sourced by that node's bundle protocol agent.

3.4.2 No two bundle protocol agents shall register in endpoints whose EIDs have the same node number.

3.5 MINIMUM SUPPORTED BUNDLE SIZE

3.5.1 Conformant CCSDS implementations shall be able to forward or deliver bundles whose total size, including all extension blocks, is less than or equal to 10*(2^20) bytes (10 MB).

NOTE – Disposition of larger bundles is implementation-specific.

3.6 BUNDLE PROTOCOL SECURITY

Implementations of this specification are not required to implement Bundle Protocol security (BPsec, RFC9172).

NOTE – RFC9171 requires the implementation of RFC9172 BPsec. If an RFC9171-compliant implementation uses security services (in particular encryption) then an implementation compliant with this specification will not be able to receive those bundles.

4 SERVICE DESCRIPTION

4.1 SERVICES AT THE USER INTERFACE

4.1.1 The services provided by the Bundle Protocol shall be made available to bundle protocol users and include the following:

a) initiate a registration (registering a node in an endpoint);

b) terminate a registration;

c) switch a registration between Active and Passive states as discussed in RFC 9171;

d) transmit an Application Data Unit (ADU) to an identified bundle endpoint;

e) cancel a transmission;

f) poll a registration that is in the Passive state;

g) receive an ADU contained in a delivered bundle.

4.1.2 The BP node shall be implemented such that virtually any number of transactions may be conducted concurrently in various stages of transmission or reception at a single BP node.

NOTE – To clarify, the implementation needs to be able to accept a primitive and thereupon initiate a new transaction prior to the completion of previously initiated transactions. The requirement for concurrent transaction support therefore does not necessarily imply that the implementation needs to be able to begin initial transmission of data for one transaction while initial transmission of data for one or more other transactions is still in progress. (But neither is support for this functional model precluded.)

4.1.3 Error indications at the service interface are implementation matters not covered by this specification.

4.2 SUMMARY OF PRIMITIVES

4.2.1 The BP service shall consume the following request primitives:

– Register.request;

– Deregister.request;

– ChangeRegistrationState.request;

– Send.request;

– Cancel.request;

– Poll.request.

4.2.2 The BP service shall deliver the following indication primitives:

– BundleSendRequest.indication;

– Bundle Delivery.indication.

4.3 SUMMARY OF PARAMETERS

4.3.1 DESTINATION COMMUNICATIONS ENDPOINT ID

The destination communications endpoint ID parameter shall identify the communications endpoint to which the bundle is to be sent.

NOTE – One can think of a DTN communications endpoint as an application, but in general, the definition is meant to be broader. For example, a single BPA (with a single endpoint ID) could service other local nodes such as elements of a sensor network using private protocols.

4.3.2 SOURCE ENDPOINT ID

The source endpoint ID parameter shall uniquely identify the communications endpoint from which the bundle was sent.

4.3.3 REPORT-TO ENDPOINT ID

The report-to communications endpoint ID parameter shall identify the communications endpoint to which any bundle status reports pertaining to the bundle are sent.

4.3.4 CREATION TIMESTAMP

The creation timestamp comprises the bundle creation time and the creation timestamp sequence number.

4.3.5 SEND REQUEST OPTIONS

4.3.5.1 The send request parameters shall indicate what optional procedures are additionally to be followed when transmitting the bundle and what optional services are requested.

4.3.5.2 The value of the send request parameters shall include the following:

a) application data unit is an administrative record;

b) bundle must not be fragmented;

c) acknowledgement by application is requested;

d) request reporting of bundle reception;

e) request reporting of bundle forwarding;

f) request reporting of bundle delivery;

g) request reporting of bundle deletion;

h) status time is requested in all status reports.

NOTE – Implementations may also allow inclusion of other information with the Send Request Parameters, such as metadata and material to be included in particular extension blocks.

4.3.6 BUNDLE DELIVERY INDICATION PARAMETERS

4.3.6.1 The delivery indication parameters shall be the ADU and the metadata from 4.3.7.2 below pertaining to the ADU.

4.3.6.2 The value of the delivery indications parameters shall include the following:

a) application data unit is an administrative record;

b) acknowledgement by application is requested.

NOTE – Implementations may also include other information with the Bundle Delivery Indication Parameters such as the source EID, creation time, and/or information from extension blocks.

4.3.7 LIFETIME PARAMETER

The lifetime parameter shall indicate the length of time, following initial creation time of a bundle, after which bundle protocol agents may discard the bundle.

4.3.8 APPLICATION DATA UNIT PARAMETER

The application data unit parameter shall indicate the location (in memory or non-volatile storage, a local implementation matter) of the application data conveyed by the bundle.

4.3.9 BUNDLE SEND REQUEST ID

The Bundle Send Request ID parameter shall identify a particular bundle. The Bundle Send Request ID comprises the source EID and creation timestamp.

4.3.10 DELIVERY FAILURE ACTION

4.3.10.1 The Delivery Failure Action parameter shall identify the response the node is to take on receipt of a bundle that is deliverable subject to the registration when the registration is in the Passive state (see 4.3.11).

4.3.10.2 The Delivery Failure Action parameter shall signal one of the following possible responses:

- defer delivery of the bundle;
- abandon delivery of the bundle.

NOTE – RFC 9171 section 5.7 (Bundle Delivery) contains more on when deferred bundles may be delivered to receiving applications.

4.3.11 REGISTRATION STATE

The Registration State is the state machine characterization of a given node's membership in a given endpoint. A registration state must at any time be in one of two states: Active or Passive.

NOTE – A registration always has an associated 'delivery failure action' that denotes the action to be taken upon receipt of a bundle that is deliverable subject to the registration when the registration is in the Passive state (refer to 4.3.10). Further definition of Registration can be found in section 5.7 of RFC 9171.

4.3.12 BUNDLE DELIVERY METADATA

The Bundle Delivery Metadata parameter shall uniquely identify the delivered bundle and shall at minimum indicate the delivered bundle's remaining time to live and the time the bundle was received.

4.4 BP SERVICE PRIMITIVES

4.4.1 REGISTER.REQUEST

4.4.1.1 Function

The Register.request primitive shall be used to notify the BP agent of the node's membership in a communications endpoint.

4.4.1.2 Semantics

Register.request shall provide parameters as follows:

Register.request	(delivery failure action, destination communications endpoint ID)

4.4.1.3 When Generated

Register.request may be generated by any BP application at any time.

4.4.1.4 Effect on Receipt

4.4.1.4.1 Receipt of Register.request shall cause the BPA to declare the node's registration in the indicated endpoint.

4.4.1.4.2 The registration shall initially be in Passive state.

4.4.1.4.3 The indicated failure action shall be taken upon arrival of any bundle destined for this endpoint, as long as the registration remains in Passive state.

4.4.1.5 Discussion—Additional Comments

Registration in particular endpoints (especially those associated with the node number of the node) may be implicit in the instantiation of the BPA or could require explicit registration requests from applications.

4.4.2 DEREGISTER.REQUEST

4.4.2.1 Function

The Deregister.request primitive shall be used to notify the BPA of the end of the node's membership in the indicated endpoint.

4.4.2.2 Semantics

Deregister.request shall provide parameters as follows:

Deregister.request (destination communications endpoint ID)

4.4.2.3 When Generated

Deregister.request may be generated by any BP application at any time when the node is registered in the indicated endpoint.

4.4.2.4 Effect on Receipt

Receipt of Deregister.request shall cause the node's registration in the indicated endpoint to be rescinded.

4.4.2.5 Discussion—Additional Comments

None.

4.4.3 CHANGEREGISTRATIONSTATE.REQUEST

4.4.3.1 Function

The ChangeRegistrationState.request primitive shall be used to notify the BP agent of a desired change in the registration state.

4.4.3.2 Semantics

ChangeRegistrationState.request shall provide parameters as follows:

ChangeRegistrationState.request	(destination communications endpoint ID, registrationState)

4.4.3.3 When Generated

ChangeRegistrationState.request may be generated by any BP application at any time when the node is registered in the indicated endpoint.

4.4.3.4 Effect on Receipt

4.4.3.4.1 Receipt of ChangeRegistrationState.request shall cause the BP agent to change the state of the registration to the requested state.

4.4.3.4.2 If the new state is Active, receipt of this request shall additionally cause the bundle protocol agent to deliver to the application all bundles destined for the indicated endpoint, for which delivery was deferred.

4.4.3.5 Discussion—Additional Comments

Changing the state of the registration to ‘active’ implicitly associates with that end point the application that issued the request. The expected effect of this association is that all bundles destined for this endpoint will be delivered to that application, but the details of this association are an implementation matter.

4.4.4 SEND.REQUEST

4.4.4.1 Function

The Send.request primitive shall be used by the application to request transmission of an application data unit from the source communications endpoint to a destination communications endpoint.

4.4.4.2 Semantics

Send.request shall provide parameters as follows:

Send.request (source endpoint ID,
destination endpoint ID,
report-to endpoint ID,
send request options,
lifetime,
application data unit)

4.4.4.3 When Generated

Send.request may be generated by the source BP application at any time.

4.4.4.4 Effect on Receipt

Receipt of Send.request shall cause the BP agent to initiate bundle transmission procedures and shall cause a BundleRequestID.indication to be returned to the issuer of the send request.

4.4.4.5 Discussion—Additional Comments

None.

4.4.5 CANCEL.REQUEST

4.4.5.1 Function

The Cancel.request primitive shall be used by the application to request termination of transmission of an application data unit for which the application previously requested transmission.

4.4.5.2 Semantics

Cancel.request shall provide parameters as follows:

Cancel.request (BundleRequestID)

4.4.5.3 When Generated

Cancel.request may be generated by the application at any time after requesting transmission of a bundle.

4.4.5.4 Effect on Receipt

Receipt of Cancel.request shall cause the BP agent to stop attempting to transmit and to discard the target bundle, if possible.

4.4.5.5 Discussion—Additional Comments

If the bundle has already been transmitted, there is no obligation on the sending BP agent to take any further action. It is an implementation matter whether a bundle that is in the process of being transmitted when a Cancel.request is received is terminated.

4.4.6 POLL.REQUEST

4.4.6.1 Function

The Poll.request primitive shall be used by the application to request immediate delivery of the least-recently received bundle that is currently deliverable subject to the node's registration in the indicated endpoint.

4.4.6.2 Semantics

Poll.request shall provide parameters as follows:

Poll.request (destination communications endpoint ID)

4.4.6.3 When Generated

Poll.request may be generated by any BP application at any time when the node is registered in the indicated endpoint and that registration is in Passive state.

4.4.6.4 Effect on Receipt

Receipt of Poll.request shall cause the BP agent to deliver to the BP application the least-recently received bundle destined for the destination communications endpoint ID, for which delivery was deferred.

NOTE – Prioritization applies only to forwarding of a bundle. Deferred bundles are delivered in the order in which they were received.

4.4.6.5 Discussion—Additional Comments

None.

4.4.7 BUNDLEREQUESTID.INDICATION

4.4.7.1 Function

The BundleRequestID.indication primitive shall be used to provide the application a reference to a particular bundle for which the application requested transmission.

4.4.7.2 Semantics

BundleRequestID.indication shall provide parameters as follows:

```
BundleRequestID.indication  (SourceNodeID,
                             CreationTimestamp)
```

4.4.7.3 When Generated

BundleRequestID.indication shall be generated by a BP agent after it has consumed a Send.request from the application.

4.4.7.4 Effect on Receipt

The effect on receipt of BundleRequestID.indication by a BP application is undefined.

4.4.7.5 Discussion—Additional Comments

On receiving this notice, the sending application can, for example, release resources of its own that are allocated to the bundles being transmitted or record the BundleRequestID so that transmission can be canceled in the future, if necessary.

4.4.8 BundleDelivery.indication

4.4.8.1 Function

The BundleDelivery.indication primitive shall be used to deliver the application data unit and associated metadata to the service user.

4.4.8.2 Semantics

BundleDelivery.indication shall provide parameters as follows:

BundleDelivery.indication	(bundle delivery metadata, application data unit)

4.4.8.3 When Generated

BundleDelivery.indication shall be generated by a BP agent upon delivery of a bundle, either on reception of bundles destined for active registrations or in response to poll requests referencing passive registrations.

4.4.8.4 Effect on Receipt

The effect on receipt is defined by the application.

4.4.8.5 Discussion—Additional Comments

None.

5 BP NODE REQUIREMENTS

5.1 DISCUSSION

5.1.1 Bundle Protocol implements the bundle mechanisms needed to generate, forward, and receive bundles. To do so it relies on the existence of services from some external source (e.g. the spacecraft on which the bundle node resides). This section lists the services that BP needs from some external source in order to function. It is broken into operational requirements (basic services such as storage and a source of time), and underlying communication service requirements (external services that effect transmission and reception).

5.2 OPERATIONAL REQUIREMENTS

5.2.1 BP nodes shall have access to a storage service.

NOTES

1 This storage mechanism may be in dynamic memory or via a persistent mechanism such as a solid-state recorder and may be organized by various means to include file systems.

2 The implementation of this storage can be shared among multiple elements of the communication stack so that reliability mechanisms at multiple layers do not have to maintain multiple copies of the data being transmitted.

3 Volume of storage required and duration of storage are mission- and implementation-dependent.

4 Storage reliability is subject to mission and service requirements.

5.2.2 The following information shall be available to BP, either from the local operating environment or from the underlying communication service provider:

a) forward advancing time that can be represented as ‘DTN time’ as defined by RFC 9171 (reference [1]);

b) A counter conforming to the requirements of section 4.2.7 in RFC 9171 to provide sequence numbers for the creation timestamp fields of bundles.

NOTE – The means by which this information is accessed by BP is implementation-dependent.

5.3 UNDERLYING COMMUNICATION SERVICE REQUIREMENTS

5.3.1 Each convergence layer protocol adapter shall provide the following services to the bundle protocol agent:

a) sending a bundle to a bundle node that is reachable via the convergence layer protocol;

b) notifying the bundle protocol agent of the disposition of its data sending procedures with regard to a bundle, upon concluding those procedures;

c) delivering to the bundle protocol agent a bundle that was sent by a bundle node via the convergence layer protocol.

NOTES

1 The convergence layer service interface specified here is neither exhaustive nor exclusive. That is, supplementary DTN protocol specifications (including, but not restricted to, the Bundle Protocol Security as specified in RFC 9172) may expect convergence layer adapters that serve BP implementations conforming to those protocols to provide additional services such as reporting on the transmission and/or reception progress of individual bundles (at completion and/or incrementally), retransmitting data that were lost in transit, discarding bundle-conveying data units that the convergence layer protocol determines are corrupt or inauthentic, or reporting on the integrity and/or authenticity of delivered bundles.

2 Additionally, BP relies on the capabilities of protocols at the convergence layer to minimize congestion. The potentially long round-trip times characterizing delay-tolerant networks are incompatible with end-to-end reactive congestion control mechanisms, so convergence-layer protocols are expected to provide rate limiting or congestion control.

5.3.2 The service provided by the protocols beneath BP (not necessarily by the convergence layer protocol itself) shall deliver only complete bundles to the receiving BP Node.

5.3.3 Delivery of duplicate bundles to a BPA by the underlying layer shall be acceptable.

ANNEX A

PROTOCOL IMPLEMENTATION CONFORMANCE STATEMENT PROFORMA

(NORMATIVE)

A1 OVERVIEW

This annex provides the Protocol Implementation Conformance Statement (PICS) Requirements List (RL) for CCSDS-compliant implementations of BP. The PICS for an implementation is generated by completing the RL in accordance with the instructions below. An implementation shall satisfy the mandatory conformance requirements of the base standards referenced in the RL.

An implementation's completed RL is called the PICS. The PICS states which capabilities and options of the protocol have been implemented. The following can use the PICS:

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

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

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

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

A2 INSTRUCTIONS FOR COMPLETING THE RL

An implementer shows the extent of compliance to the protocol by completing the RL; that is, compliance to all mandatory requirements and the options that are not supported are shown. The resulting completed RL is called a PICS. In the Support column, each response shall be selected either from the indicated set of responses, or it shall comprise one or more parameter values as requested. If a conditional requirement is inapplicable, N/A should be used. If a mandatory requirement is not satisfied, exception information must be supplied by entering a reference *Xi*, where *i* is a unique identifier, to an accompanying rationale for the noncompliance.

A3 NOTATION

A3.1 The symbols in table A1 are used in the RL to indicate the status of features.

Table A1A-1 PICS Notation": PICS Notation

Symbol	Meaning
M	Mandatory.
O	Optional.
O.<n>	Optional, but support of at least one of the group of options labeled by the same numeral <n> is required.

A3.2 The symbols in table A2 shall be used in the 'Support' column of the PICS.

Table A2A-2 Symbols for PICS 'Support' Column": Symbols for PICS 'Support' Column

Symbol	Meaning
Y	Yes, the feature is supported by the implementation.
N	No, the feature is not supported by the implementation.
N/A	The item is not applicable

A4 REFERENCED BASE STANDARDS

A4.1 The base standards referenced in the RL shall be:

a) CCSDS BP (this document);

b) RFC 9171 (reference [1]).

A4.2 In the tables below, the notation in the Reference column combines one of the short-form document identifiers above (e.g., RFC 9171) with applicable subsection numbers in the referenced document. RFC numbers are used to facilitate reference to subsections within the Internet specifications.

A5 GENERAL INFORMATION

A5.1 IDENTIFICATION OF PICS

Ref	Question	Response
1	Date of Statement (DD/MM/YYYY)	
2	PICS serial number	
3	System conformance statement cross-reference	

A5.2 IDENTIFICATION OF IMPLEMENTATION UNDER TEST (IUT)

Ref	Question	Response
1	Implementation name	
2	Implementation version	
3	Name of hardware (machine) used in test	
4	Version of hardware (machine) used in test	
5	Name of operating system used during test	
6	Version of operating system used during test	
7	Additional configuration information pertinent to the test	
8	Other information	

A5.3 IDENTIFICATION

Ref	Question	Response
1	Supplier	
2	Point of contact for queries	
3	Implementation name(s) and version(s)	
4	Other information necessary for full identification (e.g., name(s) and version(s) for machines and/or operating systems)	

A5.4 PROTOCOL SUMMARY

Ref	Question	Response
1	Protocol version	
2	Addenda implemented	
3	Amendments implemented	
4	Have any exceptions been required? NOTE – A YES answer means that the implementation does not conform to the protocol. Non-supported mandatory capabilities are to be identified in the PICS, with an explanation of why the implementation is non-conforming.	a) Yes b) No
5	Date of statement (DD/MM/YYYY)	

A5.5 BASIC REQUIREMENTS

Item	Protocol Feature	Reference	Status	Support
BP Formatting	Formats bundles as BPv7 per RFC 9171	This document: 3.1. RFC 9171 Section 4 except section 4.2.5.1 and section 4.4	M	
Previous Node	Recognizes, parses, and acts on the previous node extension block	RFC 9171 section 4.4.1	M	
Bundle Age	Recognizes, parses, and acts on the bundle age extension block	RFC 9171 section 4.4.2	M	
Hop Count	Recognizes, parses, and acts on the hop count extension block	RFC 9171 section 4.4.3	M	
BPv7	Identifies bundles as version 7 in the primary block	RFC 9171 section 9.2	M	

Item	Protocol Feature	Reference	Status	Support
IPN_naming	Support for the ipn URI Naming Scheme	This document: 3.2.1. RFC 9171 section 4.2.5.1.2	M	
dtn:none	Support for the dtn:none endpoint ID	This document: 3.2.2. RFC 9171 section 4.2.5.1.1	M	
IPN Node No	Use IPN node numbers assigned by SANA	This document: 3.2.3	M	
IPN Service No	Use IPN service numbers assigned by IANA/SANA	This document: 3.2.4	M	
Bundle Creation Metadata	Bundle creation timestamp and timestamp sequence number assigned when ADU is accepted for transmission	This document: 3.3.1	M	
Source Node ID	The source EIDs for all non-anonymous bundles shall have the same node number	This document: 3.3.2	M	
Support for dtn:none	Supports sending bundles with source dtn:non	This document: 3.3.3	O	
Registration Constraints	All endpoints in which a node is registered shall have the same node number	This document: 3.4	M	
Minimum Bundle Size	Supports processing of bundles whose total size is less than or equal to $10*2^{20}$ bytes (10 MB)	This document: 3.5	M	
Service Interface	Supports the service interface in section 4	This document: section 4.	M	

Item	Protocol Feature	Reference	Status	Support
LTP CLA	Implements bundle encapsulation in LTP blocks	This document: B2.1.4	O.1	
UDP CLA	Implements bundle encapsulation in UDP datagrams.	This document: B2.1.3	O.1	
Space Packets CLA	Implements encapsulation of bundles in Space Packets	This document B2.1.5	O.1	
BP Managed Information	Implements the BP managed information described in annex C	This document, annex C	M	
Generation of Administrative Records	Follows RFC 9171 rules for generation of administrative records	RFC 9171 Section 5.1	M	
Bundle Transmission	Follows RFC 9171 procedures for bundle transmission	RFC 9171 Section 5.2	M	
Forwarding Contraindicated	Follows RFC 9171 procedures when forwarding is contraindicated	RFC 9171 Section 5.3	M	
Forwarding Failed	Follows RFC 9171 procedures when forwarding a bundle fails	RFC 9171 Section 5.4	M	
Bundle Expiration	Follows RFC 9171 procedures when a bundle expires	RFC 9171 Section 5.5	M	
Bundle Reception	Follows RFC 9171 procedures when receiving a bundle	RFC 9171 Section 5.6	M	
Local Bundle Delivery	Follows RFC 9171 procedures when delivering a bundle to the application agent	RFC 9171 Section 5.7	M	

Item	Protocol Feature	Reference	Status	Support
Bundle Fragmentation	Follows RFC 9171 procedures when fragmenting a bundle	RFC 9171 Section 5.8	M	
Application Data Unit Reassembly	Follows RFC 9171 procedures when reassembling and ADU	RFC 9171 Section 5.9	M	
Bundle Deletion	Follows RFC 9171 procedures when deleting a bundle	RFC 9171 Section 5.10	M	
Discarding a Bundle	Follows RFC 9171 procedures when discarding a bundle.	RFC 9171 Section 5.11	M	
Canceling a Transmission	Follows RFC 9171 procedures when canceling a transmission	RFC 9171 Section 5.12	M	
Administrative Records	Formats administrative records per RFC 9171	RFC 9171 section 6.1		
Bundle Status Reports	Formats status reports per RFC 9171	RFC 9171 section 6.1.1	M	
MIB_state	Bundle State Information	This document: table C1	M	
MIB_errors	Error and Reporting Information	This document: table C2	M	
MIB_registration	Registration Information	This document: table C3	M	
MIB_CL_info	Convergence-Layer Information	This document: table C4	M	
MIB_Config	General Configuration Information	This document: annex C	M	

ANNEX B

CONVERGENCE LAYER ADAPTERS

(NORMATIVE)

B1 OVERVIEW

This annex describes various CLAs to support mission operations both in space and on the ground. There are many possible convergence layer protocols to support the various communications interfaces with which the Bundle Protocol may interact. This annex is in no manner comprehensive or rigorous but contains CCSDS supported CLAs that have been demonstrated under various environments, have been requested to be included at the time of this writing, and appear applicable to CCSDS users.

B2 CONVERGENCE LAYER ADAPTERS

B2.1 AVAILABLE CL ADAPTERS

B2.1.1 General

Compliant implementations shall implement at least one of the CLAs in this section.

B2.1.2 TCP Convergence Layer Adapter

When sending/receiving bundles using TCP at the convergence layer, bundles shall be encapsulated in TCP packets according to the Delay-Tolerant Networking TCP Convergence-Layer Protocol (reference [4]).

NOTE – IANA has allocated TCP port 4556 for the TCP CLA.

B2.1.3 UDP Convergence Layer Adapter—Encapsulation of Bundles in UDP Datagrams

B2.1.3.1 UDP Maximum Bundle Transmission Size

The maximum size of a bundle that can be encapsulated in the UDP (reference [8]) CLA is 65,535 bytes.

B2.1.3.2 Bundle Encapsulation in UDP

Each .

NOTE – Bundle protocol agents should endeavor to send bundles of such a size as not to require fragmentation by the IP (Internet Protocol) layer. In practice this generally means keeping the size of the IP datagram (including the IP and UDP headers, plus the bundle) to no more than 1500 bytes.

NOTE – IANA has allocated UDP port 4556 for the UDP CLA.

B2.1.3.3 Network Interactions

All implementations should ensure that the traffic sent by the UDP convergence layer adaptor does not adversely affect other traffic on the network.

NOTES

1 Network characteristics can best be managed on a closed network or a network with reserved bandwidth, or the utilization of congestion control procedures as described in RFC 8085 (reference [F2]) can be adopted.

2 UDP does not provide any congestion control; UDP CLAs that may be used over large shared networks like the Internet should take measures to ensure that they do not adversely affect other traffic on the network. One such measure would be to control the rate at which UDP datagrams are emitted from the CLA; another would be to define a Datagram Congestion Control Protocol (DCCP)-based CLA. (See RFC 7122 for more information.)

B2.1.4 LTP Convergence Layer Adapter—Encapsulation of Bundles in LTP Blocks

B2.1.4.1 LTP Blocks Include Only Whole Bundles

An LTP CLA shall only include an integral number of complete bundles in an LTP block.

B2.1.4.2 Length, Value Encoding of Bundles in LTP Blocks

Each bundle in an LTP block shall be preceded by a CBOR unsigned integer whose value is the length of the bundle (including all blocks) in octets.

B2.1.4.3 Decapsulation of Bundles Encapsulated in LTP

Bundles shall be extracted from LTP blocks at the receiver and shall be passed to the receiving BPA.

NOTE – Because senders may concatenate multiple bundles into an LTP block, all LTP CLA receivers need to be able to parse multiple bundles out of a received LTP block.

B2.1.4.4 RELIABLE TRANSMISSION VIA LTP

For reliable bundle transmission using LTP, bundles shall be encapsulated in LTP blocks containing only red-part (reliable) data.

B2.1.4.5 UNRELIABLE TRANSMISSION VIA LTP

For unreliable bundle transmission, bundles shall be encapsulated into LTP blocks containing only green-part (unreliable) data.

B2.1.5 SPP Convergence Layer (reference [5])

B2.1.5.1 SPP Maximum Bundle Transmission Size

The maximum size of a bundle that can be transferred using the Service Packet Protocol (SPP) convergence layer adaptor shall be 65,536 (the size of any packet secondary header) bytes.

B2.1.5.2 Bundle Encapsulation in SPP

Each bundle shall be encapsulated into one SPP packet with no additional bytes.

B2.1.6 Encapsulation Packet Protocol Convergence Layer (reference [6])

B2.1.6.1 Encapsulation Packet Protocol Maximum Bundle Transmission Size

The maximum size of a bundle that can be transferred using the Encapsulation Packet Protocol (EPP) convergence layer adaptor shall be 4,294,967,287 bytes.

B2.1.6.2 Bundle Encapsulation in Encapsulation Packet Protocol

Each bundle shall be encapsulated into one EPP packet with no additional bytes.

B2.1.6.3 EPP Protocol Identifier

Implementations with EPP shall use EPP Protocol Identifiers (EPIs) allocated by SANA (see reference [7]).

ANNEX C

BP MANAGED INFORMATION

(NORMATIVE)

C1 BASIC REQUIREMENTS

C1.1 Upon request each BP node shall provide managed information that represents the state of the node at a particular time. The minimal set of such information shall include those data items identified by RFC 9171 and collected in this annex. The manner in which the information is requested and provided / delivered is an implementation matter.

C1.2 BP nodes shall support five types of managed information:

a) bundle state information;

b) error and reporting information;

c) registration information;

d) convergence layer information;

e) node state information.

C1.3 In addition to required information, each BP node may choose to provide supplementary information. Each identified managed information item shall identify whether its collection and accurate reporting is required or recommended.

NOTES

1 In the future, managed information may be queried and delivered via a network management protocol.

2 Individual pieces of managed information may describe related events. Care must be taken when modifying these data to ensure that related data sets remain coherent. For example, when a cumulative counter ‘rolls over’ or is otherwise reset, related counters should also be reset.

C2 BUNDLE STATE INFORMATION

C2.1 OVERVIEW

Bundles do not have a natural end state within a node; they are forwarded, delivered, or deleted. As such, bundles at rest within a node exist pending a particular action. This set of managed information describes these bundle states and the transitions between them.

C2.2 SUPPORTED TYPES OF BUNDLE STATE INFORMATION

BP nodes shall support the bundle state information itemized in table C1.

Table C1C-1 Bundle State Information": Bundle State Information

Managed Information Item	Description		Req?
Retention Constraints			
Bundles Retained for Forwarding	The number of bundles/bytes associated with the retention constraint ***forward pending*** at this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Bundles Retained for Transmission	The number of bundles/bytes associated with the retention constraint ***dispatch pending*** at this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Bundles Retained for Reassembly	The number of bundles/bytes associated with the retention constraint ***reassembly pending*** at this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Priority Counters			
Bulk Bundles Sourced	The number of bundles/bytes generated by this node with the ***bulk*** priority.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Normal Bundles Sourced	The number of bundles/bytes generated by this node with the ***normal*** priority.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Expedited Bundles Sourced	The number of bundles/bytes generated by this node with the ***expedited*** priority.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Bulk Bundles Queued	The number of bundles/bytes with the ***bulk*** priority currently resident on this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes

Normal Bundles Queued	The number of bundles/bytes with the ***normal*** priority currently resident on this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Expedited Bundles Queued	The number of bundles/bytes with the ***expedited*** priority currently resident on this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Fragmentation			
Fragmentation	The number of bundles that have been fragmented by this node.	Cumulative Bundles	Yes
Number of Fragments	The number of fragments created by this bundle.	Cumulative Bundles	Yes

C3 NODE ERROR AND REPORTING INFORMATION

C3.1 OVERVIEW

Nodes generate reports in response to both anomalous and special events. This set of managed information reports on the number of errors and reports constructed at the node.

C3.2 SUPPORTED TYPES OF ERROR AND REPORTING INFORMATION

BP nodes shall support the error and reporting information itemized in table C2.

Table C2C-2 Error and Reporting Information": Error and Reporting Information

Managed Information Item	Description		Req?
Bundle Deletions			
No Info Deletions	The number of bundles deleted with the ***No additional information*** reason code.	Cumulative Bundles	No
Expired Deletions	The number of bundles deleted with the ***Lifetime expired*** reason code.	Cumulative Bundles	No
Uni-forwarded Deletions	The number of bundles deleted with the ***Forwarded over unidirectional link*** reason code.	Cumulative Bundles	No
Cancellation Deletions	The number of bundles deleted with the ***Transmission canceled*** reason code.	Cumulative Bundles	No

Managed Information Item	Description		Req?
No Storage Deletions	The number of bundles deleted with the ***Depleted Storage*** reason code.	Cumulative Bundles	No
Bad EID Deletions	The number of bundles deleted with the ***Destination endpoint ID unintelligible*** reason code.	Cumulative Bundles	No
No Route Deletions	The number of bundles deleted with the ***No known route to destination from here*** reason code.	Cumulative Bundles	No
No Timely Contact Deletions	The number of bundles deleted with the ***No timely contact with next node on route*** reason code.	Cumulative Bundles	No
Bad Block Deletions	The number of bundles deleted with the ***Block unintelligible*** reason code.	Cumulative Bundles	No
Bytes deleted	The total number of bytes in all bundles deleted at this node.	Cumulative Bytes	No
Bundle Processing Errors			
Failed Forwards	The number of bundles/bytes that have experienced a forwarding failure at this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Abandoned Delivery	The number of bundles/bytes whose delivery has been abandoned at this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes
Discarded Bundles	The number of bundles/bytes discarded at this node.	Cumulative Bytes	No
		Cumulative Bundles	Yes

C4 REGISTRATION INFORMATION

C4.1 OVERVIEW

Each node registers in one or more endpoints. These registrations allow for the reception and processing of bundles in the context of the endpoints to which they are addressed.

C4.2 SUPPORTED TYPES OF REGISTRATION INFORMATION

BP nodes shall support the registration information itemized in table C3.

Table C3C-3 Registration Information": Registration Information

Managed Information Item	Description	Req?
Identity Information		
Endpoint Identifier	The Endpoint ID of this registered endpoint.	Yes
Activity State	The current state of the EID, at the time the managed information was queried. One of: ACTIVE or PASSIVE.	Yes
Singleton State	Whether this EID is a singleton EID. One of: YES or NO.	Yes
Default Failure Action	The default action to be taken when delivery is not possible. One of: ABANDON or DEFER.	Yes

C5 NODE STATE INFORMATION

C5.1 OVERVIEW

Global node state information provides the context for using other managed information items.

C5.2 SUPPORTED TYPES OF NODE STATE INFORMATION

BP nodes shall support the node state information itemized in table C4.

Table C4C-4 Node State Information": Node State Information

Managed Information Item	Description	Req?
Node State (one occurrence per node)		
Node Administrative Endpoint ID	The Endpoint ID that uniquely and permanently identifies this node's administrative endpoint.	Yes
Bundle Protocol Version Numbers	The number(s) of the version(s) of the Bundle Protocol that is supported at this node.	Yes

Managed Information Item	Description	Req?
Available Storage	The number of kilobytes of storage allocated to bundle retention at this node and not currently occupied by bundles.	Yes
Last Up Time	The most recent time at which the operation of this node was started or restarted.	Yes
Registration Count	The number of different endpoints in which this node has been registered since it was last started or restarted.	No
Extension Information (one occurrence per extension)		
Extension Name	The name identifying one of the BP extensions supported at this node.	Yes

ANNEX D

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

D1 SECURITY

D1.1 OVERVIEW

The Bundle Protocol as defined by RFC 9171 has factored in security from the outset of its design. The necessary security architecture and services have been developed in an accompanying RFC, the Bundle Protocol Security specification. Because BP was designed for a resource-constrained environment, it is essential to ensure that only those entities authorized to utilize those resources be allowed to do so.

Also, because of the long latencies and delays in the constrained environments which utilize BP, integrity and confidentiality are essential. Without adequate protections in place to ensure that data integrity and confidentiality are maintained, the difficulty in identifying compromised data will be compounded as a result of the unique environment of CCSDS missions.

D1.2 SECURITY CONCERNS WITH RESPECT TO THE CCSDS DOCUMENT

The BPv7 specification (reference [1]) contains a security section (9), which addresses necessary measures to protect bundle protocol data and recommends the use of the Bundle Security Protocol (BPSec) of RFC 9172. Two types of security blocks are defined in RFC 9172:

a) Bundle Integrity Block (BIB) – Used to ensure the integrity of its plain text security target(s). The integrity information in the BIB MAY be verified by any node along the bundle path from the BIB security source to the bundle destination. Waypoints add or remove BIBs from bundles in accordance with their security policy. BIBs are never used for integrity protection of the cipher text provided by a BCB. Because security policy at BPSec nodes may differ regarding integrity verification, BIBs do not guarantee hop-by-hop authentication, as discussed in RFC9172 section 1.1.

b) Block Confidentiality Block (BCB) – Indicates that the security target(s) have been encrypted at the BCB security source in order to protect their content while in transit. The BCB is decrypted by security acceptor nodes in the network, up to and including the bundle destination, as a matter of security policy. BCBs additionally provide integrity protection mechanisms for the cipher text they generate.

This specification specifically does not require implementation of RFC9172. Implementations are encouraged to implement RFC9172 and/or the forthcoming CCSDS profile of it if they need security services. Because RFC9171 requires implementing RFC9172, an IETF-compliant implementation could send bundles that use security services to a CCSDS BPv7 implementation, which might be unable to receive those bundles.

D1.3 AUDITING OF RESOURCE USAGE

No mechanisms are defined in this specification to audit or assist with the auditing of resource usage by the protocol.

D1.4 POTENTIAL THREATS AND ATTACK SCENARIOS

No potential threat or attack scenarios are discussed.

D1.5 CONSEQUENCES OF NOT APPLYING SECURITY TO THE TECHNOLOGY

By not applying the native security of the BP protocol and the extended security of BPSec allowed by BP, the system must rely on security measures provided at the CLA interfaces and below. For space applications, these may be nonexistent or merely physical because of the lack of integration between payload and ground systems interfaces. If no security is applied at the BP or lower layers, then applications may be open to man-in-the middle attacks, replay attacks, or a general loss of integrity of transported bundles.

D2 SANA CONSIDERATIONS

SANA provides a node number registry that uses a space delegated to it by IANA for the registration of node numbers. While this registry is sufficient to prevent the unintentional reuse of node numbers across missions, it does not provide any information about the capabilities (e.g. convergence layer adapters, supported extension blocks, scheduled routing schedules, supported services) of specific nodes, including information about how to connect to such nodes.

To provide a link between sites supporting BP nodes and points of contact that can provide the information needed to communicate with the nodes, we propose to leverage the Service Sites and Apertures (SS&A) registry of SANA. For sites supporting BP services, the existing fields in the Service Site and Apertures registry will be used to identify the location of the node and the point of contact.

To support the linkage between Node Numbers and points of contact who can provide information about how to connect to those nodes we request that SANA add a field to the Site Services portion of the SS&A that contains a list of the Node Numbers of the BP Nodes at the site. Users should also be able to query the SS&A registry for the sites providing BP services.

Note that the union of all of the node numbers referred to by the various entries in the SS&A registry constitutes the set of all CCSDS bundle nodes that a user might need to know of in order to participate in the network. More specifically, agencies are expected to register any terrestrial BP infrastructure that might be used in cross-support activities in the SS&A registry.

This document also requests that SANA add a point of contact column to the CBHE node numbers registry for each allocated CBHE node range.

D3 PATENT CONSIDERATIONS

There are no known patents covering the Bundle Protocol as described in this document and its normative references.

ANNEX E

BP ELEMENT NOMENCLATURE

E1 BP BLOCK TABLES

This annex specifies the canonical nomenclature for DTN BPv7 block field definitions. In the terms column, the non-canonical terms are given. The full canonical name is formed by prepending 'BPv7.' and the table name transformed into camelcase followed by a dot. So, for example, the full canonical name of the 'isFragment' field in the primary block is:

BPv7.primaryBlock.controlFlags.isFragment

This annex does not imply anything about implementation, encoding of values, or range limitations set by the encoding or implementation. (For encoding and limits set by the encoding methods, see RFC 9171.)

Value limits imposed by implementations will be documented by forthcoming network management specifications.

E2 PRIMARY BLOCK ELEMENTS

Table E1E-1 Primary Block": Primary Block

Term		Logical Data Type	Range
bundleVersion		unsigned integer	(0 ..)
bundleControlFlags	**isFragment**	Boolean	(0 .. 1)
	isAdmin	Boolean	(0 .. 1)
	doNotFragment	Boolean	(0 .. 1)
	E2EAckRequested	Boolean	(0 .. 1)
	stausReportTimeRequested	Boolean	(0 .. 1)
	receivedStatusRequested	Boolean	(0 .. 1)
	forwardedStatusRequested	Boolean	(0 .. 1)
	deliveredStatusRequested	Boolean	(0 .. 1)
	deletedStatusRequested	Boolean	(0 .. 1)
crcType		unsigned integer	(0 .. 2)
destinationEID		EID	(Dependent on addressing scheme)

Term		Logical Data Type	Range
sourceEID		EID	(Dependent on addressing scheme)
reportToEID		EID	(Dependent on addressing scheme)
creationTimestamp	**bundleCreationTime**	unsigned integer	(0 ..)
	sequenceNumber	unsigned integer	(0 ..)
bundleLifetime		unsigned integer	(0 ..)
fragmentOffset		unsigned integer	(0 ..)
totalADULength		unsigned integer	(1 ..)
crcValue		byte string	(0 ..)

NOTES

1 The value of the primaryBlock.BundleVersion field for the version of the bundle protocol specified in this document is 7.

2 The fragmentOffset and totalADULength fields are only present if the bundle is a fragment.

E3 BLOCK SHARED ELEMENTS

All blocks other than the primary block share a common structure that includes information about the block, CRC information, and a block content field. Those shared elements are represented in the table E2.

NOTE – At the time of this specification, the following block types are defined:

- Payload Block: blockType Range (1);
- Previous Node Block: blockType Range (6);
- Age Block: blockType Range (7);
- Hop Count Block: blockType Range (10).

Table E2E-2 Block Metadata": Block Metadata

Term		Logical Data Type	Range
blockType		unsigned integer	(0 ..)
blockNum		unsigned integer	(1 ..)
processingControlFlags	**replicateInAllBlocks**	Boolean	(0 .. 1)
	reportStatusIfUnprocessed	Boolean	(0 .. 1)
	deleteIfUnprocessed	Boolean	(0 .. 1)
	removeIfUnprocessed	Boolean	(0 .. 1)

crcType	unsigned integer	(0 .. 2)
blockContent	blockContentType	(Dependent on value of blockType)
crcValue	byte string	(0 ..)

E4 PAYLOAD BLOCK

Table E3E-3 Block Content for Previous Node Block": Block Content for Previous Node Block

Term		Logical Data Type	Range
blockContentType	payload	byte string	NA

E5 PREVIOUS NODE BLOCK

Table E4E-4 Block Content for Previous Node Block": Block Content for Previous Node Block

Term		Logical Data Type	Range
blockContentType	eidForwarded	EID	(Dependent on addressing scheme)

E6 BUNDLE AGE BLOCK

Table E5E-5 Block Content for Bundle Age Block": Block Content for Bundle Age Block

Term		Logical Data Type	Range
blockContentType	bundleAge	unsigned integer	(0..2^64-1)

E7 HOP COUNT BLOCK

Table E6E-6 Block Content for Hop Count Block": Block Content for Hop Count Block

Term		Logical Data Type	Range
blockContentType	bundleHopLimit	unsigned integer	(1 .. 255)
	bundleHopCount	unsigned integer	(1 .. 255)

E8 ADMINISTRATIVE RECORD

Table E7E-7 Administrative Record": Administrative Record

Term		Logical Data Type	Range
adminRecordStructure	recordType	unsigned integer	(0..2^64-1)
	recordContent	Variant type (see note 1)	(Dependent on recordTypeCode)

NOTE – At the time of this specification, the following record types are defined:

Bundle Status Report: RecordType Range[1]

E9 BUNDLE STATUS REPORT ADMINISTRATIVE RECORD CONTENT

Table E8E-8 Record Content for Bundle Status Report": Record Content for Bundle Status Report

Term		Logical Data Type	Range
BSRRecordContentType	BSRStatus	BSRStatusType	(See below - BSRStatusType)
	BSRReasonCode	unsigned integer (see note 2)	(0..2^64-1)
	subjectSourceEID	EID	(Dependent on addressing scheme)
	subjectCreationTimestamp	unsigned integer	(0..2^64-1)
	subjectFragmentOffset (see note 4)	unsigned integer	(0..2^64-1)
	subjectTotalADULength (see note 4)	unsigned integer	(0..2^64-1)
BSRStatusType	receivedEvent	eventDataPointType	(See below - eventDataPointType)
	forwardedEvent	eventDataPointType	(See below - eventDataPointType)
	deliveredEvent	eventDataPointType	(See below - eventDataPointType)
	deletedEvent	eventDataPointType	(See below - eventDataPointType)
eventDataPointType	eventAssertion	Boolean	(0 .. 1)
	eventTimestamp (see note 5)	unsigned integer (see note 3)	(0..2^64-1)

[1] Variant type dependent on the value of recordTypeCode. RFC 9171 defines a recordContent for Bundle Status Record (BSR).

NOTES

1 Administrative records are carried as payloads of bundles and are signaled by the BPv7.primaryBlock.bundleControlFlags.isAdmin field.

2 Enumerated values form the set of Valid status report reason codes that are registered in the IANA ‘Bundle Status Report Reason Codes’ subregistry in the ‘Bundle Protocol’ registry.

3 Unsigned integer represents the DTN Time.

4 This is optional and is present if and only if the bundle whose status is being reported was a fragment.

5 This is optional and is present if the eventAssertion is 1 AND the ‘Report status time’ flag was set to 1 in the bundle processing control flags of the bundle whose status is being reported.

ANNEX F

IPN URI SCHEME UPDATES

(INFORMATIVE)

This document references the ipn URI scheme per RFC9171 where endpoint identifiers are of the form <node number>.<service number> The IETF DTN WG is current working an update to the ipn URI scheme to include an optional naming authority and an optional sub-authority so that fully-qualified ipn eids could be of the form <authority>.<sub_authority>.<node_number>.<service number>. The existing format (<node_number>.<service_number>), and the existing CBHE node range allocated to SANA will remain valid. Implementers are advised to track changes to the ipn URI scheme and to consider implementing those changes as appropriate.

ANNEX G

INFORMATIVE REFERENCES

(INFORMATIVE)

[F1] *Rationale, Scenarios, and Requirements for DTN in Space*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 734.0-G-1. Washington, D.C.: CCSDS, August 2010.

[F2] L. Eggert, G. Fairhurst, and G. Shepard. UDP Usage Guidelines. RFC 8085. Reston, Virginia: ISOC, March 2017.

[F3] E. Birrane and K. McKeever. *Bundle Protocol Security (BPsec)*. RFC 9172. Reston, Virginia: ISOC, January 2022.

ANNEX H

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

Term	Meaning
AA	application agent
ADU	Application Data Unit
AOS	Advanced Orbiting Systems
BP	Bundle Protocol
BPA	bundle protocol agent
BPSec	Bundle Security Protocol
BSR	Bundle Status Report
CBOR	Concise Binary Object Representation
CCSDS	Consultative Committee for Space Data Systems
CRC	cyclic redundancy check
CL	convergence layer
CLA	convergence layer adapter
DTN	delay tolerant network
EID	endpoint identifier
EPI	EPP Protocol Identifiers
EPP	Encapsulation Packet Protocol
IANA	Internet Assigned Numbers Authority
IEC	International Electrotechnical Commission
IP	Internet Protocol
IPN	Interplanetary Network

ISO	International Organization for Standardization
ISOC	Information Security Operations Center
IUT	implementation under test
LOS	loss of signal
LTP	Licklider Transmission Protocol
OSI	Open Systems Interconnection
PICS	protocol implementation conformance statement
PDU	protocol data unit
RL	requirements list
RFC	Request for Comment
SABR	Schedule Aware Bundle Routing
SANA	Space Assigned Numbers Authority
SDU	service data unit
SPP	Space Packet Protocol
TC	Telecommand
TCP	Transmission Control Protocol
TM	Telemetry
UDP	User Datagram Protocol
URI	Uniform Resource Identifier
USLP	Unified Space Link Protocol